Proceedings

Sector 2000

The Application of Advanced Informatics to the Forest Industry

May 25 - 27, 1992
Vancouver, British Columbia

Industry, Science and Technology Canada
Industrie, Sciences et Technologie Canada

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SF 2000

L'application de l'informatique de pointe à l'industrie forestière

Les 25, 26 et 27 mai 1992

Cette conférence technique était conçue afin de réunir des intervenants de trois groupes industriels: les représentants des entreprises forestières, des usines d'outillage forestière et des sociétés de technologies de l'information. Pendant cette conférence, ils ont eu l'opportunité d'étudier les barrières qui nuisent à l'adoption rapide de ces nouvelles technologies de l'information.

Plus de 50 experts de renommée internationale, spécialisés dans les technologies de l'information et provenant du Canada, des Etats-Unis, de la Finlande, de la Suède, de l'Australie et du Royaume-Uni, ont fait connaître les possibilités pouvant découler des applications de ces technologies dans le secteur forestier canadien.

Les présentations ont traité des sujets suivants:

- Robotique
- Systèmes de formation, de surveillance et de diagnostic basés sur la connaissance
- Design et gestion dans l'industrie des pâtes et papiers
- Gestion des stocks
- Acquisition et gestion de données
- Gestion de l'environment
- Fabrication
- Sylviculture

Note au lecteur:

Si le nombre de demandes s'avère approprié, la présente publication sera traduite en français. Pour obtenir de plus amples informations, veuillez vous adresser à: M. Subhash C. Junéja, Conseiller Scientifique et Administrateur, Industrie, Sciences et Technologie Canada, Division de dévelopement technologique et programmes, Direction générale des industries forestières, 235, rue Queen, Ottawa, Ontario K1A OH5 (613) 954-3127 Facsimilé (613) 941-8048.

Sponsoring Organizations

Industry, Science and Technology Canada

Forest Industries Branch,

Information Technologies Industry Branch

and

ISTC Regional Office Vancouver

in co-operation with

British Columbia Advanced Systems Institute

The Canadian Advanced Technology Association

Canadian Pulp and Paper Association

The Council of Forest Industries of British Columbia

Forest Engineering Research Institute of Canada

Forestry Canada

Forintek Canada Corp.

The Information Technology Association of Canada

Machinery & Equipment Manufacturers Association of Canada

The National Research Council Canada

Pulp and Paper Research Institute of Canada

Science Council of British Columbia

On behalf of Industry, Science and Technology Canada, I would like to thank the sponsoring organizations, the speakers, chairpersons, participants and all others who contributed to the success of Forest Sector 2000.

The objective of FS 2000 was to accelerate the transfer of advanced information technologies to the Canadian forest and allied industries. The Science Council of British Columbia and the B.C. Advanced Systems Institute had previously held workshops to discuss the emerging need for the forest industry to adopt advanced technology. FS 2000 was designed to accelerate that process by bringing together the suppliers of information technologies, the equipment manufacturers and the end users of advanced systems. The industrial and economic benefits of advanced informatics, successful case histories and state of the art information on certain technologies were presented.

Given that Canada is one of the largest producers of forest products in the world, there are tremendous opportunities to develop domestic industries to manufacture and supply equipment and technology to this important sector. We have the expertise, the infrastructure, the economic incentive and the potential to build an informatics-based forest sector capable of maintaining its competitive edge in the 21st century and assuming the world leadership in applications of advanced technology. In view of the foregoing, the creative ideas discussed at the workshop will, I believe, encourage the development and transfer of innovative information technologies to the forest sector, in order to enable the sector to realize its full potential for a prosperous future.

Change comes in small steps. This workshop and proceedings are a contribution to the process of change. I hope they will stimulate further research and development and improve Canada's ability to meet the challenges facing the industry.

Subhash C. Junéja
Chairman
FS 2000 Organizing Committee

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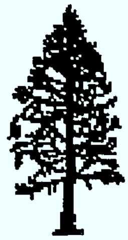

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Welcome and Introduction

Lyle M. Russell
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Vancouver, British Columbia

On behalf of Industry, Science and Technology Canada, our Minister, the Honourable Michael Wilson, and the twelve other organizations supporting this conference, it gives me great pleasure to welcome you to "FS 2000: The Application of Advanced Informatics to the Forest Industry".

The subject of this conference is indeed timely and important, for it is essential that we achieve greater efficiency, and therefore greater profitability, in our forest industry. One way to achieve both these goals is through better use of advanced information technology.

The objective of this conference is to examine how new information technologies can be applied to the forest industry, along with some associated issues, such as their economic impact and the benefits in terms of conservation and environmental protection. You will also be looking at the challenges the new technologies pose for human resource management and training. Such changes will not come easily but they will come.

History

This conference has its roots in different, but related initiatives at both the federal and provincial levels. As far as federal government programming is concerned, it is what we in ISTC call a Workshop on Informatics for Senior Executives (WISE). These are a key part of the Department's efforts to diffuse information technology and new business practices to the manufacturing sector throughout Canada.

The objective of WISE is to encourage industry associations and their members to consider the strategic and economic benefits of applying information technologies to their operations. At the end of this workshop we hope that you will have an increased awareness of the benefits of information technologies and that you will better exploit them to your competitive advantage and the benefit of Canada.

As with all WISE workshops, you will find in the audience representatives from all the players - from the ultimate users of the technology to the designers and suppliers. We hope that this meeting will give all groups the opportunity to discuss their needs and find ways of increasing cooperation that will benefit everyone.

The other sources of inspiration for this conference were the Science Council of British Columbia and the B.C. Advanced Systems Institute. Between 1987 and 1989 they both sponsored workshops and published reports on the developing information technology requirements of the forest industry. These reports, prepared jointly with the industry, examined not only the technical requirements but also the industrial and economic climate that would be needed if the opportunities were to be realized.

This conference builds on those earlier developments and brings together the three groups that must inevitably work together if we are to be successful in taking the greatest advantage of the opportunities: the forest industry, the equipment manufacturing industry, and the information technology industry.

Governments are also key players. At a time when Canada is facing difficult economic challenges at home and abroad, it is important to recognize the many successes that have taken place across Canada as a result of the close collaboration between government and industry in R&D. Some of these successes are the outcome of ISTC's Forest Industries R&D and Innovation Program which has contributed to the development of some of the technologies that will be reviewed here during the next three days.

An excellent conference program has been developed covering a very wide range of IT use within the forest sector, from the analysis of the natural resource, through its movement to the factory, and finally through manufacturing and distribution to the customer.

The application of the latest in information technologies to the forest industry is an exciting field of endeavour. The breadth of the subject is addressed by the ten, quite different sessions that are laid out before you in the program. Most of the technologies that will be discussed are ready to be applied today in practical, cost effective uses within the private sector. They are not pie-in-the-sky ideas that are of only academic interest.

I hope that the discussions that will take place over the next three days will help us bring down the barriers that sometimes occur in technology diffusion. To a large extent, these barriers are ones of perception. Obviously, the equipment and information technology companies are eager to satisfy the needs of the forest companies and the latter are certainly eager to modernize so that they maximize their efficiency.

But the forest industry is traditionally cautious and slow to change, for the costs of failure when adopting new systems are often enormous (sometimes hundreds of millions of dollars), while in the information technology business change is continuous and often very rapid.

Just examine your own lives and remember the rate of change that has taken place in the power of the average personal computer over the last ten years. The machines of the early 80's are now just toys and cannot handle the sophisticated programs used every day in our offices. Systems sometimes come and go in months, rather than years, and the cost of hardware is dropping so rapidly that in many cases it is no longer a major factor in deciding whether to proceed with a new development. In this very dynamic environment - anything but conservative - the critical factor is whether you can find or train people to undertake the work, not how much the system costs to purchase.

Conclusion

Over the next three days, we are going to discuss new technological developments in an industry where cultures and philosophies often clash. Yet all the parties should be working together. Harry Rogers, Deputy Minister of Industry, Science and Technology Canada will provide an overview of the directions for the future that will be discussed throughout the conference. Important ideas will be discussed by each of our speakers and I know this will generate active discussion amongst delegates.

A Business Perspective of the Industry & Technology

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Senior Vice-President, Finance and Administration
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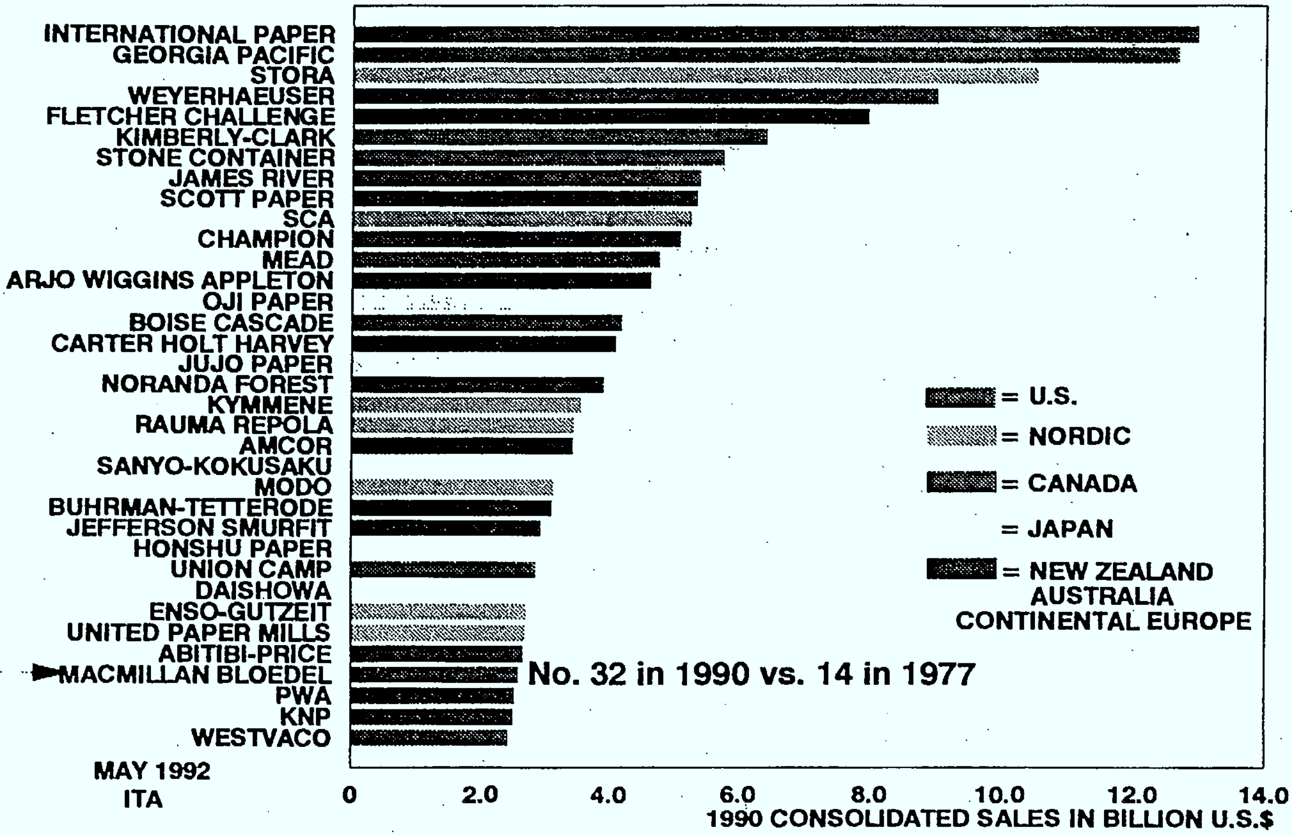
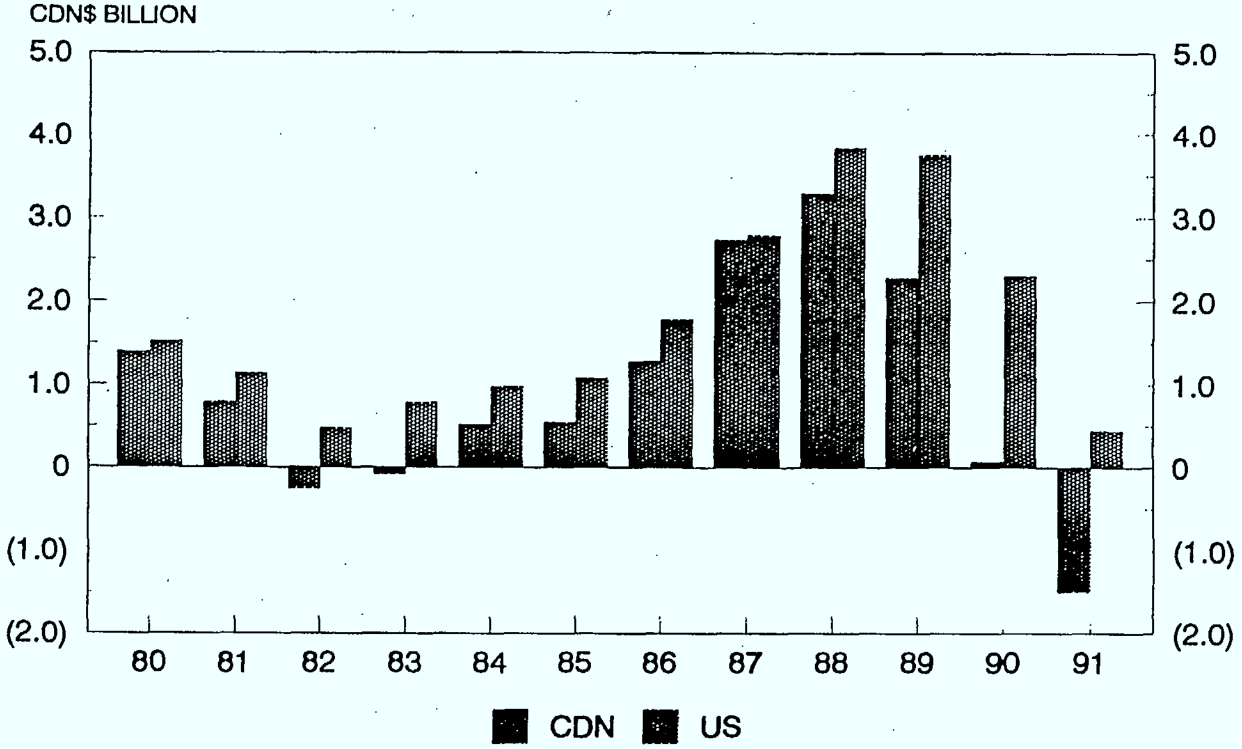
WORLD'S 35 LARGEST FOREST COMPANIES
IN 1990



MAY 1992
ITA

NET EARNINGS
EIGHT MAJOR U.S. FOREST COMPANIES vs.
PUBLIC CANADIAN FOREST COMPANIES



Slide 3

SOLUTIONS

Government - General Business Environment

Strategies are Company Specific

Systems have an Important Role

Slide 4

SYSTEMS STRATEGY AT MACMILLAN BLOEDEL LIMITED

Business Orientated/Value Added

Integrated

Slide 5

BUSINESS ORIENTATIVE/VALUE ADDED

Partnership between Systems Staff/Business Staff

Systems Staff Understand Business Objectives/Processes

Joint Priority Setting

Charge-out

Shared Applications (packages)
Cost Effective Development & Support

Either Party Can Walk

I.S. & S. Mission Statement

IS&S

MISSION

Provide MacMillan Bloedel with effective
Information Systems & Services
that satisfy our customers' requirements
and enhance the company's
competitive position.

CORE VALUES

We will deliver a Quality of Service that satisfies our Customers' requirements through:

- Partnership with our customers.
- Understanding the business Requirements.
- Integrity on a personal, customer, and corporate level.
- Recognition of Dedication to excellence.
- Qualified and motivated Employees

We take **PRIDE** in all we do

Slide 7

INTEGRATED

- Capture information once at source - must be accurate
- Carry it through
- Broad access - empowerment
- Combine/Consolidate/Summarize
- Prerequisite for work re-engineering
- Systems architect (vision of entire system)
- Small projects
- Networks important
- Limited tool set:
  - Languages
  - Vendors
  - Systems infrastructure
- De-emphasize:
  - Stand alone solutions
  - Leading edge technology
- Technology is not limiting

Slide 8

SUMMARY

- Canadian forest industry is in trouble
- Solutions are largely company specific
- Systems are an important part of company strategy
- MacMillan Bloedel's systems strategy:
  - Business oriented/value added
  - Integrated

New Perspectives in Silviculture

David G. Brand
Director
Environment, Science and Sustainable Development Branch
Forestry Canada
Hull, Quebec

Introduction

It is easy to lose sight of the purpose of silviculture. Silviculture is not about the subjugation of nature by man, it's not about social welfare, and it should not be about image and motherhood. Yet I recently heard a paper delivered in Ontario, where the thesis taken was that all forest management should be designed to sustain indicators of biodiversity and that wood production could only be considered as a side benefit of that quest. I also still see minimum standards for reforestation in all provinces that include little consideration of economics and lead to planting hundreds of millions of trees in cold, northern areas. Finally, I hope I never again hear of the statistic of number of trees planted to number harvested. This figure can range from 5 trees cut for each planted to 5 planted for each one cut. But would it really matter if either was right anyway?

No, it seems to me that the thing we have lost sight of is that silviculture is about growing trees for commercial timber production, and in the process ensuring that environmental, social, and economic values are all considered. While some might argue that we may occasionally carry out stand treatments for a purpose other than timber production, say for production of wildlife browse, these are minimal in the big picture, and are not what I want to discuss today.

What I do want to talk about is where we should be going with the growing of trees in this country for industrial fibre. I am going to concentrate on what we are capable of and what technologies we need to give us competitive advantage in the face of slower growth rates and higher labour costs than many of our international competitors.

Lets begin by looking at the issues facing silviculture in Canada.

Issues

The federal government in its current mandate has set a number of key objectives. Included among these is the area of prosperity and competitiveness. As a kick-off to that a study was commissioned to look at Canada's competitiveness. The pulp and paper industry came in for particularly heavy criticism in that report for lack of investment in new technology. The implication for silviculture in Canada from that report, written by Michael Porter, is:

1. **Competitive advantage for Canada will be driven by application of technology to offset disadvantages in growth rate and labour cost.**

We cannot go on paying $1500 per hectare to establish plantation in central Newfoundland or North of Dawson Creek. A plantation that will only product 200 cubic metres of timber in 100 years with a residual values over harvest and processing costs of close to zero is not a good investment. And particularly when it is the same amount spent on Vancouver Island or southern Ontario. This is not efficiency in the allocation of investment. Lets take a very simple example of the cost of establishing a plantation and see where we could substitute technology for labour or capital.

First, if we site prepare the area with Swedish machinery to create plantable sites, it costs $350 per hectare (these are all hypothetical ballpark figures). Why couldn't site preparation be somehow undertaken as part of the harvest? Are there not harvesting machines or skidders in boreal forests that could double for site preparation purposes? The cost of managing a separate contract, floating in the equipment, and providing service, etc. is absurd.

Second, if we plant 2000 trees per ha. at 35 cents per tree, including both nursery cost and labour, we spend $700 per ha. Assuming for the minute that natural regeneration was absolutely out of the question, is it not possibly to find a way to efficiently get seed onto the site or to use small seeded containers that germinate on site?

Third, if we need vegetation management we might use manual brushing two times at $500 per entry. Or if we are able to use herbicides we might use two herbicide treatments at $300 each per hectare. But in most cases, my research indicates that we treat far too much area. In many cases tree species are slowed down, but not killed by the competing vegetation, and eventually would succeed in dominating the site. In other cases only part of the block really needed treatment and yet we treat then entire area. Finally where species like aspen dominate the site, we have spent too much time fighting the species. We should either design harvesting to avoid stimulating aspen, or let it grow.

Finally, through all this process we probably spend about $100 per ha on surveys and evaluations. Most of which are time consuming and creating a lot of data that is not even used in the treatment decision. Much of this cost would disappear with development of remote sensing and decision support system technology.

So, our hypothetical plantation could cost up to $2150 to establish using today's methods, or could be potentially reduced to about $300-$400 per ha. I don't need to elaborate on what value you would need at rotation to recoup the first figure, but it would probably be in the order of $25000/ha in today's dollars at an age of 80 years.

There is another aspect to this lower investment silviculture:

2. In Canada, the low opportunity cost for land points to need for highly efficient extensive silviculture.

The idea of opportunity cost is that you could make more money by doing something completely different. For example, if you owned a large area of land around Quesnel, BC you could grow timber crops, or clear the land for ranching. If, after clear-cutting the area it would pay you $20/ha/year for cattle grazing and only $2/ha/year for timber production, you would be crazy to grow timber. But in most of Canada, there is no such option. If you want to make economic use of the land, you have wood production and possibly trapping. There is not heavy recreational pressure on the boreal forest, water is plentiful, and the option of agriculture is non-viable. So, that means that forest management and silviculture can be considered the highest use economically. I am referring here to integrated forest management, so that the investment would be driven by the sum of all resource values in the forest including wood, fur, hunting, and fishing.

But highest use still doesn't confer carte blanche to invest madly in silviculture. We should find the level of investment in the forest that ensures the highest economically efficient level of production. I'm not going to describe the criteria for economic efficiency, only say that discount rate, rotation age, and estimated value of products are the key items for sensitivity analysis.

Now, I said at the outset that forestry was about producing wood in a way that rationalized economic, social and environmental values. Many people have suggested that you can enhance social and environmental values without increasing wood costs. In my opinion this is rhetoric. As soon as you change your focus away from solely growing wood as efficiently as possible there will be a cost. Now, that doesn't mean that wood production has to become completely uneconomical. Rather it means that we have to make sure we know the cost of the trade-offs we are making. For example, I recently visited New Brunswick where they have a very sophisticated GIS and have been using it to examine habitat for animals vs. harvest planning. They identified key features in the forest landscape that should always be present to ensure no negative affect on wildlife from forestry. What happened when they did the computer simulation was that they realized the complexity of maintaining all these features and that harvest rates would have to fall dramatically. At this point they examined the economics of deer and wood and decided that a maximum harvest reduction of 10% would be supported.

But the moral of the story is that --

3. Concept of 'New Forestry' suggests a need to rethink stand and forest level silviculture practices.

New forestry is the term coined for a more ecologically focused approach to silviculture. Standing dead trees were always cut because they were considered a safety hazard. Smaller suppressed trees were cut down to ensure the area could be planted without competition from natural regeneration, clear-cut blocks had to be completely harvested, even in wet corners or rocky outcrops where trees were small and non-commercial, slash and debris had to be disposed of to reduce hazard and provide planting spots. Many of these practices made sense when the prevailing view was that we were trying to tame nature and create a Germanic style managed forest. But today they are more and more unnecessary and ecologically damaging. Nevertheless there is a point at which new forestry becomes more expensive than no forestry and we have to be very careful about giving up intensive silviculture on our best sites. Really all this accomplishes is to put more pressure on other lands. It may be best to practice this new forestry in the majority of Canada's land base where intensive forestry is simply unjustified or too costly, and practice intensive silviculture on accessible, productive sites a la Weyerhaeuser or Irvings.

Now, I discussed a bit the implications of new forestry, but there is another, more strongly supported forest-level philosophy that is emerging in Canada. It is the concept of integrated resource management.

4. Integrated resource management requires that timber production, biodiversity, recreation, aesthetics, Etc. be balanced at stand level and forest level

Integrated resource management is really synonymous with sustainable development. The central idea is that stakeholders in the forest, be they the forest industry, recreationist, or native people, must work together to specify the goals of forest management. Then based on those values or features that are identified, goals are set and a management plan is designed to sustain are achieve the goals. It is theoretical at this point, because the tools that would be needed just to evaluate whether any schedule of forest management could sustain wildlife, water quality, hiking, and timber production at the same time over 100 years are not available. And what is more worrisome, if the tools were available they would show that all values cannot be sustained and that significant trade-offs must be made. At the level of finding a common system of valuation for these competing goals we have a lot of work to do. But again, it will be a technological solution in the end, because it is only through new information technology that we can evaluation spatial features of the forest and simulation impact decades into the future.

Despite this, we still do not have to tools to practice integrated resource management, and won't have them for at least another 5 years. So to date:

5. Public concern is being combated by attempts to move to panacea of integrated resource management. But, due to the fact that timber production is still a goal there will be a continuing conflict.

The spotted owl is an excellent example of what happens when you can't answer the public's questions. Let's say you have a species that requires continuous blocks of forest land of about 500 ha to support a breeding pair. It might be an owl species or a fur-bearer or whatever. Then lets say that you decide you want 500 breeding pairs sustained, so that the genetic base of the species is preserved, etc. Then say you choose on a harvest rate that ensures there is always more than 250,000 ha of forest greater than 200 years of age. You might say great, the owl is sustainable given this regime. Unfortunately, someone might argue, how do you know you can fulfil the criteria that each area of old forest is more than 500 ha in size. You don't have a gis system that can track and show where the old growth is in each time period. What if it is all high-elevation? or fragmented into small patches. So you fail to convince the public and a law is enacted that specific areas must be preserved ending the possibility of integrated resource management.

6. Potential future strategies could include either a land use planning approach involving partitioning land into intensive silviculture, extensive silviculture, and protection forest; or IRM over the entire landscape.

As you can imagine, IRM will never really be achieved, because values and concerns are better specified all the time. So we will endlessly be striving to solve new problems, and always at the expense of the economic returns from silviculture.

There is at least one option to this scenario. That would be partitioning the land base. This is not a new idea and has been proposed in different regions of the world. You take some proportion of the land base that can support economically attractive timber production and state that timber production is clearly the highest use. Then, the remaining areas are managed for integrated resource management with low silviculture investment or as protection forest with neither silviculture or harvesting. The problem in Canada would lie in the transition to such a scenario. There would be a period of time, say 40 years before the intensive management area could take over the bulk of timber production. But on those areas, which might be 10-20 of the land base, silviculture could be practised economically and rationally. There would still be environmental controls, and wildlife management, but these would be as secondary constraints on timber production.

In any event, this debate over the future philosophy of forest management is of overriding importance to silviculture. Because it defines the practices, techniques and technology that will be required.

I would like to turn now to the specific activities involved in silviculture, and some of the specific needs for new technology.

7. Phases of silviculture requiring technology:

INVENTORY AND HISTORY MONITORING: At the most fundamental level, silviculture requires information on the forest composition, structure, and spatial location. Because treatments must be ecologically sound and justifiable in a forest management context, it is important to know the state of the forest. Inventory and history monitoring have generally been undertaken through forest cover mapping, and more recently through digital databases. Yet in both cases the problem has been to keep these maps or databases up to date, and many are more than 20 years out of date. This makes the process of wood supply analysis and silviculture planning very difficult. There is a major need to invest in the information infrastructure for planning-up to date inventory with annual updating for harvesting, fire, insects, and silviculture accomplishments.

SURVEY AND ASSESSMENT: Silviculture prescriptions originate from the assessment of stand condition and prescription of a series of activities to meet management goals for the stand. This has always been done by having someone visit the stand and either examine it or take direct measurements. These surveys cover millions of ha. each year in Canada, with the majority being undertaken by contractors or summer students. The data collected is costly, and rarely used to potential. There is limited use of remote sensing, a technology that could often give a much more complete picture of stand condition. We need to systematize data collection and information flow to the decision maker.

TREE IMPROVEMENT: Conventional tree breeding in forestry is such a long term proposition as to be almost irrelevant. It takes about 20-30 years per generation to improve trees. Yet biotechnology already holds promise to clone superior trees, and mass produce superior offspring. There may also be the opportunity to genetically engineer trees for pest resistance and aspects of wood quality. Yet the investment in these technologies has been limited.

PRESCRIPTION SUPPORT AT STAND AND FOREST LEVEL: Silvicultural prescriptions are complicated decisions requiring evaluation of seven or eight criteria-what is best for the stand, what is best in the whole forest context, what is practical, what is available, what season should the treatment be made in, what is the intensity or rate or preferred species, what is the chance of failure, are contractors available, etc. etc.

Unfortunately, man has the habit is using only 3 or 4 criteria in making a decision. This is the essence of gut instinct or intuition-identify the key factors and accept some level of error. But now we have new technology in the form of expert systems that can systematically evaluate any number of criteria and find workable solutions for each prescription. Yet to date there has been little interest in evaluating this technology in practice.

NURSERY OPERATIONS: Nurseries are potentially among the better users of technology in forestry, as new greenhouse operations have the latest in sensor controls and mechanization of operations. Yet there are still many new technologies to be developed in such areas as seedling quality assessment, biochemical control of seedling composition, and seedling storage.

SITE PREPARATION: Site preparation has been largely aimed at creating good conditions for planting and we have borrowed heavily on Scandinavian technology. The problem with site preparation is that it is expensive and inefficient. We must find better ways to either avoid site preparation or integrate it with harvesting or planting

PLANTING: Tree planting has been a political panacea in Canada, and yet it now appears to have peaked and will probably subside in the future. We have been planting almost 1 billion trees per year recently, largely guided by regeneration standards. There needs to be a reduction in planting and development of new low cost technologies to get seeds or seedlings into sites.

VEGETATION MANAGEMENT: Vegetation management has been another widely used technique in Canada. For many areas the regime of clearcut, plant, spray was a convenient way to reestablish conifers on a site. But with growing public opposition to herbicides, and the cost and lack of efficiency of the alternatives, the solution must be found in ways to harvest and regenerate forests with minimal requirement for vegetation control. This means better understanding of vegetation ecology and better survey and information on plantation status.

THINNING: Given that Canada is 'the low cost, marginal producer of the world', there has never been much interest in commercial thinning. Most thinning is done as precommercial or non-commercial thinning. This is an expensive proposition, often costing $1000 per ha or more. There is a need for more efficient technologies to thin young forests.

FERTILIZATION: Fertilization has never really proved itself as a commercially attractive option in Canada. Estimates are that fertilization-grown incremental wood costs $30-$40 per cu m. and this is just not viable. Possibly the use of sewage sludge or other low cost options might be worth exploring.

GROWTH AND YIELD MODELLING: One of the basic weaknesses in Canada has been our inability to come to grips with forecasting the future development of stands under alternative silviculture regimes. The reason has been our lack of long term study of the impact of silviculture on forest growth, but also a lack of investment in forest production study. New simulation models and growth studies must be supported to allow proper evaluation of silviculture prescriptions.

Each of these phases or aspects of silviculture must be examined critically in terms of innovation and efficiency. I once spent a week in New Zealand at a meeting of a IUFRO group who were concerned with operational efficiency in silviculture. It was particularly interesting to see a large research group with the New Zealand Forest Research Institute who had the mandate to increase the operational efficiency of reforestation. They had decomposed every aspect of the chain of operations involved in establishing a plantation. They had changed and improved every aspect steadily from the bundling of bare-root trees, to the shipping of stock, to the re-use of stock shipping containers, to the very act of planting the tree. They had redesigned planting tools, site preparation equipment, nursery mounders, and herbicide applicators. They had reached unbelievable levels of efficiency in the operation such that they had incredible success in reforestation. I have often thought that this dogged examination of every phase of every treatment, and belief that everything can be done better, that is often lacking in Canadian silviculture programs. In fact, when you think about it, it was exactly this type of refinement that went into the Japanese success in automaking and consumer electronics.

I would like to briefly turn now to some of the more promising new technologies with application in silviculture.

8. Application of Technology

- Many technologies have application in several aspects of silviculture.

9. Information Technology

GIS-the ability to hold data in a spatially referenced database is of course important to forest inventory, but equally can assist silviculture planning. Most Canadian silviculture programs are allocated at a program level. That means that goals are set for planting, weed control, thinning, etc. In most cases this is designed to meet forest level wood supply needs and is not build up from the field level prescriptions. However, we have never really examined the efficiency of treatment allocation at the stand level and this requires GIS. All aspects of operation and strategic planning can benefit from GIS

EXPERT SYSTEMS are another new information technology with major potential in silviculture. As I mentioned earlier, prescription decisions are almost always made by the seat of the pants and it is almost impossible to systematically consider every aspect of ranking among treatments or sites needing priorized for treatment. Expert systems could allow much more systematic consideration of options.

DATABASE MANAGEMENT: With all the surveys and data that is collected in silviculture it is easy to reach the state of information overload. It is also easy to reach a point where masses of data are inaccessible to decision makers because of database design or limitations. New relational databases are able to cross reference and classify data so that it is easy to extract summaries or special requests to support decision making. Yet many of our databases are still residing as flat files.

SIMULATION MODELLING: Much of our growth and yield modelling and studies of forest productivity were the results of empirical studies and simple regression fits to data. Increasingly there is a need develop simulation models that include stochastic variables and reasonable assumptions about variance and risk. Early examples are emerging and these will help better predict the growth of forests and response to silviculture

OPERATIONS RESEARCH: OR has had limited use in forestry. A former professor of mine at the University of Toronto has spent a large part of his career developing operation research solutions and linear programming solutions to forestry problems but has never had them used practically. This despite the fact these tools have been shown to reduce costs and improve efficiency of operations. Let me give you an example. There was a system developed by Monty Newnham at PNFI called LOGPLAN. This system takes the various silviculture, harvesting, and transportation costs, the location and demand of mills and other constraints and designs the lowest cost scenario. He showed at one point that he could reduce delivered wood cost by 1-2 dollars per cu m.

10. Remote Sensing

Remote sensing is another major technology that could assist our attempts to increase the efficiency of silviculture. Both satellite and airborne remote sensing could be used for much of the survey problems we currently have. It has the benefit as well that the imagery can be brought to the actual decision maker as opposed to the data being collected by contractors and students. Also, contract thinning operations could be monitored by aerial imagery and density checks could be done automatically. Insect and disease survey can also be automated.

11. Communications

Both data and voice communications technology are growing at rapid rates. New global positioning technologies allow accurate tracking of where workers are located and the location of vehicles and equipment. Data transmission from things like weather stations is making direct tracking of things like soil temperature for tree planting a possibility.

SENSORS: sensor technology is also growing rapidly. I was very interested to see the species identification device of FORINTEK that used a military designed sniffer. But in forestry for monitoring site conditions, environmental damage, etc. there have been major new developments. It is a simple job now to install large nos. of sensors in the field to directly monitor conditions and report on a frequent basis. I know Peter Kourtz has proposed doing this in his fire management system.

12. Mechanization including robotics; site preparation; nurseries; thinning;vegetation management; transportation.

Many aspects of work in the forest could be assisted or replaced by robotic approaches. Almost all manual labour and tedious repetitive practices could be eventually replaced. I think we will here about this in a while from Murray Strome

13. Biotechnology
Tree improvement
Pest control
Vegetation management

Finally, biotechnology is becoming a new alternative to conventional tree breeding and pest control. Somatic embryogenesis, the practice of multiplying the seeds from a single embryo is almost ready to be commercialized, and systems to propagate from the single cell are being developed. This means that when you have the ability to propagate a plant from a cell you can insert new genes for things like pest resistance or growth.

14. Technology transfer and technology pull vs. technology push

Traditionally poor record of forestry -- Canadian forestry, as I have pointed out, should be leaders in the application of new technology in forest management. We have a tremendous demand for technologies given the magnitude of forest management programs, we are a well educated society and very computer literate, and we have a particular need for efficiency in investment to replace our cost of labour and slow growth rates.

Yet there has been some frustration over the pace of technology transfer. Many of the silviculture programs are strongly regulated with negotiated standards and rates of pay that prevent innovation. I heard a story once about a regeneration survey contractor who was not allowed to computerize the reporting of results because reports had to be on an approved form. Even within governments there has been a stifling of innovation because of a resistance to "having everyone going off on their own direction". In effect it comes from the attempt to control by headquarters organizations.

A second problem has been the remoteness of forestry and resistance to many to new technology. This was once expressed by the chairman of the Forest Research Advisory Committee of Canada (now retired), who said he didn't know why we needed these damned computers anyway. He could still outthink them. So with a senior company representative who thinks this way, it is difficult to justify a GIS and new workstation.

15. Importance of Canadians supporting technology development.

Origin of benefits to Canadian companies must be acceptance of technology in our country first, but by lagging in our pace of acceptance of new technology we hamper the competitiveness of our service sector, a sector with tremendous international opportunities. They can best sell their services and products when they have an installed base to point to and demonstrate. Without that they are just part of the pack of people out there selling a good idea. This has been one of the objectives of our Federal Model Forest program-to get the state of the art Canadian technology implemented and working in real world scale applications.

16. Training and technology explorations to facilitate technology pull.

One of the key elements of this technology transfer problem has to be developing the technology pull as its known. That requires commitment at high levels of organizations to reward innovations, and an interest in seeing what people are doing. We need much more familiarization of working level people about new technologies, because they will be the eventual users who have to actual specify the applications.

17. Do we have strengths that are acknowledged-communications, remote sensing, and GIS?

These must be maintained by conscious effort. Even more crucial to a country like ours is to ensure that we don't lose the edge in those technologies where we have the edge currently. I was over in Japan last summer and we gave a seminar on the use of GIS in Canada. Over 400 Japanese showed up and it was the first time the new Tokyo embassy theatre had been 'sold out'. But after I toured some of the Japanese labs, such as at Hitachi, where they spend $2 billion per year on research. There I saw people systematically recreating GIS systems and experimenting with 3 or 4 dimensional systems. So if we don't keep a strong engine of demand for our software products, we may soon be buying from foreign suppliers.

18. Michael Porters's study and the essence of competitiveness originating in how countries apply technology to solve problems.

So as a country I think we need to recognize that our competitive advantage in these technologies will emerge from our potential internal demand for them first. International marketing will follow, not lead Canadian applications.

19. Where are key strengths and weaknesses in our silviculture practice today?

I will just finish by saying that I think the greatest restriction on Silvicultural innovation today is our government control of forest land and the inherent desire of bureaucracies to limit innovations and new approaches. We have standards for every conceivable silviculture practice and while most are well intentioned and needed to satisfy the public, they do not allow innovation easily. We have developed highly efficient nursery systems, and our remote sensing and GIS capabilities are world class.

20. A challenge to the future

So I will just finish by reiterating that we will never be able to justify intensive forest management across the Boreal forest, and that even in Coastal BC a small proportion of the forest could economically support intensified investment. So we have to become increasingly efficient. With a low opportunity cost for land, a high level of technology, and a high quality resource, we should be able to continue to support a healthy forest industry.

Future Technological Demands of the Forest Industry

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Future Trends

The forest industry must remain competitive in the future. It has to compete with substitutes and offer solutions in the form of new applications. There will also be increasing internal competition between the companies, mills and factories of the forest industry.

In many countries the forest industry, more often than other industries, has participated in joint research projects. In many cases the development has been led by machinery suppliers. The tendency has been to increase capacity with bigger and better machines. The economical success of the industry has been dependent on sufficient capacity.

The competing forest industry companies have much in common as a result of the way they have been developed. As an industry matures the competitors start resembling each other. In the machine manufacturing industry the result has been that the machines differ only in colour.

I believe that the forest industry could also follow another path in the future. The capacity-driven industry will maintain its position in the years to come. There will, however, be an increasing need for differentiation to improve competitiveness on the mill level. More attention than today has then to be paid to product development and process improvements in the mills. That development requires more than big money - ingenious technological applications become more and more important.

In light of the foregoing, four difficult questions arise. The search for solutions to them does, however, enhance development of the sector. It is useful to bear in mind that the perfect solution is often the enemy of a good solution. All four questions set technological demands for the forest industry.

Which are the needs of end-users of wood-based products in the future and how can they be met better than today?

What new possibilities does the overall development of technology give to the forest industry product and process development?

How can the "Just On Time" principle be effectively applied to the forest industry, and how can "Total Quality" be achieved?

How does the forest industry respond to environmental demands?

Facing the Technological Demand

The basic scientific knowledge and most of the technological wisdom required for commercial applications in the forest industry in the next ten years already exist. Smart people are aware of the fact and get an advantage from using and combining the available technologies.

I will illustrate the general features of long range development with two pictures.

In all R&D work we should have a vision of the future. (Fig. 1). On the technology - time axis we cannot reach our visionary goal in one big step. The visionary goal sets the direction and we approach the goal by systematic hard work step by step. Each step can fulfil short term need and can thus also be readily utilized.

In the second picture (Fig. 2) I use a simple model to show how the real future need can be determinated and how the solution for that need can be created.
I will point out some opportunities for forest industry development based on existing technologies. The forest industry should understand the potential in these technologies for the long range development of the industry.

Some of my examples may look very complicated, but on closer examination you can discover their positive consequences in the development of the forest industry process. There are also technologies which might revolutionize the industry in the long run. We have to remember that major changes in the forest industry are slow. If we, however, can speed up this development, the forest industry will not only maintain but improve its competitiveness.

If we want to develop the "Just On Time" system in the forest industry, information on available raw materials becomes essential. We have to develop the methods to measure both the quantity and quality of timber "in situ" in the forest. The mill should get timber from the forest to the process as soon as possible. The basic technologies for measuring timber quality and quantity in the forest are available. Harvesting to meet the daily needs of the mill is going to become a reality. If we start working seriously for this goal now, the system can become prevalent in ten to twenty years.

Today's timber-harvesting vehicles on tires or tracks cannot be used on some promising harvesting sites. Existing vehicles can not negotiate steep slopes and they damage environmentally sensitive or otherwise difficult terrains. A walking vehicle is the solution to this problem. It is no longer science fiction but a realistic possibility. It is also a more logical solution than one might think at first (Fig. 3).

Combined Technologies

Environmentalists and governments regard chlorine as the main culprit in pulp bleaching. Researchers are continuously looking for alternative bleaching processes. Processes using oxygen are one alternative.

The so-called high-speed technology, which was originally developed for quite different purposes, may enable us to reduce the size of the oxygen generating plant essentially. Then pulp and paper mills should be able to take advantage of it.

Supercritical fluids offer interesting possibilities in pulp making. The capital costs of the pulp mill could be significantly reduced and the effluent problems of the present mills eliminated. The application of supercritical fluids to pulping is waiting at the door. The advantages seem so big that it would be foolish to leave that technology undeveloped.

Mechanical pulping requires a lot of energy. Sensor technology and signal processing combined with good process knowledge are new tools that may well reduce the energy consumed in the thermomechanical pulping process (Fig. 4).

That is an example of what can be done in an existing mill to improve productivity. The main problem is not usually technological but human.

A closed-system mill would be ideal from the ecological point of view. The related difficulties and dangers can be overcome only by developing the necessary technology. Various technologies must be known, mastered and utilized to solve the problems of closed-system mill.

The forest industry's environmental impact should be judged on the basis of life-cycle analysis. The ecological balance of fiber products must be also considered. The best sources of improvements and technological development should be found and decided on the basis of the results of this approach.

From Unit to Concept

There are three ways of developing papermaking and mills

- development of unit processes
- development of subprocesses
- development of new concepts

The difficulty and risks increase when we move from unit processes towards new papermaking concepts.

Today we can attain a maximum consistency of 3 % at the wet end of a paper machine. New technology is needed for developing the unit process to reach a consistency of 10 % - 15 %.

Pressure drying and impulse drying processes are examples of development which can lead to a maximum 20 % water content in the web that needs to be evaporated.

The aim of development is to minimize the usage of water in the papermaking process.

The present technologies do not offer an acceptable solution for making composite paper with layers of different properties. The composite structure of paper products opens many new uses for paper.

The paper mill is most often seen as a system covering everything from debarking to the paper roll. The whole process should also be considered a fiber-flow system from forest to the user of paper. Models to control this fiber-flow system should be developed. They should help in the daily running of the mill. Flexible papermaking is possible in the future if this can be done.

Wood is Always Wood

Wood is a natural composite. The sawmill and building industries have used wood in very conventional ways. I would like to think that the future of wood will be even better than the past.

Fig. 5 illustrates the development trends for the use of wood as a material and component in the building and woodworking industries.

The direction for the development of the increased and improved use of wood should be based on better molecular understanding and molecular models, as well as on good knowledge of wood structure and its mechanical properties. Then we can set the goals for the technological development of machines, equipment and information systems.

Machine vision and other sophisticated systems can also be used in the saw mill, when we know the kind of product we want to make. The desired qualities can be sorted out whereby the mill meets the specific needs of the customer.

Demands Can be Met

Do not let the burden of the present and the past limit the use of your ingenuity. Approach the technological opportunities with an open mind. The decisions which will set the competitiveness of the industry and the mill in twenty years are made today. Technological demands have to be met but they also can be met.

See following pages for slides.......

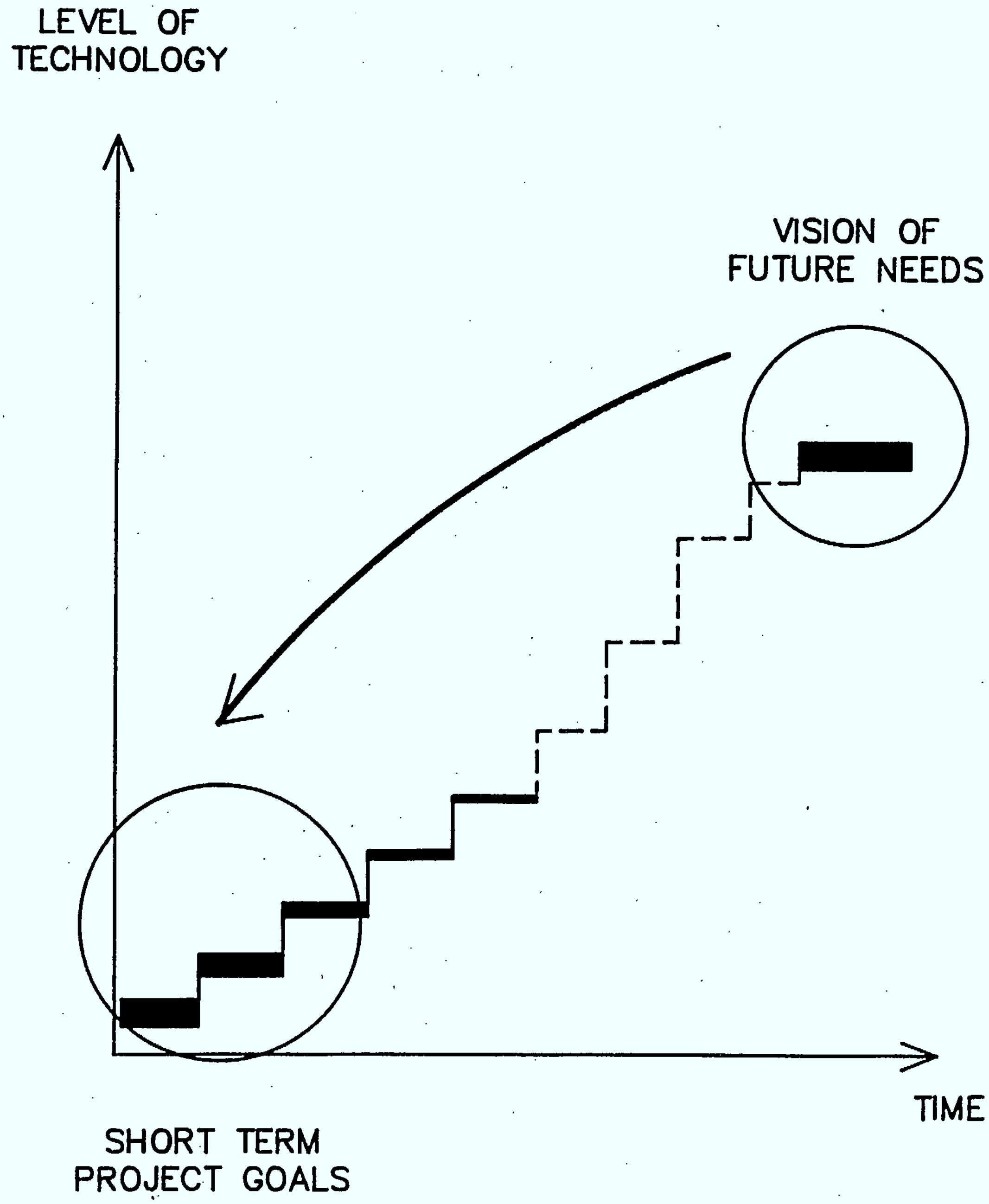


Fig. 1. Vision is vital in technological development, but the steps have to be taken in well managed projects.

CUSTOMER'S OWN IDEA OF WHAT IS NEEDED

WORK PROCESS ANALYSIS

THE "REAL" NEED

NEW POTENTIAL MADE POSSIBLE BY DEVELOPMENT OF TECHNOLOGY

+

INNOVATIVE SOLUTIONS FOR FOCAL QUESTIONS

KNOW-HOW

NEW BUSINESS OUTLOOK

PRODUCT APPLICATIONS

Fig. 2. When the real need is known the technology potential can be utilised.

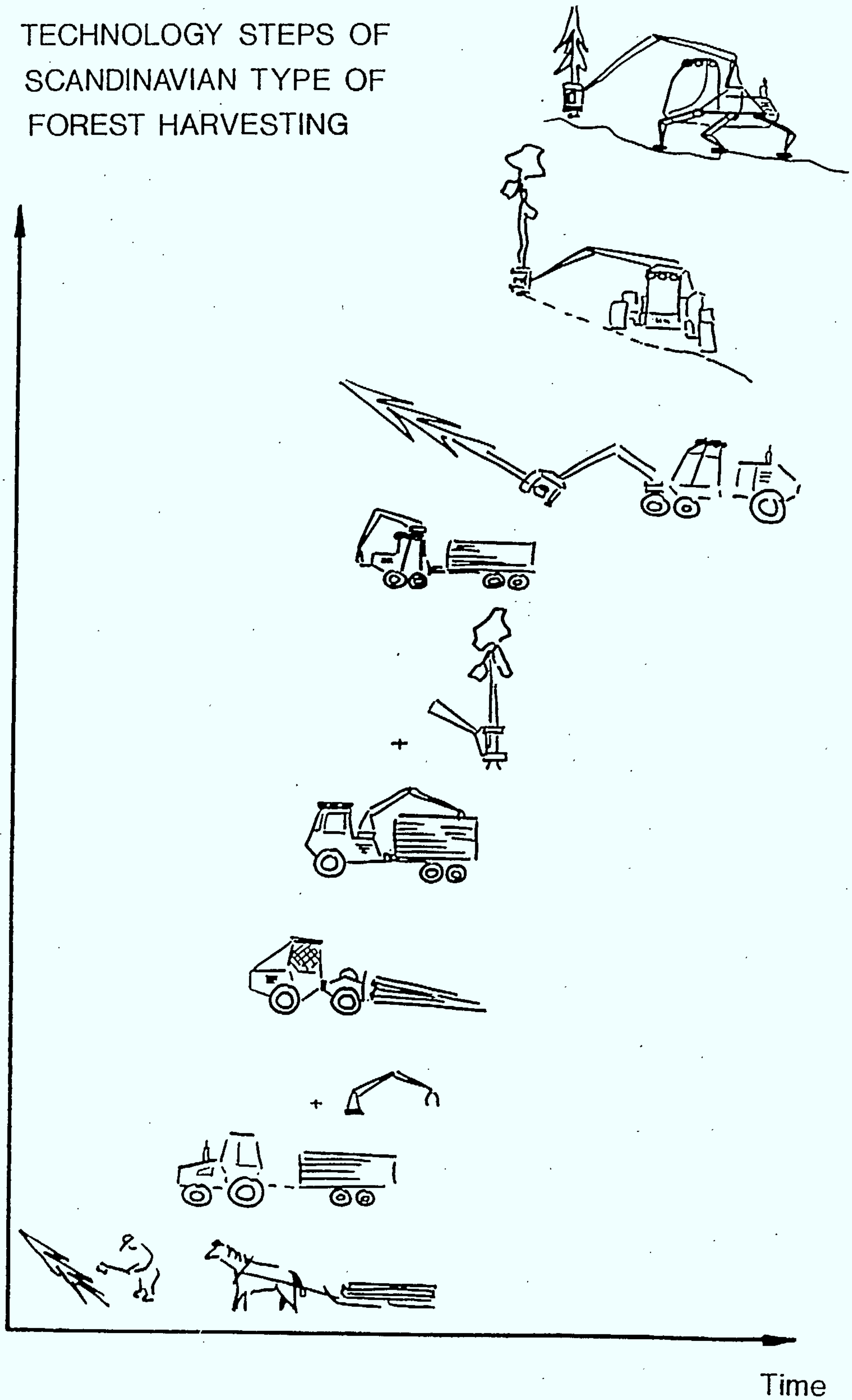
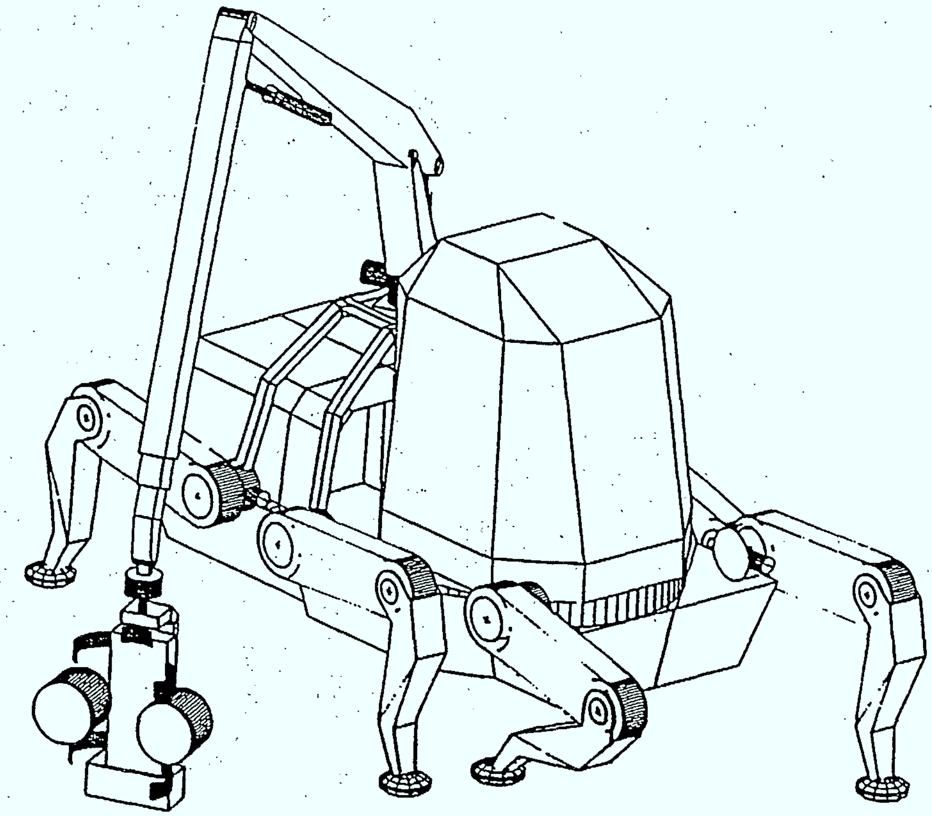


Fig. 3. In the development of wood harvesting walking machine is a logical next step



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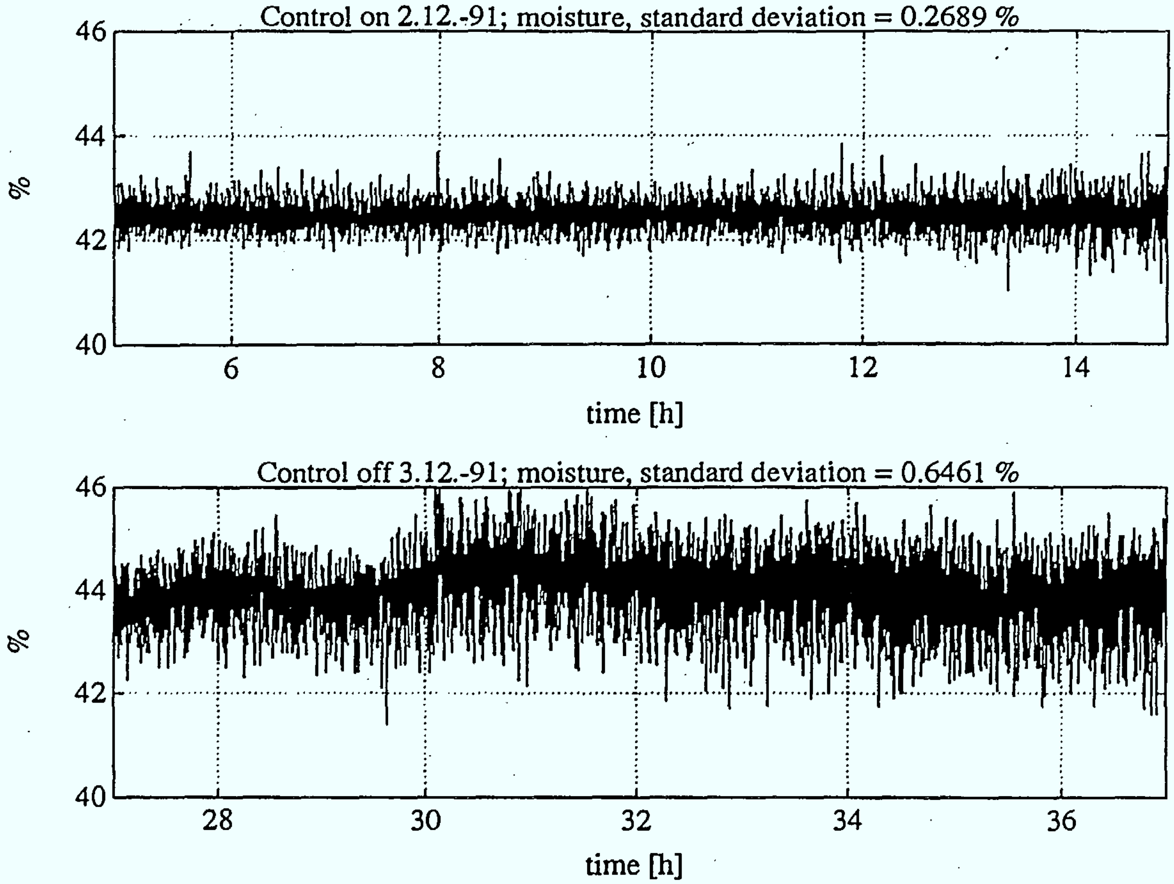

Fig. 4. Signal processing and the new measuring technology make much better control of mechanical pulping process possible and lead to essentially improved useage of power.

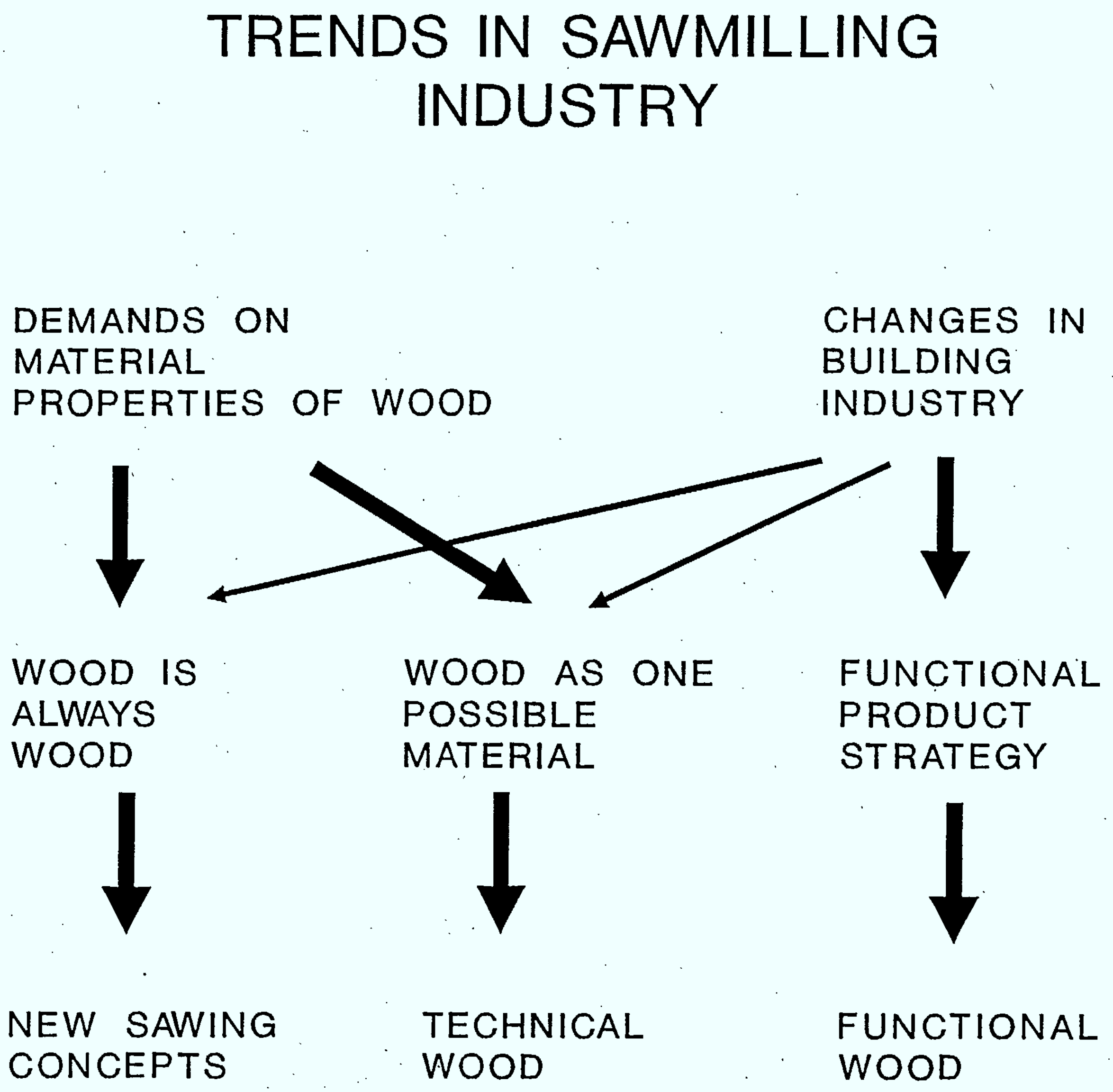

Fig. 5. Wood has a bright future as a composite and building material.

" Radio has no future "
(Lord Kelvin)

" When the Paris Exhibition closes, electric light will close with it and no more will be heard of it "

(Prof. Erasmus Wilson, Oxford, 1878)

" Wood is a friend of mine. The best friend on earth of man is the tree. When we use the tree respectfully and economically we have one of the greatest resources of the earth. It is a beautiful material, friendly to man, the supreme material for dwelling purposes. If man is going to live, he should live with wood "
(F.L. Wright)

" The U.S. Patent Office should be abolished because everything useful has already been invented "
(U.S. Commissioner of Patents - 1844)

" The horse is here to stay, but the automobile is only a novelty - a fad "
(Henry Ford's Lawyer, 1903)

Technology and the Future of Solid Wood Product Manufacturing

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Continuing worldwide political and cultural changes will adversely impact on raw material supplies in the 1990's, and probably be the precursor of worse to follow in succeeding decades. Significant changes are taking place in the world's forest industry.

For example, until this time we, in North America, have viewed overseas countries only as markets. Foreign exchange, foreign aid to emerging nations, and high quality fibre combined with cheap labour may prove that North America is vulnerable to foreign influences beyond its control. While we may have great forests, the combination of other factors will require us to become more efficient in the conversion of our fibre.

For sound commercial reasons the whole stand of a forest, including hardwoods, must be converted into value added products. As well, sociological imperatives will demand it.

Reduction of the North American and world commercial forest base is inevitable due to the demands of environmentalists, aboriginal groups, urbanization, inadequate pest control, infestation, wild fire, entrepreneurial groups, etc. Consequently, there will be more bidders for less timber. Because some of these bidders may include speculators (domestic and foreign) increased timber costs will result.

The corollary is that:

- world manufacturers of the 90's must extract all potential value in the fibre available;
- manufacturers cannot afford the wasteful procedures of the 70's and 80's, both in the woods or in the conversion plant; and
- stems that might have previously been left behind in the forest will have to be brought out, not only for sociological reasons, but because of the value as fibre, either in a solid wood product or as fibre for a pulp mill or homogenous panel mill.

Volume production mills of the 70's and 80's will be replaced by mills whose efficiencies are measured by value and not volume.

Fibre that is today consigned to commodity high speed production that can yield grade and cross sections suitable for further manufacture, will be redirected to facilities that can extract the full potential. This is the fundamental challenge for the primary breakdown plant of the future.

Optimization was the buzzword of the 80's. It will become a necessity of the 90's, and to be profitable an operation will require optimization as a reality and not just as a buzzword. Fortunately, worldwide technology can now provide the tools to make optimization a realistic objective.

The manufacturer of the future will produce better products more accurately, and with greater efficiency. In order to improve yield and value, he must reduce the current high waste of fibre. Improved technology can provide precision manufacture and greatly improve yields. Robotics may remove some of the inconsistencies of human effort in many places in the production line.
In the 90's, we will see inside the log and determine where the rot is, where the knots are, which side the compression grain is located on, and where the shake or other defects are located. We will scan the log and a computer will provide a printout with total log details. In milliseconds, manufacturing pattern will be established for the individual log. A com-

puter will operate the primary breakdown of the logs, and, further, computers will optimize the recovery of product values in the manufacturing process. The product will then be directed to a sorting facility where it will be graded and assigned piece by piece for further processing or for shipment.

If the product is be further manufactured, it can be directed to a satellite operation where, after electronic scanning, the full potential value of a given stock of product is determined and processed with accuracy.

The computer will know the state of the inventory at all stages of manufacture at all times, and will relate the raw material to the order file commitments and the product in process. Overruns, reruns and shortages will be reduced substantially.

In the last two decades, the industry has made major reductions in the man hours of unskilled labour needed to operate a manufacturing facility. The next decade will see even fewer man hours, but the persons on the production floor will have to be trained in specifics relating to value of fibre. The important function will be not so much hand and eye coordination but mind and instrument, and industry should use its influence to direct the curricula of the appropriate learning institutions in advance of the demand.

Maintenance will be monitored and probably directed by computer. The implications of continuous operation will require a precise and diligent maintenance program. Breakdowns can be reduced to a minimum only through a program designed for such needs.

One of the most valuable employees of the management team of the future will be the person who can design and control the computer program. All departments of management and operation will be interdependent. The benefits from their interaction will be in direct proportion to their mutual effectiveness.

In fact, while cost effective labour reduction has been a prime purpose of good management in the past, the next decade will produce worthwhile rewards only if a true synergism exists with each production unit and between that plant and the complementary raw material supply departments and the marketing functions.

The technology exists today to implement these objectives. It remains for the manufacturer to bring them into practice. A fully automated mill can be designed today, but the investment will not be practical until some time in the future.

Notwithstanding, it becomes more and more essential to work toward this optimization, because the value of the fibre will not permit the wastes of the day. It will not permit such imprecise manufacture that extra thickness and width must be planed off to get the desired accuracy. The manufacturing facility of the future will have its machinery on such solid foundations that precise manufacturing can be achieved and dressing of the product will only be a polishing job by a sander, if at all.

Manufacturing in the future will have to become more efficient. The relatively high cost of energy in the form of electricity or fossil fuels will probably make energy from wood waste and bark a viable alternative. Materials handling in present procedures is far too expensive and design opportunities exist to improve this aspect. Most importantly, manufacturing must become more precise to fit the customer's needs, and it must be done to enhance the grade of the lumber and to reduce the high percentage of fibre that is currently destroyed in the manufacturing process. Marketing of products in the global perspective will bring about some significant changes in world trade.

Optimization in the manufacturing facility is a technical reality today and a necessity for the future. However, even more important is the computer enhanced decision making process for the log merchandising before the log ever gets into the manufacturing plant. Ideally, the first computer analysis is made before the stem is bucked, preferably in the woods, or in the log yard or on the jack ladder depending on the size and grade of the stem. It makes no sense to try to correct the mistakes of log bucking after the log is in primary breakdown. It is technically possible to see inside that stem and buck it to enhance the value to the greatest extent. Anything less must be considered a waste of a valuable resource, which the corporation cannot permit any more than the community should or will tolerate it.

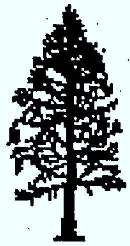
Canada is a world leader in the designing and implementation of optimization systems. The next generation of optimization systems will allow for better coordination between the raw material supply, the plant and the marketing department. This dynamic decision making, based upon the computer enhanced intelligence, will allow us to improve fibre recovery, improve the quality of the product and will give us the ability to quickly take advantage of market niches.

Canada has a very opportunistic future in the solid wood manufacturing. It has one of the best fibre qualities remaining in the world. We are on the leading edge of the state-of-the-art solid wood manufacturing technology. We recognize the need for the next generation of technology in order to remain competitive on a global basis. The next generation of technology will have a greater emphasis on management information systems which will allow for improvements in the overall integration and management of the operation. Finally, the largest opportunity exists in believing in your product and the proper marketing versus the selling of that product.

The future of solid wood manufacturing will be challenging, but profitable.

Remember wood is good!

Information Technology in the Year 2000 - Portable, Powerful and Pervasive -



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Introduction

I would like to share with you my thoughts on changes in Information Technologies, anticipated to occur over the next 10 years. I will be speaking in fairly general terms, not about specific applications in the Forest Industry. I hope that by the end of this paper, you will be at least a little excited about what lies ahead, and ready to look for ways to apply these technologies within your own organizations.

Past Predictions (The hazards of the crystal ball)

Predicting the future is a risky endeavour. In preparing this paper, I went looking for earlier predictions of where information technology would be by the early 1990s.

To start, let's go back to the first digital computer, the Eniac, created in the late 1940s and used for solving purely numerical problems, like computing ballistic trajectories. The people working with that system predicted that it would take at most 6 of these electronic brains to satisfy the foreseeable computing needs of the entire United States. The flaw in this early prediction probably arose from their limited view of digital computers as expensive number crunchers. When inexpensive computers were later developed that could also handle text, we got word processing, and things really started to take off. Today, computers can also handle graphics, sound and video; consequently we're in the midst of another major round of change.

In The Book of Predictions, published in 1981, Malcolm Peltu, editor of the British Publications Computer Weekly and Dataweek, is quoted as predicting that between 1988 and 1990, "A computer program would make an original scientific discovery that is considered worthy of a Nobel Prize." He also predicted that between 1990 and 1992, the keyboard would cease to be the main method of communications between a person and a computer, to be replaced by direct-speech communication.

In the OMNI Future Almanac, published in 1982, I found the prediction that by 1993,
"Two connected computers, sharing one memory that communicates with both systems, will have the capability of defeating the human world champion at chess." This is a prediction with a long history; it has appeared, in various forms, since work began in the field called Artificial Intelligence.

What these last few predictions have in common is that they underestimate the incredible complexity of some activities that humans take for granted. These problems will eventually, I think, be solved with computers; but the predictions have been consistently over-optimistic. By the way, many of the other predictions in these two books have proven to be accurate, if not as amusing.

With these earlier wrong guesses as a warning, the predictions I am about to offer may prove to be somewhat conservative. In any event, please take them with a grain of salt. The sources I am drawing upon include various academic papers, technical journals, and presentations by senior executives at Apple Computer, Sun Microsystems, Silicon Graphics, Microsoft, and so on.

The User Interface (Reach out ...)

A logical place to begin is at the user interface, the most visible aspect of information systems, and an area that has seen a lot of activity in the past decade. The hot item right now is the GUI, or Graphical User Interface, originating from work at Xerox

PARC in the 70's and now popularized by Apple's Macintosh, Microsoft Windows, and others. What will·the user interface look like by the year 2000?

A couple of years ago, Apple Computer produced a videotape, entitled Knowledge Navigator, that presents a scenario of future computer use. Hewlett-Packard has produced a similar tape, with its own vision of the future. From these and other sources, several trends are clear.

The use of keyboards will decline; but not disappear. Computers are becoming more portable, which makes full-sized keyboards impractical. As well, more and more software programs are adopting graphical user interfaces that can be operated with a mouse, or pen. Electronic mail and voice mail systems will merge, with videophones and video mail not far behind; so, sadly or not, we will probably rely less and less on formal, written reports. Keyboards will not disappear entirely, however; they will still be used for high-volume text input, and in noisy environments.

Voice input systems are improving at a steady rate, and will be commonplace by the end of the decade. There are, in broad terms, three levels of difficulty in dealing with voice input. Discrete word recognition systems, inexpensive and commercially available now, force the user to say each word separately, with a distinct pause between words. These systems can recognize thousands of different commands; but do not give you a very effective talking typewriter. Continuous speech recognition can; but it's a harder problem, since the computer must first figure out where one words stops and the next begins. Nonetheless, there are commercial systems available. Their vocabularies are more restricted, and they must usually be trained to each user's voice. What you get out of these systems is a transcription of what the user said. Even more difficult is speech understanding or language understanding, in which the computer can interpret the meaning in what you are trying to say; for example, that it can interpret a casual request to retrieve information from a database, without the need for a specialized query language. Speech understanding is hard because English, like all natural languages, relies heavily on context and metaphor.

Here's an example of the problems caused by context. Suppose we want the computer to, "Look on the main computer, in the news clippings database, for the article about Nintendo's annual revenues, and print it on the screen." Let's make a leap of faith and assume that we can get a computer system to properly interpret 'main computer' and 'Nintendo'. The word 'it' in this sentence could refer to 'the main computer', 'the news clippings database', or the article we're looking for. To a human looking at this sentence, there is no ambiguity, because common sense tells us that you don't print a computer, and that we wouldn't bother mentioning an individual article if we wanted to print the whole database. But to a computer these assumptions are not at all obvious.

Will computers overcome these problems in this decade? So far, the field of Artificial Intelligence has succeeded in delivering useful tools only in fairly restricted problem domains, so sceptics are doubtful; but an AI project at MCC in Austin is addressing the issue by studying the way children develop common sense knowledge of the world around them, and applying those principles to develop a common sense knowledge base in a computer. They hope that by building the computer's knowledge base from the ground up, they can teach it to deal with many of the subtleties that people take for granted.

In the next few years, organizations will be using improved telephone interfaces based on voice response (discrete word recognition) and, by the end of the decade, limited-vocabulary talking typewriters (continuous speech recognition).

Another, very visible trend at the user interface is the increasing combination of text, graphics, sound, and video. Termed Multimedia, this smooth integration of different forms of information has, for the past 10 or 15 years, been predicted as an imminent, new mass market. Electronic books, training materials, compound documents and multimedia electronic mail are among the predicted products.CD-ROM (Compact Disc, Read-Only Memory) is the predicted publishing medium for many mass market materials. While there are hundreds of multimedia titles available, the field has grown more slowly than predicted. There are two important reasons. First, most consumers are not interested in creating their own multimedia presentations, pulling together the shoe-box full of snapshots or stack of home videos. Like CD Audio, the home multimedia market will take hold only when there is a selection of reasonably priced CD-ROM playback units, and an assortment of interesting and entertaining titles. Second, until there is a recognized standard multimedia format, as there is for CD Audio, consumers will stay away in droves; nobody wants to be stuck with another 8-track cassette player.

For corporate and industrial applications, these barriers to acceptance are less important. Many firms are already using multimedia for their training materials. Such systems, done well, are entertaining and engaging; but production costs can be very high. Getting the right level of production quality and style is a tricky business, because we're all familiar with the quality and intensity of television programming, which is very expensive. If you set out to produce a body of material close to TV quality, you had better go all the way, or your work will look shabby by comparison. One way that companies can keep production costs down is by sharing those costs; look into industry organizations that may be in a position to develop training materials to be shared by participating companies.

Compute Power (More for less)

Computer manufacturers are predicting that by mid-decade, systems priced at the level of today's personal computers will offer speeds of 200 million instructions per second, where each instruction is a simple, hardware-level action, like an addition or multiplication. That means systems on our desks that are about 20 times faster than what is now commonly available. By the year 2000, desktop systems will be pushing 1 billion instructions per second, or about 200 times faster than today's machines, for about the same price.

Computers are getting faster for several reasons. There has been steady progress in improving low-level computer instruction sets, in making chips smaller, and in finding new, faster semiconductor materials. As well, many computer manufacturers are developing parallel computer systems, where a few, or even a few thousand individual computers are combined, each working on some part of a larger problem. Finally, by connecting computers together in networks, it becomes possible for spare compute power on one person's desk to be used in solving a larger problem at someone else's desk. This approach is called distributed computing. So far, there is no single method of large-scale computing that works well for all problems, so we will likely see continued progress on all these approaches.

Do all these increases in power mean that computers will be able to do anything and everything we'd like them to do? Unfortunately, no. Some problems are inherently too complex, provably so using the mathematics of computability, for computers to produce perfect answers to them in a reasonable length of time. Other problems, like language understanding, will not suddenly become trivial because of faster computers; it first requires the discovery of a solution that works! It is important for organizations to realize that not all their computational problems can be solved by buying bigger or faster computers.

Portability (you CAN take it with you)

Portable, or laptop computers have been available for some time. Now there's a new kid on the block, generally referred to as the pen-based computer. It is smaller than a laptop, about the size of a hardcover book; but it has no keyboard. Instead, you operate it using a pen.

The front surface of the computer does double duty, as the display screen, on which you see text and graphics, and as a sensor for the position and movements of the pen. You operate the pen much as you would a mouse on the desktop; but a pen is more direct, and easier to use for many tasks. One task that these new computers support reasonably well is hand printing of text, which is how they can operate without keyboards. Work is underway on supporting handwritten script, for longer text passages, like reports and memos.

Pen computer manufacturers and industry analysts agree that by mid-decade, the market for pen-based computers will reach the dollar volume that laptop computers are at today. There are already a half dozen pen computers on the market, which are finding early adopters among mobile workers, like insurance adjusters, and delivery personnel. When connected via network to home base, these systems keep mobile staff in contact with the home office, while improving the quality of customer contact and decentralizing decision making.

Gadget computers are also making a strong showing. In addition to an endless variety of audio and video gear, you can already buy hand-held translators, spelling checkers, games and personal organizers. We can expect, in the next few years, to see hand-held multimedia units, navigational aids, and other functions. At some point, these same functions will be available in general purpose, hand-held units; but special-purpose gadgets will continue to sell well, at lower and lower prices. Disposable computers-computers so inexpensive that when they break down, when the batteries wear out, or when they are no longer fashionable, we will throw them away.

Researchers at Xerox PARC in California suggest that computers will, like electric motors in the past 100 years, become increasingly ubiquitous and invisible, that they will be built into everything from white boards and telephones to light switches. Not mere microcomputers, automating the functions of household appliances, but computers powerful enough to perform complex functions, coordinated by our home and office computers. I think they're right; but I hope that these ever-present computers are smarter than today's ever-present digital clocks. At last count, I had 15 digital clocks in my home, each and every one needing to be adjusted for Daylight Savings Time!

Picture this... you leave you office for an important meeting; but all you take with you is your hand-held computer. Instead of deciding, in advance, what reports or files to take along, the hand-held computer lets you take your whole electronic desktop with you. You still have access to all your on-line files and services, by means of a wireless network connection, built into the hand-held computer. At the meeting, if you have material you want to show to the other attendees, you send a copy to each of their hand-held computers, or you post it to a large, common display like an electronic whiteboard or overhead projector.

Database Systems (Like a needle in a haystack)

Databases are widely used to store and retrieve information in relatively fixed formats. The relational database model, for example, is an accepted standard in industry and business, as a way to store many types of information. Its use, however, is limited when it comes to storing less structured forms of information, like the contents of newspapers, multimedia presentations, and those stray bits of information that end up on our notepads, Post-It Notes, and chalkboards. Watch for the development of new data management systems that can handle just about any kind of information you can throw at them.

Improvements in database technology, combined with digital networking, will allow us to interconnect data from a variety of sources. One important development in this area is the Personalized Newspaper project at MIT's Media Lab. The researchers at MIT recognize that most of us cannot keep up with the volume of reading we would like to do each week, and that much of that reading is skimming, looking for items of interest. They have proposed an electronic agent or surrogate, a piece of software that will scan whatever sources you are subscribed to, looking for articles that match your interest profile. The agent will then assemble those pieces of information in a personalized newspaper, thus saving you considerable time. If you have ever used a clipping service, you know how valuable this can be. The framework for this kind of service is coming together, as more newspapers and other publishers are making their information available in electronic form.

Every organization should be looking for ways to capture more of its business information in digital form, where it can more easily be reused, as well as looking for ways to use the vast amounts of information published elsewhere.

Visualization (What you see is what you get)

Computer graphics has improved steadily in the past 10 years, from simple, slow illustrations to photo-realistic images and real-time Virtual Reality.

Computer graphics has had the greatest impact in industries where design plays a key role. Alias Research of Toronto is a leading software company that typifies this field. Alias produces software packages that are used by companies around the world in the design of automobiles, consumer electronics, jewelry, food packaging, architecture, graphic arts, and motion picture special effects.

With these software packages, designers are able to create new, proposed products in detail, in three dimensions, and look at them on a computer screen. The ability to visualize proposed designs, long before physical models or prototypes are built, lets designers identify problems sooner, evaluate a wider range of design choices, and ultimately get the right product to market faster. The more design time you can give a new product, the more opportunity you have to add value, to create a differentiation between your product and your competitors'.

The benefits of better design are not limited, however, to the slick, smooth shapes of cars and CD players. The concepts apply equally well to financial modelling using spreadsheets, or any activity where ideas are proposed, analyzed and selected. Organizations should look for ways to put their ideas into pictures, whenever pictures can help people understand and evaluate new ideas. Increasing compute power will make it more feasible for companies with large physical plants, for example, to run simulations of new designs or proposed changes. Simulation won't tell you everything about the operation of a facility; but it can help make the difference between a well-run plant and an optimal one.

Virtual Reality is both a hot media buzzword and an exciting new way to use computers. In a nutshell, VR is a continuing attempt to improve the realism of computer-generated scenes... in a sense, to break through the front of the television tube and put the user inside the picture. It draws heavily from research on flight simulators, and head-mounted cockpit displays. Current VR technology creates computer graphics images in real time on a wide-angle, head-mounted display, and incorporates stereo or even 3D sound coordinated to what's happening in the scene. The head-mounted display contains sensors, to tell the computer where you're looking, so that it can draw the appropriate view for you as you turn your head. These systems can be operated with special gloves, that allow you to manipulate objects within the simulated scene. The overall experience is quite convincing, although the imagery is still rather cartoon-like.

VR equipment is available now, at prices starting from 30 thousand dollars. High-end systems are already being used in R&D projects at automotive, aerospace, and similarly well-capitalized companies, while less expensive systems are making their way into entertainment applications. There are about a dozen VR arcades operating in various parts of the world, with many more coming soon. Within a few years, simplified versions of these systems will be introduced at the consumer level, supporting interactive games and other entertainment. While there are almost unlimited applications for VR in design, education, medicine and telecommunications, the next few years will be dominated by entertainment applications. It is sobering to note that Nintendo, the leader in the video game market, had annual revenues for 1990 of $4 billion (U.S.), with profits at $750 million.

Digital Networking (The glue)

In the next few years, wide-area cellular networks will play in increasing role in supporting mobile computing, while office-based systems will begin using local-area networks based on radio and infrared. These wireless office networks will reduce or eliminate the need for special wiring to computer stations, for those applications that need only modest bandwidth. For more demanding applications, conventional wire or optical cable networks will continue to be used.

The client-server model of network-based computing is already widely used. In the years ahead, expect to see a wider variety of network-based services available on your desktop or hand-held computer, many of them supported from within organizations, others provided by outside service companies, like those offering news services or statistical databases.

It is inevitable that high-speed digital networking will come to our homes, whether through the efforts of the phone company or cable TV company. With it will come a variety of interactive services made possible by high-speed, two-way communication, and we are likely to see computers and television merge, in the form of digital HDTV (High Definition TV). One of the biggest proponents of this approach is Nicholas Negroponte, Director of the Media Lab at MIT, who also suggests that , "Within 20 years it will be perverse, if not illegal, to use satellites for broadcast TV." Instead, he suggests a switch-over, in which the broadcast spectrum (used largely for TV and radio today) will be used to communicate with things that move- cars, boats, airplanes and people, while the delivery of information to the desktop and living room will be by fibre optic cable.

Aside from movies on demand, more video games, and still more home shopping, these communications services will be used by many people for telecommuting, electronic mail, and other services. By way of example, the American Internet and related networks now reach several million users on hundreds of thousands of computers around the world. A growing number of organizations use electronic mail to communicate with field offices, customers, suppliers and other contacts.

FAX machines, on the other hand, are universal, and dumb. Dumb, but effective. Most FAX messages are composed on a desktop computer, printed on paper, fed through a FAX machine, printed at the other end on god-awful thermal paper, and delivered. For plain text, the same message can be sent by electronic mail using a much shorter phone call, while saving paper and giving the recipient the electronic text to work with. FAX is a dumb technology; but it's going to be with us for quite a while.

Conclusion (Getting our act together)

It's clear that the information technology sector is evolving at a steady rate. A recent Reuters news article, reprinted in the Toronto Star, estimates that by the year 2000 the I.T. Sector will be the single largest sector of western economies, surpassing Petroleum, which currently stands in first place. In order to succeed in an increasingly electronic, global economy, every organization, private or public, large or small, must understand and plan for changes that keep on coming. Here are several specific actions that everyone can take to heart:

Get wired. Re-examine how your organization is using information technologies, especially networks of office and mobile systems, and electronic mail, which is far better than FAX for many types of business communications.

Look for ways to make your products or services smarter, better designed and higher value-added, more responsive to the needs of your customer.

Read. I've listed my references at the end of this paper; but they aren't the only good sources. Make an effort to stay up to date.

Hire talent. Our universities and community colleges are producing some really bright people, more and more of whom are computer-literate.

Learn to adapt constantly. As Tom Peters puts it, Thrive on Chaos.

Keep smiling! You may soon have a videophone on your desk.

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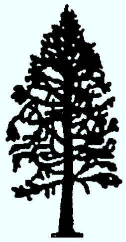
Computer Integrated Manufacturing: The Role of Management



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Introduction

In today's competitive environment every organization must seek and analyze new potential business opportunities which will support the organization's goals. In high volume manufacturing, automation has assisted many corporations, however acquisition of automation requires high capital expenditure and skilled people. Computer integrated manufacturing on the other hand provides the information necessary to make good business decisions of which automation may be a choice.

The essence of integration is to create "an environment of change" whereby a systematic proactive organization becomes used to change and is constantly seeking new methods to improve their processes. There is no startling industrial revolution motivating us to change, only an evolution in which the best elements survive.

Change

To become integrated an organization's acceptance of the need to seek ongoing improvements is necessary. When a climate to embrace improvements through change is established, many people will tend to resist by not sharing the necessary information among business units. Regrettably in most cases, resistance to change is only overcome by a major crisis; such as, a threatened plant closing. Failing a crisis, most organizations with reasonable returns remain stable and often view change skeptically. Failure to initiate change is an opportunity for your competition to surpass you. If you don't pursue the opportunity your confronted with, you run the risk of being punished by that same opportunity.

Changes due to integration do not necessarily mean huge capital expenditures. Management can start modernizing the organization by identifying and simplifying tasks within the company, or prepare the company for necessary future expenditures. Integrated management will have the information necessary to make the right decision in a more timely fashion.

"Barriers to successful technology infusion and to successful culture change hinge around an attitude of change. It is human nature that people do not like to publicly display what they do not know." (McCracken, p. 14) But once they do change, they won't go back.

Management Commitment

Within Computer Integrative Management, managers must focus on the entire enterprise and not just the manufacturing functions. Because computer Integrative Management is integrative, not integrated, the process is continually evolving, we will not awaken one day to find everything integrated. Each business unit function or sub-function becomes a node, or decision point working in parallel, on a network capable of bringing their accumulated knowledge to bear on common value added objectives.

Managers generally feel that they have no time in their busy schedules to learn and understand these new techniques, but they must focus on the essence of the business, not the details. Their knowledge cannot be considered second to, nor wasted on committees, speeches, etc. Management's challenge is to give focus and direction, allowing decisions to occur in their natural settings.

Integration involves two major components, technology and a willing organization. While technology is abundant, and capable, it is utterly sterile, if the organization is not committed to managing the process. VP's will function differently than today's executives. "Rather than giving orders, they will be sharing their vision. Moreover, they will spend a lot of time identifying and developing the talents they need." (Savage, p. 29) Finally, the person on top needs to be more than just committed, he/she needs to be able to convince others to be committed in order to make the program succeed. Without the motivation to change, a management group will not remain competitive for long.

"What is important is the organization's responsiveness and ability to provide appropriate incentives. In addition to gaining acceptance of an ever-changing environment, today's organization must recognize integrated solutions as opposed to isolated ones." (Hahn, p. 11) Accountability for performance is a necessary element of the overall strategy.

There are three critical elements to a modernization program:

- direct executive involvement;
- motivation to change;
- champions, who have a stake in the success of a program.

Without these three elements, the potential for failure is increased considerably.

Vision

In spite of great technological advantages in equipment, computers, controls, and communications, many systems fail to deliver the expected productivity gains, WHY? The major obstacle is that the "problem" has not been accurately defined therefore focusing on the wrong problem has occurred. Why is the definition lacking? The key to any future success, is a current situation analysis with emphasis on where you are, your limitations, your resources, and where you want to go (a Vision).

"Planning should concentrate on how the business and function should look in the future without being concerned with how it looks now." (Zivan, p. 6) Just because something can be done now, doesn't warrant the effort if it is not part of a larger plan. To do so means that management must look beyond the traditional, high-level financial indicators and benchmark their performance in other key areas against the BEST in the world. "Key areas for bench marking include cost, quality, productivity, flexibility, and market share." (Willis, p. 5)

CIM must support the strategic business vision. "The initial task of any improvement program is to work on the company's corporate culture; to build in a mind set that maintaining competitiveness is a continual process, that does not come from one or two 'big' solutions. The key element is to show continual progress, to always be doing things a little better today than was done yesterday." (Muir, p. 23)

Strategy

"Three elements to a comprehensive manufacturing improvement plan are: 1) reducing costs (on a per unit production basis), 2) improving quality, and 3) improving timing (responsiveness)." (Muir, p. 21)

Manufacturing strategies must be based on an overall understanding as to how all the pieces will fit together into the manufacturing plan. Technological improvements that don't support the business plan should be eliminated from implementation. Simply put, if something can be done, and it is outside the overall plan, it is worse than doing nothing at all.

"All investments must pass two tests:

- Does it meet the strategic needs of the company?
- Does it meet the needed return on the company's assets?"

(Howard, p. 8)

The glue of the organization is in place once a plan is created and the strategies identified to achieve the plan.

Champion

In order for the glue to bond effectively a catalyst will assist the process, a champion of the cause can act as the necessary catalyst. "A champion is necessary as a focus for change and momentum. Someone who has the respect of his or her peers and is really making change happen." (Stukel, p. 16)

The champion must be the focus for team building. No matter what the type of organization (matrix, hierarchical, etc.), the champion must be involved with all areas of the organization and is a essential for guidance through the changing culture of the enterprise.

Education

The bottleneck of most information processes is the inability of middle management to digest information and communicate that information as part of the company's desire to keep everyone up-to-date on changes within their industry.

"Education is the tool to effect change and, sometimes, is the only way to achieve an appreciation for the benefits to be gained from a strategy based on improvement through change." (Hahn, p. 11)

To assist the champion and ultimately the company we must pursue continuous training and education for all employees throughout their careers. Each employee will need different training, and it must be customized to a company's changing needs. The conclusion is that the fundamental skill set is changing for the employees and that awareness of this is mandatory. Rather than giving orders, all employees regardless of position will be sharing their vision. Moreover, management will spend more time identifying and developing the talent they need today and for future. "Education rather than training is key. People will be expected to "grow in understanding" of their professional responsibilities." (Savage, p. 29)

Culture

With the evolution of integration within an enterprise a new culture will arise. The resulting culture will combine and cross pollinate the various business disciplines, to produce 1)a superior hybrid team spirit, 2)improve productivity and 3)a feeling of pride in the organization.

Each and every person in the enterprise plays a more significant role in this new knowledge environment. "New leadership styles emerge capable of both achieving and expecting more success within the windows of business and technical opportunity. Moreover, human interaction is recognized as an important issue, if the competitive advantage is to be achieved." (Savage, p. 3) Finally, this knowledge environment taps into the power, wisdom and insight of its managers, professionals and employees who have, as a team in a nodal network, learned to use computer-based resources to enhance their decisions making capabilities.

Conclusion

"Failure is almost never the fault of the technology, but of its misapplication." (Wisnosky, p. 13) Business should not be motivated by pain, panic, fear, or crisis but rather by using the talents of their professional resources successful manufacturing companies achieve exciting results. Integration information by its very nature enables avoidance of misapplied technology.

"The keys to effecting organizational support for a strategy of continual improvement through change are to:

- Gain commitment "top to bottom"
- Make each individual aware of his/her role in the effort
- Evaluate and reward based on ability to add value to the product
- Select an internal champion
- Provide appropriate education and training of all personnel
- Recognize that there may be those who will fail to accept an environment where change is the norm. Formulate policy for evaluating the activities of those who do not add value to the organization" (Hahn, p. 11)

"In conclusion, technology for its own sake is not the answer to the productivity and competitiveness issues. Technology is a tool that must be applied with good business sense just as time and money is applied. At the same time, technology cannot be ignored or the consequences can be equally disastrous for the future of an organization." (Wisnosky, p. 13) "We must be aware of all good ideas, even those of our competitors, in order to compete, and we cannot be arrogant in our view that we are the superior supplier." (Willis, p. 5)

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The Future of Robotics in the Resource Industries

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AINSWORTH AUTOMATION INC.

Objective

- Provide to the FS 2000 conference, an insight into Robotics in the Mining Industry.

AINSWORTH AUTOMATION INC.

Agenda2

- Robotics in Underground Mining
- Enabling Technologies
- Conclusions

AINSWORTH AUTOMATION INC.

Robotics in underground mining3

- Current mining equipment
- Experimental equipment
- Future equipment

AINSWORTH AUTOMATION INC.

Brief description of the Ore extraction process

- Drilling and blasting
- Local transport -Tramming
- Local processing- Crushing
- Transport to surface

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Drilling
Current mining equipment

- Hand operated
- Set-up by surveying
- Problem areas

AINSWORTH AUTOMATION INC.

Drilling
Experimental equipment

- Smart drill
- Self orienting drill
- Impact on operations

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Drilling
Future equipment

- Autonomous - Task deployed

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Local transport - Tramming
Current mining equipment

- Man operated trains
- Man operated rubber tired vehicles
- Problem areas

AINSWORTH AUTOMATION INC.

Local transport - Tramming
Experimental equipment

- Teleoperated
- Automatic
- Impact on operations

AINSWORTH AUTOMATION INC.

Local transport - Tramming
Future equipment

- Autonomous vehicle - Task deployed

AINSWORTH AUTOMATION INC.

Local processing - Crushing
Current mining equipment

- Man local operated
- Man local watched
- Problem areas

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Local processing - - Crushing
Experimental equipment

- Man remote operated
- Man remote watched
- Impact on operations

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Local processing - Crushing
Future mining equipment

- Vision system machine
- Automatic operation

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Transport to surface
Current mining equipment

- Surface controlled man hoist
- Automatic skip hoist for lifting ore
- Problem areas

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Transport to surface
Experimental mining equipment

- Operator controlled man hoist (off cage)
- Automatic ramp haulage vehicles
- Impact on operations

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Transport to surface
Future mining equipment

- Operator controlled man hoist (on cage)
- Autonomous ramp haulage vehicles
- Logistics based scheduling

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Enabling technologies3

- Sensor based systems
- Computers that reason and are adaptive
- Communications

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Sensor based systems

- Vision systems
- Navigation systems with GPS for surface

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Computers that reason

- Neural network based systems
- Artificial intelligence systems

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Communications

- The back-bone of all robotic systems
- High bandwidth digital circuits which support voice data and video

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Conclusions1

- Robotics will have a significant impact on underground mining operations

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Conclusions2

- There is no reason to think that robotics will not have a similar impact on forestry operations

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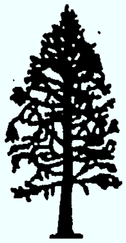
Improving Synergy Between Mobile Hydraulic Machines and Their Operators



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Introduction

The excavator is one of the most basic machines used in primary industries today. The basic design of these machines has been relatively stable over many years. The machine consists of an engine, a hydraulic control system, a linkage structure carrying an implement, and an operator's cab. Recent improvements in these machines mainly address fuel economy or maximize power delivery to the implement for a selected task. However very little consideration appears to be given to the role of the human operator of the machine.

Standardization

An operator of today's machine has to put up with a confusing set of "standards". As a driver of an automobile imagine how you would feel if the vehicle you drove had the brake pedal on the left and the accelerator pedal on the right, while your spouse's car had these controls reversed, and your recreational vehicle allowed the driver to reverse the function of these two pedals by a switch on the dashboard? Could you get used to each system? What would happen in an emergency?

This is exactly the situation in the excavator industry today. In one model of machine, the hand-control for the machine's boom is on the left, while on another it is on the right and on a third it is switchable. Other controls can also be different in various machines. The major companies may rationalize this as "product differentiation" but it is certainly confusing and unsafe.

Naturalness

Beyond this issue however is a more general one. That is the question of "naturalness" of operation. Suppose your friend is washing the outside of a window on your residence. You are inside the building, you see an area your friend missed and you point in the direction that you see needs more cleaning. You would then quite naturally expect your friend to see the direction you are indicating and move the cloth in that direction. In the context of the present discussion, you would be analogous to a machine operator, your friend would be analogous to the machine, and you would be cooperating in a natural way to move the cloth around.

This naturalness is an outgrowth of our ability to control our own arms to reach and touch objects that we see in the world. We think in terms of "moving my hand to pick up the glass that I see on the table", not in terms of "flexing my upper arm a bit, and extending my lower arm down a bit so that my hand gets near the glass at which time my hand should be open". To people in the robotics industry, the former type of control is called Taskspace Control and the latter is called Jointspace Control. At a very young age the human brain learns how to convert its wishes expressed in taskspace (observed through its visual system) into control signals to its muscles to cause the proper rotation of its joints — a conversion known in the robotics literature as Inverse Kinematics. During periods of rapid growth children can become clumsy or uncoordinated, possibly because the body is recalibrating its control system to the new bone lengths.

All excavators today accept control from the operator only in jointspace terms. In other words, to move the implement from point A which is far out from the machine base, along the ground to point B which is close in and to the left, the operator must think in terms of: how much to rotate the boom joint (upper arm) upward now and later downwards (achieved by moving the right hand control inwards now and later outwards), how much to rotate the stick joint (lower arm) inwards (achieved by moving the left hand control inwards), how much to rotate the cab to the left (achieved by moving the left hand control leftward). All three hand control actions must be coordinated together by the operator in different amounts depending on the current position of the implement in order to achieve a task. Learning to accomplish such coordination is in concept, similar to the motor coordination learning task of the child. Furthermore if the operator changes to a different machine with different link lengths, the operator's internal model must be "recalibrated".

The concept of naturalness has been referred to in at least one standards document as "logical coordination". For example, ISO 1503--1977 (E) entitled "Geometrical orientation and directions of movement" states that:

"Movements in control elements and the intended changes in the considered object should be logically coordinated. A linear movement to the right, for example, should be logically obtained by movement of the hand to the right."

Computer Coordinated Controls

In the work that has been undertaken at the University of British Columbia, the task of coordinating the joints to perform tasks has been relegated to an on-board computer. The control system has been called "coordinated control" (or "resolved motion control" in the Robotics literature). Coordinated control has been accomplished on a log loader by using a single hand controller. The operator pushes the hand controller in the direction that he/she wishes the grapple to move at any instant of time. The amount that the hand controller is moved away from its spring-returned neutral position, controls the speed of motion of the grapple in the direction the hand control is pushed from the neutral position (at the neutral position the speed is zero). Grapple rotation is achieved by rotating the hand controller in the direction the operator wishes the grapple to rotate. Grapple closing is accomplished by a pulling-the-trigger action of the forefinger on the control handle. Grapple opening is accomplished by an opposite motion of the same forefinger.

Advantages of Coordinated Control

With the modified control, we can see several potential advantages for the industry. Unify machine operation. If the controls are natural and relate easily to the task, machine operation will be simpler and common concepts can be transferred to the operation of other machines. Reduce learning time. Because of the simpler operation, the novice can expend effort learning the task as opposed to learning the operation of the machine. Broaden the range of operators. Operators which previously did not have the coordination required to operate a machine, can use simplified controls. Improve productivity. If the coordination of the machine is taken care of, there should be less correction to the position of the links of the machine required and hence the task can be carried out more rapidly. Reduce maintenance. The operation of the machine should be smoother, since corrective actions will not be as frequent, resulting in less "flogging" of the machine. Additional checks can be placed in software to prevent obvious machine abuse. Reduce product damage. Smoother operation of the machine also implies more gentle handling of product. Improve safety. Since the operator's concentration can be increasingly devoted to the task, less accidents should occur. In addition, computer checks of machine stability can be implemented in software.

Method of Implementation

The following components were added to the basic machine to provide coordinated control.

Electric Hand Controls

A single joystick is used to provide control of in/out, left/right and up/down linear motion of the grapple, grapple rotate, and grapple open/close. The joystick can be located either on the left or the right side of the operator. The joystick is spring-centered on all axes, and has a contoured handle. The output signals of the joystick are a set of voltages which are connected to a computer via an analog interface.

On-Board Computer

The computer currently contains a VME-bus SPARC processor card and Inmos Transputers. A/D, D/A, DIO and R/D cards are used in the experimental prototype. The system is shock-mounted. Software was developed in the C programming language on an SUN Microsystems host development system and downloaded to the machine target processors. Power for all the electronics was supplied by a battery charged by the machine alternator.

Electrohydraulic Pilot Valves

Commercially-available pilot valves are used in controlling the main valve bank. The pilot valves are controlled by command voltages from the D/A converters which in turn drive the valve's power amplifiers.

Machine Joint Angle Sensors

Resolvers are used to detect cab swing, boom, stick, and grapple motions. The resolvers are mounted over the joint pins in order to directly sense the controlled variable (joint angle).

Machine Pressure Sensors

All hydraulic lines are instrumented with pressure sensors which has been very helpful in debugging the control system. Some pressures are also involved in the control system itself.

Inverse Kinematics Software

The inverse kinematics equations allow the endpoint position of the machine to be controlled in workspace coordinates. Since the mechanical structure up to the grapple joint is not redundant, the inverse kinematics equations are straightforward. A general purpose routine for solving for the inverse kinematics of any machine structure has also been developed.

Hydraulics Control Software

The hydraulics software ensures that the desired endpoint position is achieved by closing the loop on the individual joint angles produced by the inverse kinematics relationships.

Future Work

Implementation on New Machines

Every effort was made to make the existing prototype general, powerful and expandable in order to test new ideas and collect data on-line. A much simpler system can be envisaged for manufacture. The cost of a commercial version of the control system depends on the number of units to be manufactured. If the system was re-engineered for large-scale production, it may be possible to manufacture it for less than $10,000. Even a 2% improvement in productivity over 5 years would justify this cost on most machines.

Future Research

At the present time an effort is being made to develop machine parameter measurement systems to assist in the process of setting up a control system on a new machine. In addition, work on new sensing systems is underway to reduce costs and enhance reliability.

A parallel study is underway to develop a complete simulation of the machine including real-time kinematics, dynamics and hydraulics models of the machine. Such a simulator can be used to study machine and human performance in much the same way a flight simulator is used to study pilot and aircraft performance. A simplified version of this simulator was used in fact to develop and test the key ideas used in the present control system, and to tune the machine control system.

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Coordinated Control Systems Applied to the Forest Industry

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Introduction

The forest industry utilizes crane type heavy equipment in many phases of its operations (excavators, grapple yarders, log loaders, feller bunchers, etc.). Operating this equipment requires the concurrent operation of several components or limbs to realize a desired movement or motion. For example, a pure horizontal movement of an excavator bucket requires the operator to control both the boom and the stick functions at varying rates throughout the bucket's trajectory. Over time, the concurrent control of the various machine components becomes second nature to the operator. The complexity of control and the lack of control standardization or intuitiveness, however, leads to long learning times and the limiting of operator performance. Although many of these control decisions become subconscious, we hypothesize they still require mental exertion and generate operator stress.

In 1985, Dr. Lawrence of the University of British Columbia (UBC) embarked upon a project to develop a logical control interface between the operator and machine. The perceived advantages resulting from such a control system included:

1. Unified/standardized machine operation and control
2. Reduced learning time
3. Enlarged population of potential operators
4. Improved productivity
5. Reduced maintenance
6. Reduced product damage
7. Improved safety.

Coordinated Control

The objective of coordinated control is to provide a logical and natural link between the operator and the machine's end point or tool (eg. earth-moving bucket, log grapple or felling head). Control is achieved via the manipulation of a multi-degree-of-freedom joystick. Instead of the joystick controlling individual machine components, it's deflection or motion directly controls the velocity and trajectory of the machines end point. Raising/lowering, the joystick causes the end point to move vertically, forward/back motion causes the end point to move horizontally and sideways motion causes rotation of the machine. The magnitude of joystick deflection controls end point velocity. Lower level control and regulation of the machine's individual components is achieved via a computer, algorithms and joint angle sensors.

Application and Human Factor Testing

Simulation

The initial demonstration of the coordinated control was via a display presented on a Silicon Graphics Iris system. The image presented simulated a perspective view for the operator from an hydraulic excavator. Two control configurations were evaluated - a two-joystick standard joint control and a single joystick resolved-motion control. Twenty right handed male students performed a series of tasks simulating normal machine operation and motion (Wallersteiner et al 1988). Task complexity was progressively increased to allow determination of control strategy on learning time.

Results

Consistent positive results were measured for coordinated control for all tasks. The simulation showed that coordinated controls would promote accuracy and skill without compromising speed of operation and would significantly reduce the learning time for new operators.

Hydraulic Excavator/Log Loader

In 1985, a Caterpillar 215 excavator was retrofitted with a coordinated control system (Lawrence et al 1990). This machine was later equipped with a log grapple to allow repetitive human factor testing. From 1985 to the present, a number of refinements have been made based on comments made by operators and the maturation of the technology. Consistent throughout, however, has been the ability to switch electronically between joint control and coordinated control (Figure 1). Most recently the ability to incorporate both grapple and machine control into a single joystick have been evaluated (Figure 2) (Wallersteiner 1992). Testing was carried out in a controlled task environment (Figure 3). A semi circle of three sets of three log cradles was located around the machine. Each set consisted of cradles at different heights; test subjects were required to move three logs between cradle sets in a predetermined order. Some tests incorporated the use of a buzzer to measure reaction times (Wallersteiner 1991).

Results

Tests for novice operators showed that, on average, coordinated control improved performance by 20% (Wallersteiner 1991). The performance impact for experienced operators was unclear. Initial testing identified that there was no significant performance differences for the joint and coordinated control strategies (Lawrence et al 1990). This test did, however, identify the performance variability that existed between "experienced" operators and the difficulty they had unlearning joint control. Subsequent studies of experienced operators which allowed increased learning time for coordinated control and improved operator-control ergonomics showed:

- with moderate training (approximately 10 hours) all four experienced operators tested performed as well with coordinated controls as they did with joint controls; two performed 10% better and the others appeared to be still learning
- a single joystick incorporating machine and grapple functions proved superior to the two-joystick configuration.

Throughout the tests operator comments were positive towards the coordinated control. Many saw them as the "way to go" for future machines.

Grapple Yarder

Grapple yarding (Sauder 1980) is a common method of transporting logs from the stump area to roadside. MacMillan Bloedel currently operates a fleet of 41 grapple yarders of various makes and models, the most prevalent of which (29 units) is the Madill 044 (Figure 4). The perceived advantages resulting from retrofitting coordinated controls to these machines are similar to those predicted for hydraulic machines. For MacMillan Bloedel, the estimated benefit of these controls applied to the 29 units is \$1.6 - 2.1 million per year.

In June of 1990, the existing controls (Figure 5) of Machine # Y46 were replaced with a one-hand controller and computer (Figure 6) designed and manufactured jointly by RSI Research and MacMillan Bloedel. Initial tests indicated that the fine control required for grappling the log was not achievable utilizing the system. Further refinement was required including the sensing of line lengths and utilization of grapple location data in the winch control program. Drum rotation sensors were installed on the machine's three drums in the spring of 1992.

Results

Incorporation of grapple location data into the control program has significantly improved the control sensitivity. The Y46 has been moved into a woods setting which allows both up and down hill yarding with field testing of the control system by experienced operators. This testing is scheduled for May/June 1992. Concurrently, RSI Research is designing manufacturing and testing the electrical hardware required for a commercial control system. Final acceptance of the completed system is anticipated by September 1992.

Conclusion

Coordinated control has been successfully implemented and appears superior to standard joint control for the control of crane type heavy equipment. Tests with the hydraulic excavator have shown the benefits of reduced learning times for new operators, the ease of operation and the opportunity for increasing experienced operator productivity. Experience with the grapple yarder will determine if the same advantages are achievable with a cable machine.

Coordinated control represents a significant Canadian technology with realizable economic benefits through both manufacturing and utilization. The ultimate value of this benefit will be determined by how rapidly we apply and utilize this technology.

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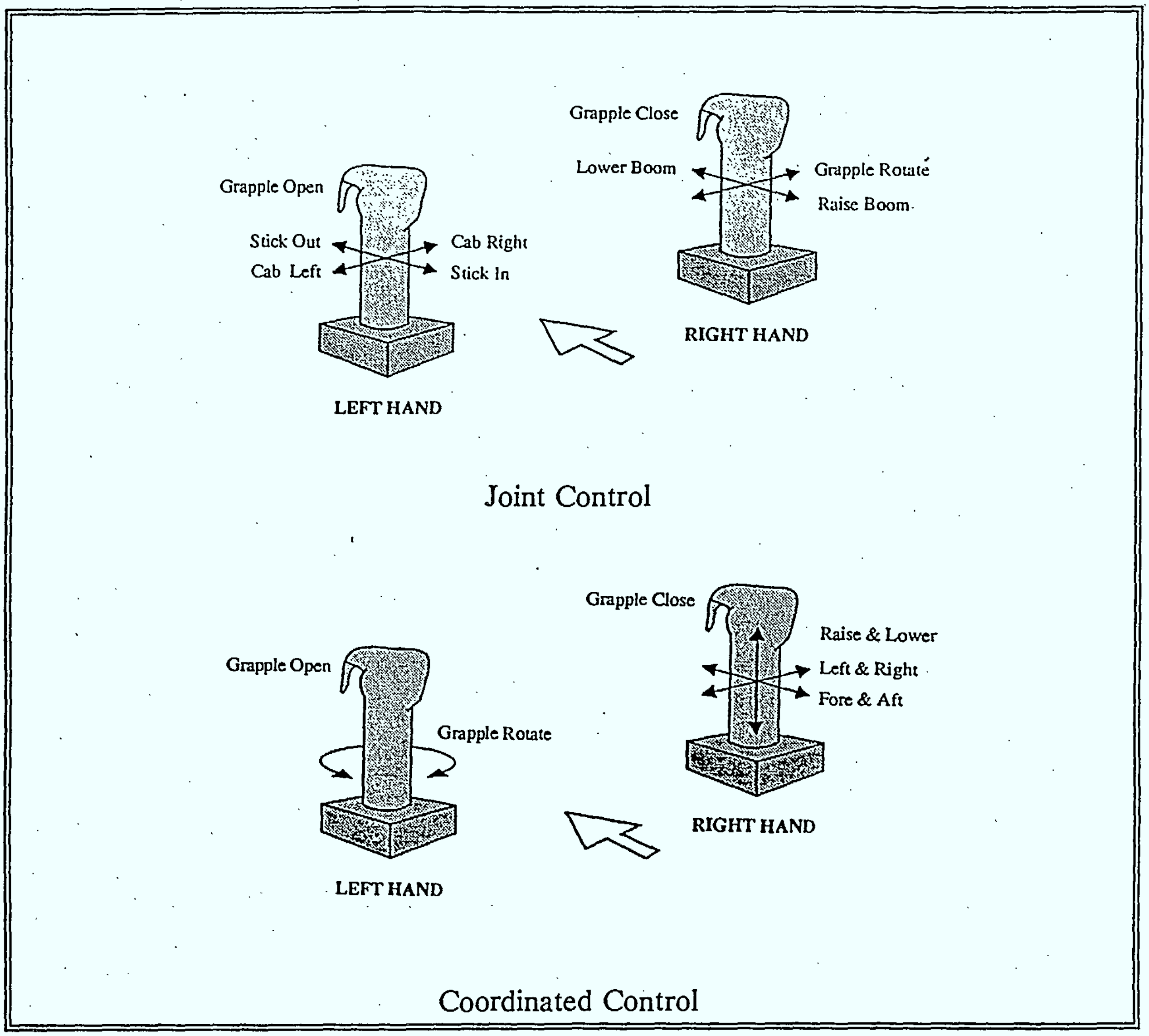

Figure 1. Joint and Coordinated Control Joystick Functions

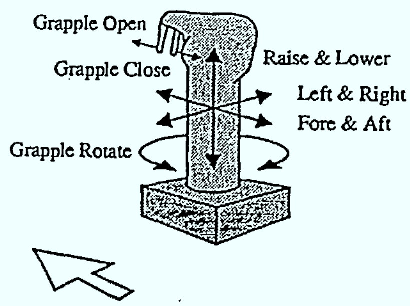

Figure 2. Single Joystick Coordinated Control

Figure 3. Layout for Human Factors Tests

Figure 4. Madill 044 Grapple Yarder

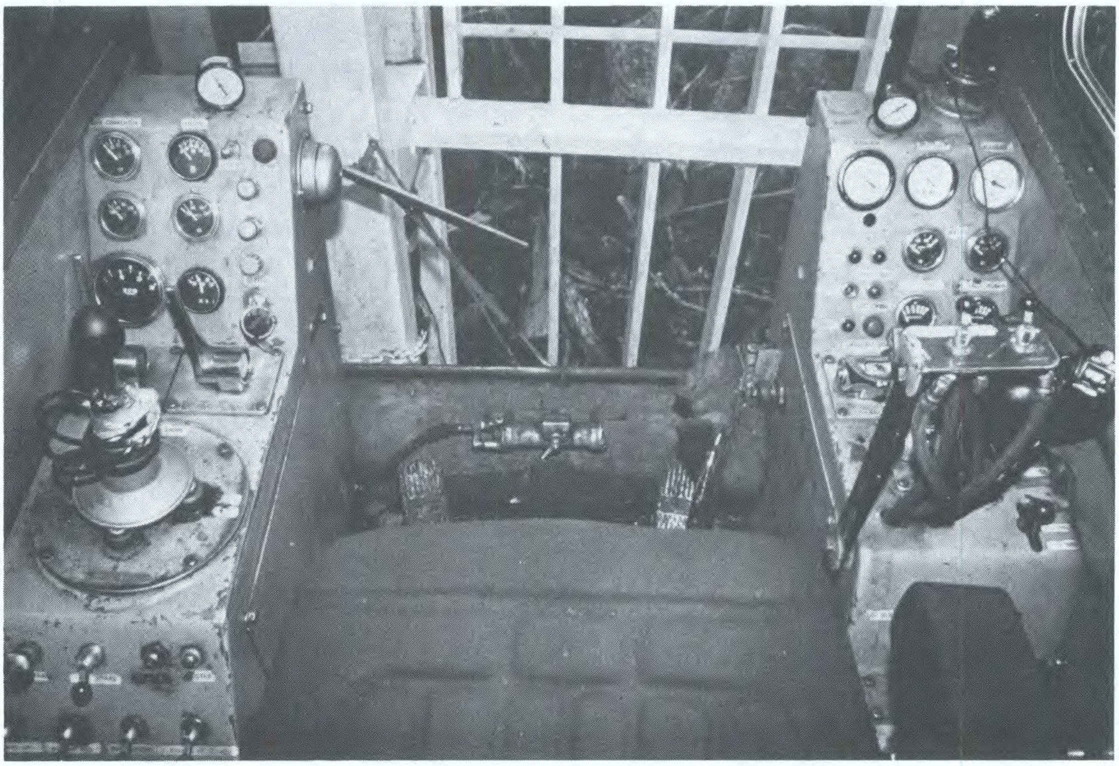

Figure 5. Current Grapple Yarder Controls

(L-R: Swing Joystick, Swing Brake, Treadle Valves, Knee Throttle, Hand Brakes, Clutch Valves, Tag Dray, Maxi Brakes)

Figure 6. Coordinated Grapple Yarder Controls
(L-R: Control Console, 4-Axis Joystick)

The Use and Payback of Robotics in the Pulp and Paper Industry

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Today's world economy is marked by recession which has nearly stopped capital investment in the Pulp and Paper Industry in North America. Through this period, however, investment in high capacity green field mills and mill modernization in countries such as Indonesia, Chile, and Brazil has continued at a slightly accelerated rate. In the post recession economy we will be positioned poorly to compete in the world market against new or state of the art mills that operate with fewer environmental restraints, lower raw material costs, and lower labor costs. To remain competitive and a leader in the world economy return on investment must be short term and productivity for each man hour worked must increase. The implementation of Robotics in the Pulp and Paper industry provides a means to support these goals while maintaining our role as a leader in the advancement of technology.

Today, Robotics are used successfully in Pulper Charging operations, Pulp Bale and Paper Roll Finishing, and in Warehousing applications.

Pulper Charging/Dewiring Systems

Pulper Charging/Dewiring Systems are differentiated by the product being handled into two categories: Recycled Fiber and Market Pulp.

A Recycled Fiber system consists of an entry station, bale storage, Recycled Fiber Wire Wolf (automatic dewiring machine), bale breaker or trammel, load leveler, and batch forming or continuous feed chainbelt conveyor. Systems are designed to process 100 to 1200 tons of material per day. It is introduced into the system in bales that range from 1000 to 2500 pounds with a maximum size of 84 inches wide, 48 inches deep, and 60 inches high. The product may be old newsprint, magazines, corrugated containers, or mixed office waste. The bales may be wired with between 4 and 10 wires all placed in one direction. The machine has also been tested on tire and plastic bottle bales with satisfactory results. Each Wire Wolf can process up to 40 bales per hour with one operator. The operator is responsible to feed bales with a fork or clamp truck and to oversee the system.

A Market Pulp system consists of an entry station, stack storage conveyor, destacker, Market Pulp Wire Wolf, metal detector, manual dewiring station, and batch forming or continuous feed conveyors. Systems are designed to process 280 to 750 tons of material per day. It is introduced into the system as 3 to 6 high stacks of bales that range from 400 to 550 pounds each. Page 2 of 5

Bales may be of any market pulp size with maximum dimensions of 36 inches wide, 36 inches long, and 29 inches high. The bales may be wired in both directions with a total of 3 or 4 wires. A system with one Market Pulp Wire Wolf can process up to 60 bales per hour. A system with two Market Pulp Wire Wolf machines in line can dewire up to 160 bales per hour. Each system requires only one operator to feed stacks and oversee operations. The operator is also required to manually remove any missed wires or pieces of wire that are detected by the wire detector.

Pulp Bale Finishing

Pulp Bale Finishing systems may be divided into two separate disciplines based on furnish and moisture content of the finished product. Market Pulp consists of virgin or a mixture of virgin and recycled fiber that has been dried to 70-90% Bone Dry. Wet Lap Pulp consists of furnish that may vary from 100% virgin to 100% recycled fiber that has been dewatered to 45-70% Bone Dry.

Market Pulp Finishing systems typically consist of an automatic Pulp Cutter, a Layboy, several drops of storage, Bale weighing, pressing, automatic wrapper feed, wrapper dispensing with a Duowrap, wire tying, folding, package marking, stacking, and unitizing. It accepts the web from the dryer and creates a shippable package of individual or grouped bales. These systems are designed to process between 500 and 1500 tons of product per day with two operators. This requires the formation, wrapping and handling of up to 350 bales per hour. The primary function of the operator is to oversee the line and to replace consumables such as baling wire and stencil ink.

Wet Lap Finishing systems typically consist of an automatic pulp Cutter/Layboy, several drops of storage, and a bale pick-station. The system may be built up to provide bale pressing, weighing, wrapping with Uniwrap or Douwrap, folding, tying, marking, and stacking. These systems are designed to process between 100 and 800 tons of product per day with one operator. Again the primary function of the operator is to oversee the line and replace consumables.

Roll Finishing Systems

Roll Finishing systems consist of machines that prepare reel shafts with cores, transport jumbo rolls to the winder, and process paper rolls after the winder. These systems consist of jumbo roll carts, winder shaft prep stations, sorting decks, roll storage conveyors, lowerator, scale, barcode readers, positioner with length and diameter measurement, Index conveyor, wrapper dispenser, roll marker, bilge label applicator, band dispenser, crimper, automatic head placement with Headmasters, header, end label applicator, upender, and warehouse conveyors. Systems are designed to process up to 180 rolls per hour which weigh between 200 and 15,000 pounds each. The rolls may vary from 18 to 84 inches in diameter and 8 to 130 inches in length. Options for wrapping material range from lightweight kraft to laminated vapor barrier to stretch film. The system operates reliably with two operators at the winder deck to separate roll sets and attach bar code tags, one operator overseeing the wrapline and replacing consumables, and one operator part time to assist with replacing wrapper stock.

Warehousing Systems

Automated material handling extends into the Warehouse and Loading Dock areas to simplify storage, loading and unloading of the product. Automatic Guided Vehicles (AGV's) may be implemented to transport finished product from the wrapline to the storage area of a warehouse. AGV's may then retrieve the product and deliver it to an automatic truck loading system. The AGV is a self contained DC motor driven vehicle that is guided and controlled from a central computer. The interface may be accomplished continuously through infra red, radio frequency, or computer mapping or may be intermittent through information points. The AGV system can be as small as one vehicle with two destinations to as large as required. A current installation has 30 AGV's that pick rolls up at 20 points and carry them to 130 destinations with each order being executed simultaneously. Automatic truck loading and unloading is accomplished with the use of a Roll-Load. In this system, the truck driver is able to unload 20 news print rolls in 5 minutes. In order to do this the driver backs the truck into the loading area, connects a pneumatic supply hose, and enables the automatic system. The load is removed and the driver disconnects the hose and drives away. The same system can be used to load the truck with reject rolls, skids of newspapers, or waste materials.

Capital Costs

Each of the above systems implement Robotics of high and low level design to reduce the overall manpower required to produce a saleable item. The Pulper Charging/Dewiring system is successful because of automatic dewiring in the Wire Wolf. The bale Finishing system is successful because of Automatic bale forming in the Cutter and Layboy, wrapping with the Uniwrap or Duowrap, and automatic folding, and tying. The Roll finishing system is successful because of the automatic wrapper dispenser, automatic head selection and placement with Headmasters, crimping, and heading, and package identification. The Warehousing system is successful because of the AGV and automatic truck loading and unloading with the Roll-Load. These systems cover a very wide range of scope of supply and perform many functions in the industry. The machinery and controls within each type of system also vary widely depending on the individual customers requirements. Sale prices vary with scope of supply. A typical Pulper Charging/Dewiring system sells for $250,000 to $800,000 a Bale Finishing system for $750,000 to $4 Million, a Roll Finishing system for $500,000 to $3 Million, and a Warehouse system for $150,000 to $5 Million.

Cash Payback

Not very long ago the only option available to perform each of these tasks was manual labor. Today, even though the technology is tested, proven, and reliable a majority of the Pulp and Paper Industry continues to use the manual approach. In doing this a continuous cost is imposed instead of taking advantage of short term return on investment. In the Pacific Northwest the average annual cost of a pulp and paper employee is $50,000. In order to maintain production on a 24 hour basis, seven days per week, four shifts are required. This implies that each manual position imposes an annual cost of $200,000. In order to justify most capital expenditures, a two year direct payback is expected. Therefore, by eliminating one manual position, a capital expenditure of $400,000 can be justified. Each paper company and mill location has different operating philosophies, rules, and laws which effect the payback calculation, and therefore, each application and system must be evaluated. As robotics are introduced into a traditional environment, such as Pulp and Paper, careful attention must be paid to the displaced worker. A reduction in manual tasks and a reduction in manual positions does not necessarily reduce the work force by a one to one ratio. Many of the displaced employees have talents and skills that will allow them to continue within the organization and add profit and value to the product. The resources can be used in quality, process control, preventative maintenance, and emissions monitoring programs. Although most of the employees will require specialized training, the investment in those who are already familiar with existing processes and products provide the most long term return.

Cost of Accidents

Accidents cost the pulp and paper industry millions of dollars annually. The Washington State Department of Labor and Industry assigns value to injured items as standard payout allowances. A damaged beyond use or lost finger is valued at $12,150, all fingers off one hand at $29,160, an eye at $21,600, a leg at $54,000, and hearing loss at $43,200. Each of these injuries may include tax free lost time pay at up to 75% of the workers wage and may include all costs of training in another trade or continued physical therapy and emotional counselling. The cost of litigated negligence claims is difficult to analyze because most settlements are not released to the public or if any amount is specified it only indicates cash pay-outs. To think of the value of injury in terms of dollars really does a disservice to our employees because injuries impact the entire lives of individuals. The current trend in United States industry is to hold those in management positions criminally liable in negligence cases. Project engineers, Purchasing agents, and mill managers are currently being prosecuted for negligence with jail sentences intended as the end result.

Reduction of Accidents

Robotics that are implemented properly and are properly maintained and operated reduce the frequency of injury. This is accomplished by isolating the employee from dangerous or repetitive tasks. As an example, manual dewiring for pulper charging operations involves clipping wires with side cutters or pneumatic clippers and pulling the wires off of the bale. This is usually done at a pulper floor opening or near a pulper feed conveyor where they are loaded using a ram or fork truck. The manual clipping process creates the possibility for hand and wrist injury due to the repetitive task. The wires are pretensioned in the wrapping process which forms a nice package but causes the wires to spring when clipped creating an eye hazard. When the wires are pulled it creates the possibility of hand, arm, back, and eye injury. When disposing of the wire into a bin or dumpster the same injuries may result. The Wire Wolf completely isolates the operator from the area of danger and coils the wire into an easily disposable ball. Bale and Roll Finishing systems implement robotics to apply material as wrappers and then secure it to the product. Bale Finishing systems remove the necessity of manually performing functions twice every 15 seconds. Roll Finishing systems move the operator away from paper rolls which weigh up to 15,000 pounds and are rolling at 3 feet per second and almost completely eliminates all manual processes. AGV's and Roll-Load eliminate the need for fork and clamp trucks in the loading dock area. This moves them out of an area which is often occupied by truck drivers and shipping-receiving personnel.

Conclusion

In conclusion, current use of Robotics in the Pulp and Paper Industry illustrates that advanced technologies can be applied to harsh environments with successful results. The capital costs are quickly recovered through higher and consistent production, labor savings, employee satisfaction, and reduced accidents. The continued implementation of Robotics will be instrumental in maintaining our position as a world economic leader and as a leader in the advancement of technology.

Wood Volume Measurement Using Range Sensors

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Introduction

Timber scaling, or the art and science of estimating timber volume, has evolved from a very labour intensive craft to the refined technique in use today. It is an integral part of any timber harvesting operation used to determine stumpage payments to governments and producers. Since timber license holders are accountable for scaling, it has become a quest to maximize accuracy at minimum cost. The techniques used involve the establishment of representative sample plans, taper factors, volume tables, and weight-to-volume ratios. The extensive use of statistical methods has served well in controlling the cost of scaling, while providing sufficiently descriptive information for gross accounting and inventory purposes. Current methods, although appealing to many, suffer from shortcomings. While they describe entire populations very well, they lack the detail necessary to optimize processing operations; although their simple, clearly defined methodologies make them easy to use, the price to pay for this standardization is a varying degree of error [1,2]. This paper therefore proposes a radical departure from current scaling practices in asking the following question: why not record exact volumes, taper profiles, and reductions for <u>every</u> tree at the harvest site, and at lesser cost?

Sources of Scaling Error

Scaling errors manifest themselves in two forms: administrative and structural errors. Administrative errors are difficult to quantify and result from faulty planning, human error, or a mixture of both. The most common causes are failure to successfully meet sampling requirements, the use of population statistics to calculate volumes of unrepresentative sample, or the use of outdated statistics [2]. Structural type errors are built into the scaling methodology and are easier to quantify. These are caused by the quantization methods used to simplify the work procedure, e.g., dividing the logs into diameter and length classes. For example, log volumes can vary from -13% to +14% within a given diameter class [3], although these variations usually cancel out with large samples. Other errors, however, do not cancel out because of constraints associated with log processing. For example, trim allowance in mechanically processed wood consistently produces logs of given length at the upper or at the lower limit of length classes, thus creating a cumulative bias [3]. In practice, mechanized slashing to nominal lengths tends to underestimate the volume of wood processed. Another example is diameter measurement using calipers, diameter tapes, or delimber arms in processors, which tends to overestimate volumes [1,4].

Structural and administrative errors are tolerated mainly because current scaling practices are as accurate as possible when instruments such as tapes, rulers, and calipers are used. The standards governing scaling practices are also rigid enough to achieve excellent repeatability economically, which should be acceptable to those who buy and sell wood, but can still be a source of conflict because of perceived human bias.

Scaling to Maximum Accuracy

What level of accuracy is technically achievable on an industrial scale? Sawmill scanners are a good indicator. These systems currently achieve ±3% error on volumes, even though they have a diameter measurement error of ±1 mm (assuming a perfectly circular log) and length measurement errors of ±23 mm [3]. By comparison, the 20 mm diameter classes and the 200 mm length classes used in conventional scaling methods create errors of up to 19% [3], which is certainly no match if the aim is detailed information and consistent accuracy.

Why then invest in accurate log measurement in the field? First and foremost is cost reduction. Scaling directly costs the forest industry between $0.20 and $0.80 per cubic metre in Québec, and $0.15 per cubic metre has been reported in British Columbia [5]. The technology proposed in this paper could effectively reduce this cost to $0.10 per cubic metre by using either of two methods: scaling during log processing (radial scanning) or high-speed diameter scaling (axial scaling). Scaling during processing can provide acceptable volume figures, as demonstrated in Finland and Sweden where tree-harvester scale volume is now legal for trade. High-speed axial scaling is still in the conceptual stage.

Other less tangible benefits stemming from increased accuracy are improved control and planning. In the short term, accurate log measurement will certainly achieve better log optimization and thus reduce waste. In the long term, sawmills and pulpmills will be able to use log characteristics to plan their production schedules "just in time". More specifically pulpmills will know ahead of time how many oversized pieces can potentially jam debarkers or conveyer belts, or what debarker or chipper adjustments to make for an optimal performance.

How can timber volumes be accurately measured at the harvest site? Many approaches have been used until now; however, designers have often traded maximum accuracy for repeatability and operational reliability. It is easier to constantly obtain "near-enough" log volumes and emulate current volume measurement techniques than to measure exact volumes consistently. Practically speaking, calliper-type measuring devices currently found on tree harvesters and processors are still prone to overestimation of diameters, and length measurement can also be inaccurate because of slippage between drive rollers and the stem. Furthermore, no harvester or processor on the market today can yet accurately measure more than one stem at a time, which makes these systems unreliable when handing small diameter trees. Sawmill scanners on the other hand, while providing excellent accuracy, are not adapted to the rigors of a forest environment. The solution to these problems could possibly lie in a novel laser-scanning camera called BIRIS.

Optical Techniques and the BIRIS Range Sensor

The rigors of a forest environment require very robust technologies capable of working in the worst environmental conditions. Furthermore a new system will never be economically and technically viable if it is not capable of surviving the mechanical and thermal shocks and stresses that are common to forestry applications. All these possible conditions are difficult to completely simulate and test in a laboratory environment. It is therefore imperative that any new development must have the potential of being capable of working in such difficult situations.

It is generally believed that optical systems have a reputation of being fragile and difficult to use. This is true for very accurate systems such as astronomical telescopes or low-cost cameras (mainly because of the mechanical construction used to reduce weight and costs). However, in practice many optical systems have found applications and uses in very difficult environments such as the military, space, and underwater applications. One main advantage of an optical system lies in its capabilities of obtaining information and measurements without having to be in contact with the object under inspection. In that respect, optical range sensors have the extra advantage, over conventional imaging devices, of directly providing the information about the shape and dimensions of the object with a minimum of computer processing and therefore reducing complexity and cost of a system.

The BIRIS range sensor has been developed to work in difficult environments where reliability, robustness, and ease of maintenance are important. The optical principle of the BIRIS range sensor [6] is shown in Figure 1. The range sensor consists basically of a mask with two apertures, a camera lens, and a standard solid state compact video camera. In a practical implementation, the double aperture mask replaces the iris of a standard camera lens (thus the name bi-iris). A laser line, produced by a solid state laser diode and a cylindrical lens, is projected on the object (Figure 2) and a double image of the line is measured on the CCD video camera. The separation between these two imaged lines is proportional to the distance between the object and the camera and provides direct information about the shape and dimensions of the object.

The very high robustness to shocks and mechanical vibrations and reliability of the BIRIS sensor are obtained because no moving part is involved in the range measurement and because of the long life times of the electronic parts (e.g., laser diodes are rated at >50000 h). Furthermore, use of special realtime video image processing algorithms, added to the redundancy in the acquisition caused by the double aperture mask, gives very high immunity to ambient illumination (such as sun illumination) and false measurements. Table 1 shows the characteristics of the prototype used in this experiment. It is based on a Panasonic video camera slightly larger than the Pulnix camera used in previous studies [6,7] but mechanically more robust.

Calibration, Sensor Registration, and Auto-diagnostics

Calibration and maintenance of a system are very important aspects which must be addressed, especially in situations where repair and maintenance *in the field* are required. These topics are often neglected, especially at the research stage in laboratories where equipment is readily available. In this research, to be viable a systems must address calibration and maintenance problems, especially if a piece of equipment can be installed in very remote locations. This statement is also true at the factory where assembly can be simplified and costs associated with the production of the sensor can be reduced. It also helps to demonstrate that a new technology is mature enough for commercialisation.

As mentioned previously, the main objective with the BIRIS project is to obtain a low-cost but very reliable optical sensor. This means that inexpensive parts with low mechanical and electrical tolerances must be used, which once assembled must be calibrated to produce exact measurements. Many considerations associated with the calibration and maintenance of a 3-D range sensor within an application must be considered for a system to be commercially attractive and useful:

1) calibration of the sensor to compensate for the tolerances and distortions of the parts used for the construction of the camera head and to produce exact 3-D measurements,

2) automatic registration of the camera or cameras within the host processor to obtain a global reference (i.e., to correlate the measurements from one camera to the other cameras or to other measurement systems (e.g., length encoders)),

3) automatic update of the calibration and registration parameters to compensate for the shifts and drifts of the parts introduced during the operation of the machine,

4) auto-diagnostic capabilities for easy maintenance.

In a forest environment the calibration must be self-contained within the sensor head and totally transparent to the operator. Because of the low cost of the head, it is possible to replace a damaged optical head very quickly with a backup device and ship only the damaged camera, but not the whole system (e.g. the computer), to the factory for repair. Special techniques must therefore be developed for self-contained calibration, automatic camera registration, and update of the parameters. Methods and algorithms have been developed to calculate the optimum parameters which minimize the errors associated with the camera measurements and to remove the distortions and to calibrate the system in real time. This is done using very small parameter tables easily self-contained in the camera head electronics and downloaded in the main processor memory during power up. Similar methods are also being addressed for the other points mentioned previously.

Experimentation

Two test benches have been built to validate the BIRIS range sensor technology for measurement of the volume. The first validated radial measurement and the second axial measurements. Table 2 enumerates possible applications of the two techniques.

Radial Measurement

The radial measurement experiment consists of measuring thè diameter of one or several logs simultaneously using one, two, or three BIRIS cameras to dynamically test different possible configurations of the sensors. The three cameras are mounted on a triangular structure. The logs are placed on a rotating plate to test the repeatability in the volume measurement for different orientation and position of the same object. Figure 3 shows the concept associated with this technique.

For this demonstration, four different methods have been tested to measure the cross-section of the log:

1) Best fit of a circle to the range data to minimize the error (minimum least square) and calculation of the diameter **D**. The surface is $\mathbf{S} = \pi \mathbf{D}^2 / 4$.

2) Best fit of an ellipse with detection of the minor and major axis **a** and **b**. The equivalent diameter is given by $\mathbf{D} = \sqrt{\mathbf{ab}}$, the surface is given by $\mathbf{S} = \pi\, \mathbf{ab} / 4 = \pi \mathbf{D}^2 / 4$.

3) Detection of the major and minor axis of the log by pivoting a segment by its centre (best circle) and evaluating the longest and shortest segments intersecting the range measurements. This method is conceptually identical to the technique used for the 20 mm diameter classes.

4) Direct measurement of the surface delimited by the range measurements and evaluation of the equivalent circle diameter using $\mathbf{D} = \sqrt{(4 * \mathbf{S} / \pi)}$.

These methods were used to compare the laboratory results with the techniques currently in use to obtain the volume of wood [8], that is measuring the diameter of the log manually. By moving the sensor along the length of the log the exact volume can then be calculated: $\mathbf{V} = \mathbf{S}\, \Delta\mathbf{L}$ where $\Delta\mathbf{L}$ is the length increment between each measurement, errors in the cross-section measurement being reduced by acquiring multiple profiles (surface S) for a single timber.

Table 3 shows the measurements obtained using two or three BIRIS sensors for three different specimens. Only one profile is acquired then the log is rotated and the process is reproduced every 15° to test the repeatability for each camera of the method for a single cross section with different orientations. Table 3 shows the absolute maximum and minimum diameter obtained by calculating the surface of the cross section of the log; the standard error is under 2.1% using two cameras and under 0.6% using three camera. Table 4 summarizes the results obtained using the four techniques mentioned previously. These measurements compare advantageously with current practice.

Two algorithms have also been tested for the simultaneous identification and detection of multiple stems (Figure 5): robust fitting [9] and a split-and-merge technique based on minimization of the MLS error, for application where multiple logs are present simultaneously (e.g., when delimbing small diameter stems). These two algorithms are first used to segment the range data and to identify each log separately. The volume of wood is then calculated using one of the four methods used previously with single log measurement.

Axial Measurement

Axial measurement is the method most currently used to measure the volume of a pile of wood. Different types of scaling methods have been prescribed by governments [8]. Figure 6 demonstrates the basic approach which is used for the measurement, either the sensor or the pile of logs (on a truck) can be moved. Figure 7 shows a range image obtained using the BIRIS range sensor. Range intensity is encoded in grey levels with intensities related to the distance of the object from the camera (the brighter the object the closer it is to the camera). Different methods can also be used here for proper image segmentation. A technique based on a hierarchical merging method developed at NRC [10] has been tested to identify each log separately and to measure minimum and maximum diameter of each stem, preliminary results are encouraging. Figure 8 shows the result of a second simple technique called threshholding which consists simply of measuring only the pixels or points which are closer than a given range (threshold). As can be seen, the logs have been clearly identified and the total volume is obtained by either identifying each stem and multiplying the calculated surface (ellipses or circle fit) by the length and summing the results, or simply by accumulating the surface of valid pixels (points) multiplied by the range (length).

Conclusion

The applicability of the BIRIS range sensor for scaling has been shown using two different approaches on real samples of logs: (1) a radial method to evaluate the cross section of a stem and (2) an axial method for butt scaling of tree length piles. In both cases reliable and accurate diameter measurement and log detection have been demonstrated. The advantage of using range data to directly obtain accurate information on the exact cross section of timbers has resulted in simple processing of the data to extract the desired information such as the volume of wood, number of logs, and dimensions for each log.

The robustness and reliability of the sensor have also been considered and special techniques related to maintenance and calibration of the system have been described, one of the main objectives being a sensor designed to work directly on log processors or harvestors at the harvest site.

As this work is only an initial feasibility study, much work is still to be done before a fully operational prototype capable of working in the worst environmental conditions that foresters know so well will be available. Also, more refinement in the processing algorithms and the measurement process is needed.

Acknowledgements

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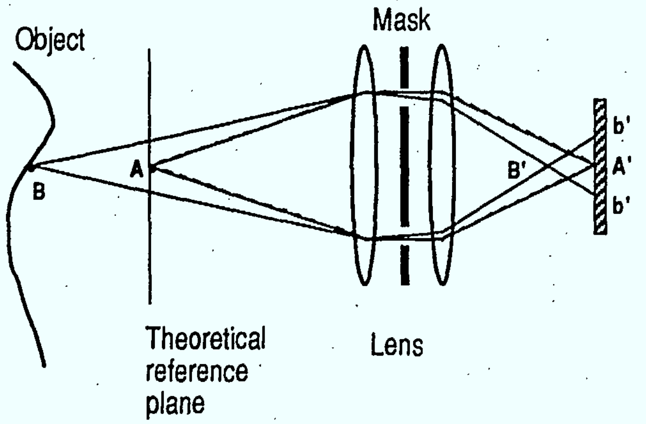


Figure 1: Optical principle of the BIRIS range sensor.

Physical dimensions	20 cm x 14 cm x 5 cm
Measurement range	0.4 - 4 m
Accuracy (rms)	1.6 mm @ 0.5 m 2.5 mm @ 1 m 4.2 mm @ 2 m
Field of view	22 / 30 deg
Acquisition time	50 ms
Points per line	128
Laser power	16 mW
Eye safe distance	> 16 cm

Table 1: Characteristics of the BIRIS range sensor used for these experiments.

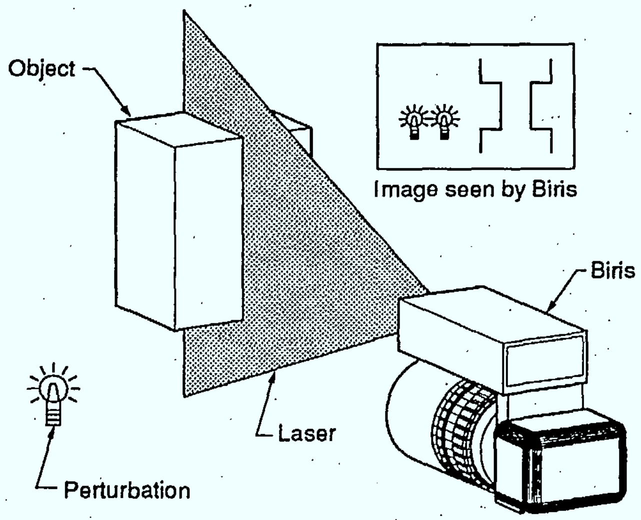


Figure 2: Effect of ambiant perturbations on the BIRIS sensor. The laser line projected on the object is imaged as a double line on the video sensor. Reliability in the range measurement is obtained through the symmetry in the video image.

Axial measurement

- Butt scaling of tree length piles
- Diameter scaling of logs
- Truckload measurement
- Complementary measure to radial measurement in log processors

Radial measurement

- Log processors and harvestors
- Delimbers
- Mobile slashers and delimber debarker chippers
- Stationary slashers

Table 2: Applications for two configurations of the BIRIS camera (in increasing order of potential accuracy).

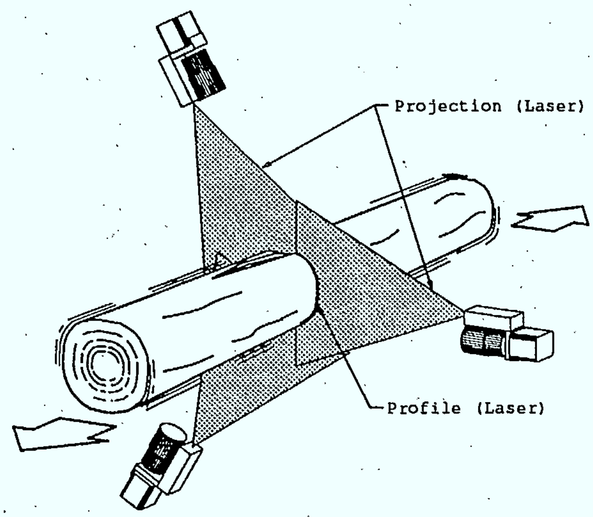


Figure 3: Basic principle of radial measurement using one, two, or three BIRIS cameras.

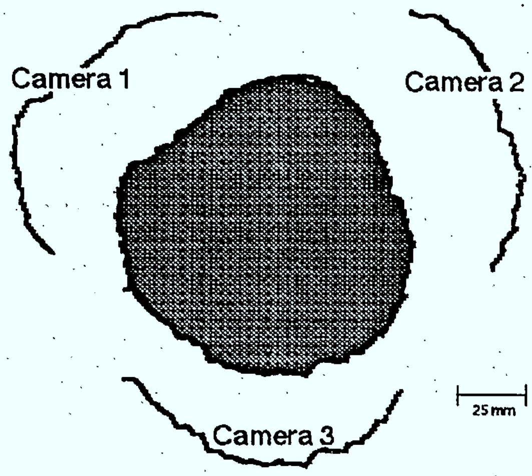


Figure 4: Acquisition of a single log (radial measurement).

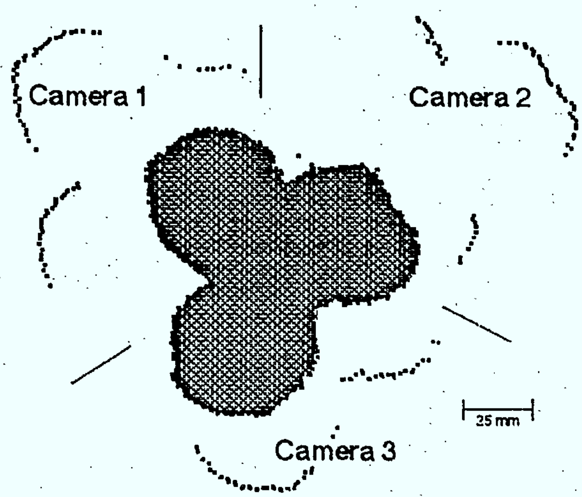


Figure 5: Acquisition of multiple logs (radial measurement)

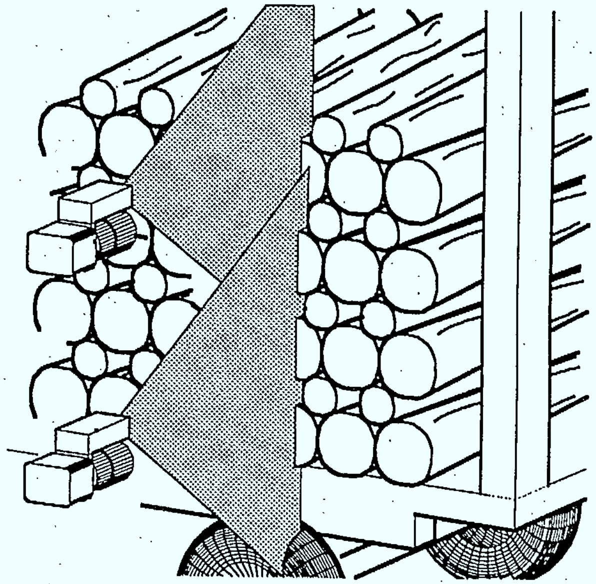


Figure 6: Basic principle of axial measurement of the volume of a pile of wood.

Sample # / diameter	# of camera	External Diameters (mm) Average	Minimum	Maximum	RMS	Error
1 / 182	2	180	176	185	2.0	(1.1%)
	3	179	178	179	0.4	(0.2%)
2 / 107	2	106	101	110	2.1	(2.0%)
	3	104	103	105	0.6	(0.6%)
3 / 287	2	299	287	307	4.6	(1.5%)
	3	298	297	298	0.3	(0.1%)

Sample diameter: approximate mechanical measurement
External Diameter = (4 x surface / π) $^{1/2}$

Table 3: Repeatability on the calculation of the diameter using the surface measurement, for three different samples of logs acquired at approximately every 15 degrees of rotation (total number of acquisitions for each log: 50).

Sample # / diameter	# of camera	Circle Fit Avg.	Std Error	Ellipse Fit Avg.	Std Error	Comp. Scale Avg.	Std Error	Surface / Dia. Avg.	Std Error
1 / 182	2	179	2.0 (1.1%)	181	1.6 (0.9%)	178	2.4 (1.3%)	180	2.0 (1.1%)
	3	179	0.4 (0.2%)	179	0.4 (0.2%)	179	0.8 (0.5%)	179	0.4 (0.2%)
2 / 107	2	107	1.9 (1.8%)	110	5.6 (5.0%)	104	2.8 (2.7%)	106	2.1 (2.0%)
	3	107	1.0 (0.9%)	106	1.1 (1.0%)	103	1.1 (1.1%)	104	0.6 (0.6%)
3 / 287	2	300	5.9 (2.0%)	303	4.7 (1.6%)	297	6.5 (2.2%)	299	4.6 (1.5%)
	3	299	0.4 (0.1%)	298	0.3 (0.1%)	293	1.2 (0.4%)	298	0.3 (0.1%)

Table 4: Repeatability in diameter (surface) measurement for four different processing techniques (see text for details). Measurements are in millimetres, total number of acquisitions: 50 at every 15 degrees of rotation of the log.

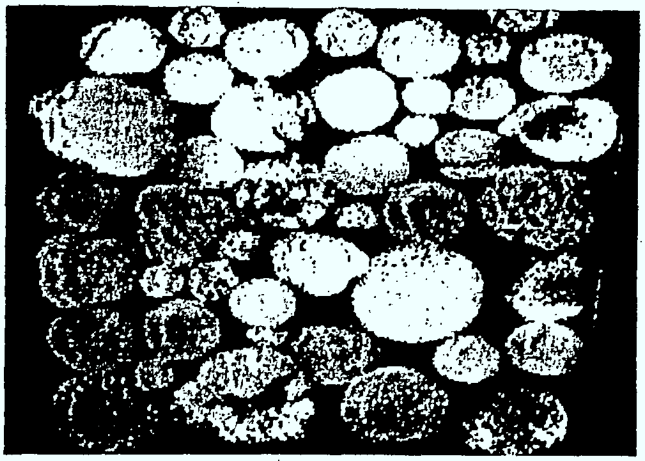


Figure 7: Range image acquired using the BIRIS sensor, the intensity of pixels in the image is directly proportional to the distance of that pixel from the camera.

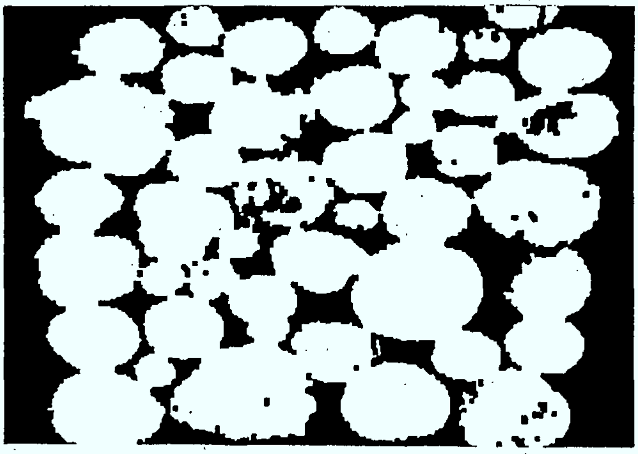
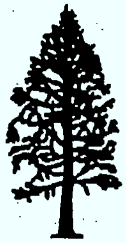


Figure 8: Thresholding the range image of Figure 7, logs are clearly identified. Some of the missing parts are caused by rotten wood or damaged timber.

Reaching into Space for Canada's Future



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Introduction

- This presentation focuses on Canada's manned space programs as a source of technology for Canadians.
  - Primarily the Mobile Servicing System (MSS) Canada's contribution to the U.S. International Space Freedom (SSF) program.
- Provides a brief overview of the SSF and MSS Programs.
- Describes the processes previously used to spin-off technologies and some of the lessons learned
- Describes the process now being implemented and planned for the future to increase spin-off successes from Canada's Space programs.
- Describes the type of technologies being developed and available to Canadian industry.

Space Station Freedom Program Overview

- The program has four international partners
  - United States
  - Canada
  - Europe
  - Japan
- The MSS is moving from the detailed design phase to hardware production and element launches will occur between 1995 - 2000.
  - 1995 - First element launch
  - 1997 - Man tended capability
  - 2000 - Permanently manned capability

- Space Station missions include:
  - Life sciences
  - Microgravity
- The program represents a worldwide investment in technology of over $ 20B.

Mobile Servicing System Overview

- The Mobile Servicing System comprises four major elements:
  - Space Station Remote Manipulator System (SSRMS)
  - Special Purpose Dexterous Manipulator (SPDM)
  - Mobile Base System (MBS)
  - Ground Segment (GS)
- The MSS roles include:
  - Space Station Assembly
  - Inspection & Maintenance
  - Equipment Change-out
  - Astronaut support
- The MSS launch manifest is:
  - SSRMS - 1995
  - MBS - 1996
  - SPDM - 1997
- Canada's contribution to Space Station is $ 1.2B, which includes:
  - MSS
  - Strategic Technologies
  - User Development
- Canada's expectations are that more than $ 5B in spin-offs will result

The Spin-Off Process and Results - Past

- The most directly equivalent program from the past is the Canadarm
- The Canadarm program has proven significant spin-offs can result from space programs
- To date over $ 400M in incremental business has accrued to Spar
    - Over $ 300M in exports
    - In the space, nuclear, defence, mining and advanced manufacturing markets
    - Over $ 1B in benefits have resulted when subcontracts and indirect effects are included
- The majority of the benefits occurred after the completion and launch of the first Canadarm
- The process for achieving Canadarm spin-offs was ad hoc and reactive
- The process was primarily internal to Spar
- The approach was that Spar would achieve all spin-offs
- As a result Spar attempted to pursue many diverse markets
    - Space
    - Defence
    - Nuclear
    - Mining
    - Advanced Manufacturing

A Case Study - The Mining Industry

- In the mid-to-late eighties Spar targeted the mining industry for spin-offs
- The only significant result was a contract from Inco to develop a roof bolting and screening machine for hard rock mines
- Spar developed the prototype and delivered it to Inco for testing in their experimental mine
- The product met all technical requirements
- The product never went into production

Lessons Learned

- Spin-offs require a committed long-term effort to introduce new technology into industry
- Spar understands the technologies but it cannot understand all of the markets
- Spar does not have the infrastructure to support typical industrial markets
  - Dispersed sales organization
  - Field support and service organizations
  - Volume production capabilities
- A catalyst/supporter would greatly help to facilitate the process of technology transfer
  - Perform a matchmaking function
  - Translate
  - Minimize risk
  - Support investment

The Spin-Off Process - Future

- A proactive approach is planned to maximize benefits to Canada
- Three types of Spin-offs are anticipated:
  - Direct
    - The MSS team acquiring new space business
  - Indirect
    - The MSS team acquiring new business in other focused markets
  - Diffused
    - Other companies taking advantage of MSS technologies for incremental sales in their specific markets

Direct and Indirect Spin-Offs

- Each team member has produced a spin-off plan addressing the above

Diffused Spin-Offs

- Spar and the Canadian Space Agency are working on a plan to achieve diffused spin-offs
- Spar, the Canadian Space Agency and consultants have completed a study to inventory MSS technologies and identify potential applications
- The study identified 29 technologies that have been developed to date on the MSS program
- This technology identification process will be ongoing at Spar and will be expanded to include other MSS team members
- A three tiered process is planned to communicate to industry the available technologies
    - attend nationwide technology conferences (eg. FS2000)
    - work with selected industry associations to prioritize opportunities
    - communicate with individual companies to transfer technologies and achieve spin-offs
- In parallel, Spar and the Canadian Space Agency intend to work with potential government agencies to identify catalysts to assist in the technological transfer process
- The vehicles for transferring technologies will be determined on a case-by-case basis
    - licensing
    - joint ventures
    - joint R&D

Available Technologies

- MSS technologies identified fall into four broad categories
    - Microelectronics
    - Intelligent Robotics
    - Software
- All of the above are applicable to the forestry industry
- Some specific examples follow

Technologies for the Forestry Industry - An Example

- Stereo Vision System
  - The MSS program is developing a vision system capable of producing a 3-Dimensional image of an object as well as determining its range and rate of travel with respect to the camera
  - The system could be used to analyze logs or determine the best cut if tied into systems identifying market/sales trends, company inventory, etc.
  - The system could help automate log handling by determining position and orientation of individual logs within a pile
- Maintainable Joint for a Robot
  - The MSS program is developing a robotic joint that can be maintained in space where there will be limited equipment, a difficult environment and limited manpower
  - The ideas developed could be applied to forestry equipment that operates in remote areas with many similar constraints to space

Conclusions

- Canada's Space Programs have been and will continue to be a source of technology available to Canada
- The generation of significant diffused spin-offs will require the cooperation of CSSP contractors, companies established in other markets and the government
- Spar believes the forestry industry could benefit from available technologies
- Let's talk!!!

Education and Enterprise: The Unbreakable Links

Janice Moyer, President
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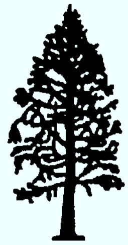

Introduction

For years, Canada's forest industry has been a major economic success story. As far as anyone could see, the forests stretched across the hills with the promise of endless profit. The trees were gathered using the best management practices of the time. The industry saw no reason to change.

And then, something began to go very, very wrong. Wrong for forestry, and wrong for Canada.

Basically, we were hit from behind. Nations that had less natural advantage -- Japan, Sweden, Finland and Germany -- were forced to take a high-road approach to forest products. By pouring about twice our level of research and development into their products, they successfully increased the value of their exports. Almost as a spin-off, they minimized the brute environmental impact and enhanced their prospects for long-term viability.

Let's put some facts around our decline. In the last few years our share of the U.S. softwood lumber market has slipped from 30 per cent to 27 per cent. The kraft market pulp area is also slipping out of our grasp -- perhaps because our facilities are often twice as old as our competitors. In the newsprint sector, our inattention to quality is costing us dear. Canada has dropped from 60 per cent of the U.S. newsprint market to 56 per cent. This has been the result of challenges from substitute products, recycled material and new production processes. The human impact is depressing. We have 7,000 fewer forest workers now than two years ago; 16,000 fewer pulp and paper workers; obsolete mills that are closing; and 29,000 fewer sawmill jobs than four years ago.

What happened?

While we were busy cutting down the trees, the rules of the game changed. The world has moved from an industrial economy to a knowledge economy. In this, the challenges to the forest industry are similar to those facing other Canadian sectors. The main event today is not the resource, it is your capacity to conceive and execute new products and processes using the resource. For the forest industry in particular, I would capture this idea in the thought that: <u>the resource today is the forester, not the forest.</u>

The challenge to forestry is not: "How can we best use our forest?". The challenge to forestry is: "How can we best use our <u>people</u>?" How can we think creatively about new knowledge-added products and uses?

This puts the main responsibility for prosperity squarely on the shoulders of those responsible for human development within our forestry companies. Their task is to optimize the contributions of their workers.

What I'd like to do now is set stage for the next speakers, by describing the backdrop for this competitive new world. I will discuss the <u>economic drivers</u> of these human resources changes. I will then relate them specifically to the <u>forestry situation</u>, and some contemporary uses of technology-based training solutions.

I said that the world is moving to a "knowledge economy". I don't want you to take my word for it. Is there any evidence for this, and what does it mean for our workforce?

Here are a few observations:

- Regarding the growth in how we value human skill, in 1850, human capital accounted for less than half of the wealth of an advanced industrial country; by 1984 human capital was accounting for 80 per cent of national wealth.

- the growth of world trade is two- to five-times faster in knowledge intensive goods and services than in resource intensive goods. Unhappily for Canada, we are selling rocks and trees when the market wants value-added items. We are selling yesterday's products to buy tomorrow's products.

- the network between information users is growing incredibly quickly. A billion telephones are now in use; telecommunications is a trillion-dollar industry; and it will grow even faster with the advent of the wireless phone.

- in terms of use, the flow of information is now a flood. In the past two decades, the volume of phone call traffic in the U.S. increased thirty times. Canada is even more addicted to the phone -- we are in fact the world's most talkative nation! And there is plenty to talk about! Today, for example, more than 40,000 science articles alone are being published every year -- two articles a minute.

- in terms of jobs, in the past 20 years approximately 90 per cent of all new jobs were in the information and knowledge areas. In the next ten to fifteen years, some experts expect that ALL employment growth will be in the service sector -- and in JUST those areas associated with the development of the knowledge economy.

- corporations now depend on knowledge development. In a survey of some of the largest companies in America, it was found that the higher they rated in human resource development, the better their long-term performance. It seems that companies that are best positioned with the key competitive resources of knowledge and information are the most likely to prosper.

Why are these changes happening? What value does information technology give an organization?

ITAC did a study a while back to find out. We discovered that information technology is of course important in its own right. In Canada, it is one of our largest sectors -- larger than the auto, steel, mining petroleum or natural gas industries PUT TOGETHER. But its real value is its ability to <u>catalyze</u> other sectors -- to enhance the performance of manufacturing and service sectors. We at ITAC call it the "enabling resource", because of this galvanizing effect.

It has a number of different virtues. First, it speeds up transaction times -- it accelerates the clock of change around the world.

In terms of industrial processes, for example, it took Henry Ford 20 years to develop the "Model T" car. Today, Honda uses software packages -- designed in Canada -- that allow them to go from concept to finished car in less than 20 <u>months</u>.

Second, it is a lever that <u>everyone</u> can use. In terms of social penetration, twenty years ago there were 50,000 computers installed world-wide. Now, we install 50,000 computers <u>every day</u>. In the U.S. alone, 50 million personal computers are active. In fact, 90 per cent of the people who used a computer last year <u>were not using one only ten years ago</u>.

It is important to stress here that this "knowledge economy" does not mean the replacement of other activities. It means we build onto previous skills. Just as the agricultural revolution was complemented by the industrial revolution, the information revolution will complement the industrial. We need to apply these new powers in every sector.

Third, in terms of the computing power in these machines, there has been another revolution. There is more computing power under the hood of your 1991 car than was available to Neil Armstrong in his lunar lander!

To continue the car comparison, if the price of automobiles had dropped as fast as the price of computing power, it would be cheaper for you to abandon your Rolls Royce at the parking meter, than to pay the meter! And your car would be getting three million miles per gallon.

The hands of the clock of technological change will continue to spin faster and faster. There is no inherent "friction" in a knowledge economy -- there is nothing to slow it down. In ten or twenty years, we will be in a "science fiction" world -- but not in the usual sense of "science fiction" as a future beyond your lifetime. We will be living this science fiction.

So there is no doubt that we are experiencing the rise of a new, information-driven world. How can Canada respond?

ITAC has just completed a new study called Investing In People -- the key to Canada's prosperity and growth. Investing in People reviews our choices, and draws a strong connection between education and profitability.

It says we have two economic options today. We can try to lower our prices and wages to levels prevailing in competing economies. I don't know about you, but the prospect of working for a few cents an hour doesn't appeal to me.

To make this threat concrete, take the forest industry as an example of the dangers of the low-cost approach. Low-cost, high-quality plantation-grown fibre from Latin America and Oceania could cut the ground out from under our industry. And with low profit margins, the forest sector could find itself in a downward spiral regarding our ability to pay for research, training and plant upgrades.

There is an alternative. We can seek a comparative advantage through product innovation, quality, service and specialization. This is the recommended course for people like Harvard's Michael Porter. He calls it a "differentiation strategy" -- distinguishing your goods and services from those of low-cost competitors.

This is the only option for an advanced economy like Canada's. Simply, we've got to keep trying to push up the value of the work we do. It is a strategy with immense impact for our human resources activities. It means that the assembly-line worker is becoming a relic of a bygone age.

Instead, we must create a highly-skilled, flexible and motivated workforce. We must train it to think, to use information, and to value change. Marshal McLuhan put it well when he said that the future of work would consist of LEARNING a living.

Is Canada ready for a human resources revolution like that?

The evidence examined by Investing In People clearly states that we have an under-investment in human resources compared to other leading economies. Consider a few of the disturbing signals:

- we rank 14th on the productivity scale for industrialized countries, and we have slipped to fifth place in overall competitiveness;

- our outlays for research and development are inadequate -- only 1.32 per cent of GDP, well behind the U.S., Japan and Germany; and

- our spending on education is ineffective -- we do not train enough of the skilled workers that business needs.

To effect a transformation to a knowledge economy, Investing In People proposes four cornerstones for employee empowerment. These proposals are the core of the ITAC study. Our industry makes these recommendations knowing that they are radical departures from the way we organize ourselves today. We do not apologize for being radical, however. In fact, it is our view that national economic renewal is only possible by making some drastic changes -- information age changes. We believe that successful organizations in the future must follow these four strategies:

- First, invest in training, to create a highly skilled workforce. In a marketplace driven by innovation, workers must renew their skills every few years to remain relevant to market needs. They must also be given the opportunity to develop a "generic" set of skills -- in problem-solving, communications, delegation, planning and goal-setting. A number of other specific actions are outlined to achieve the training strategy: create apprenticeships for every job as a form of institutionalized on-the-job training; increase skills training expenditures at all levels; and develop standards for ongoing education and upgrading similar to those offered by professions like engineering and accounting.

- Second, involve the workers, to tap their creativity. The workers, after all, are the real experts in a company. The strategy is to give workers more voice, authority and responsibility. This is in contrast to the old hierarchical organization, which encouraged a strict separation of managerial and employee roles. Many specific actions are recommended: give workers more control of their production areas; solicit their views on areas outside their immediate work concerns; and create systems to red-flag issues that could otherwise become areas of dispute.

- Third, promote sharing, to create a sense of partnership at all levels of the organization. The strategy focuses on the introduction of plans to share information, financial success and other resources equally in the organization. The specific actions we outline include: circulation of corporate performance reports in a timely manner; sharing all plans for organizational change; adoption of egalitarian policies; and adoption of profit sharing whenever possible.

  And finally,

- Organize Work Flexibly, to create a workforce that can respond with agility to changing market needs. In response to a dynamic market, companies must be able to anticipate change, and adapt quickly to consumer demand shifts. This flexibility is sometimes threatened by overly-rigid collective agreements and workrules. Action items include the broadening of the job definitions, so jobs consist of a wide range of skills. We would also recommend that work be assigned to groups rather than individuals, to ensure a multidisciplinary team approach.

Investing In People points out that these four strategies are interlocking strategies. The effectiveness of any of these policies without the support of the other three will be severely compromised.

Let me describe a few positive stories of companies where these kinds of changes have been made.

At Northern Telecom's Bramalea facility, for example, the plant introduced a program called the "Six Sides of Success". The key elements were greater employee participation and involvement, extensive sharing and flexible work practices.

In 1990 the plant began to organize all employees in teams of eight to ten people. This new structure of work demanded new skills. And this meant more education. Each member of the self-directed work teams received 12 days of full-time training in 1990. They learned such skills as how to run a meeting, problem solving, statistical process, and quality control.

Quality improved sharply. Downtime was reduced. Materials were better employed. Employees also testified to the new sense of purpose and excitement in their lives. In 1991 Bramalea won the federal government's Gold Award for Quality.

Another success story is IBM. Its recent re-sizing adjustments should not obscure a very successful human resources strategy. It has steadily migrated its workers into knowledge-economy positions. Twenty years ago only a third of its staff was classed as "professionals". Fully ten per cent were secretarial. Today two-thirds are professionals, there are NO secretaries left, and the number of R&D employees has shot up to almost 1500. In its shift to higher value-added products, IBM's total education and training expenditures have reached the level of a medium-sized university!

Our study focuses on other companies: Manitoba Tel, Hewlett-Packard, Xerox, Northern Telecom's Calgary facility -- all cases where workers have been successfully empowered. I am satisfied that we can demonstrate the value of our "four cornerstones of empowerment".

But in an innovative, information-driven world, a total social response is crucial. Innovation is not something that can be isolated and nurtured by itself. "Innovation" comes from attitude and desire. It is embedded in the social structure surrounding our organizations, as much as it is found in the organizations themselves. Investing In People addresses three critical areas in detail: the public sector agenda, labour-management relations, and industry's interaction with the education community.

In terms of the public sector agenda, the study calls for a move to a new era of knowledge infrastructure development. It recommends increased public and private spending on training; strengthening of skill-based immigration policies; encouragement of private-sector workforce changes, rather than imposition of changes; and funding of research on the move to knowledge work.

The study was critical of labour-management relations. Historically, this relationship has been marked by mistrust and conflict. We must come together with common goals in mind. Both unions and management must recognize that long-term job security and profits depend on gains in productivity. Decisions on quality and technological change must result from a dialogue of equals. Joint committees are needed in areas of mutual interest.

Finally, our industry-education linkage has to ensure that students get the strategic skills necessary for competing in the global economy. Industry has to work with schools to encourage enrolment in science and engineering programs. Community colleges and CEGEPS need help in developing technology courses relevant to industry challenges. And more alliance-building has to be done with the teaching community, to stress the message of life-long learning.

Investing In People makes all of these recommendations and action plans with a focus on the workplace. But the study has a wider and higher purpose. It concludes that the ultimate goal of a more competitive Canada is not the profit of a few, but a more equitable and prosperous society for all. To achieve this, the Investing In People Vision for Canada is to "create a pool of the most effective knowledge workers in the world, transforming Canada into an exemplary environment for global investment in knowledge-based work".

The forest industry could be an excellent candidate for this "human revolution".

To start with, the need is real. The industry itself has a skills problem. Further, the problem is going to accelerate, as the new information technologies seep into the sector from other fields.

Regarding the skills question, a recent Science Council of Canada study reveals that we have a frightening competitive weakness in our forest sector. Frankly, it says that our forestry engineers, scientists and managers are less qualified than their competitors in the Nordic countries. In fact, European firms have better-trained people throughout their corporate organizations. Aiming for high-quality processes demands and produces high-quality people. Again, that's the danger of being satisfied with a low-cost approach to competition: you are also satisfied with low levels of human development. And if the key resource is the forester, not the forest, then you are in deep trouble.

This need for human upgrading extends into all levels of our forestry organizations. A study done by the B.C. Council of Forest Industries and the International Woodworkers union, found that more than half of the employees tested at eight mills had difficulty reading at a Grade Four level! Only a quarter were fully functional at a Grade Twelve level! Even worse, some 40 per cent of those with reading problems had actually completed Grade Twelve!

This is no reflection on the intelligence of the workers. They merely need greater instruction. But in the meantime, this is hurting us. What it hurts, is the <u>potential</u> of these employees. And I am not referring just to their potential as individuals, but as <u>contributors to the company's competitiveness</u>. There is no telling how much a company is missing by not developing an employee's ability to contribute to the enterprise.

Let me repeat that the concept of value-added is shifting beyond a search for lower-cost ways of doing things. Firms are instead migrating upstream to more knowledge-intensive activities. They are capturing and retaining competitive advantage by deploying core competencies based on intellectual capacity. In many cases, it seems as if our workers are chained to their oars, while the world moves to speedboats.

Here is where the notion becomes important that the clock of technological change is running faster and faster. In addition, fact, we can see that information technology is impinging more and more on the forest industry. Pressure is building for skilled people, who can use computers and advanced technology. Consider a few of the ways I.T. is being used:

- In Quebec, the Societe de Conservation de l'Outaouais (SCO) is considered to be at least a decade ahead of the rest of the world in its ability to control forest fires. SCO uses a sophisticated Fire Management System, which uses information technology to help predict and stop forest fires. The system combines weather, lightning, historical and topographical information. SCO can then identify high risk areas, and focus its monitoring activities. This has given it an unprecedented ability to predict where forest fires are likely to occur, and to initiate a fast and strong counterattack. The system is already credited with dramatically reducing the amount of forest destroyed by each forest fire. It has had enabling effects at all levels, from cost and labour reductions, to improved forest fire control, and a restructuring of the entire forest industry in Quebec. By April 1993, all of Quebec's forest fire protection will be conducted from one central location. This is a new development in an industry which traditionally must operate several costly remote stations. And from the viewpoint of human resources training, you can see that new kinds of people are required by this system: people who can cope with information technology; who are comfortably "computer literate".

- This kind of system is spreading rapidly. There is an <u>Intelligent Fire Management Information System</u> developed in Edmonton by Forestry Canada's Northern Forestry Centre. It is an interactive computer program. It marries information about weather, current and predicted fire behaviour, and available fire fighting resources, to data bases and computer systems and graphics. The result is up-to-the-second recommendations on the most cost-effective deployment of resources for any given fire. The system is called "intelligent" because it contains a component that simulates human thought processes. If it was to be deployed completely across Alberta, the potential savings have been estimated at up to five million dollars annually. It won an Honourable Mention for the first annual Alberta Forestry Innovation Award. Again, this requires a different breed of forester: one with an ability to understand what the computer is saying.

- As you might expect, information

technology is also helping with forest inventories. The federal and provincial governments in Nova Scotia are cooperating on a project that will help modernize the storage of forest data by large landowners. A customized computer system is being set up, to give easy access to data required for forest management planning, layout of access roads and mapping. Management planning will be simplified, easing tasks like efficient road routing, and erosion control. It is inevitable that this kind of system will spread, and that forestry managers will have to be comfortable with computer-based careers.

- You can even see a day coming when an important forestry export could be our knowledge of forestry, instead of forest products. Some modest efforts are underway today. Forest Technology Systems Limited is a Canadian company exploring export opportunities in the U.S. It sells a computer-based fire hazard monitoring system, and U.S. forestry officials are said to be greatly interested in the product. It has been sold in almost every province in Canada -- showing that domestic market experience is a valuable proving-ground. Their system consists of a remote, battery-powered weather station that communicates with a personal computer at a designated base station. Here again, the system turns the forester into a knowledge agent, with a need for high-level skills.

- As we look further into the future, we can see information technology reaching deeper into every forestry operation. You can see the trend in an operation like log scanning, used in sawmills to measure logs and cut lumber precisely. Existing systems already use lasers to create a "ring of fire" around the log, with TV cameras to scan its true profile. At a "blue sky" conference in the U.S., delegates explored the future of scanning, and predicted that practical scanners could be developed which could see inside the log or board. Developed as a spin-off from medical scanners, the machines can show intimate details of the inside of a log, and help the sawmill's "optimizing computers" boost lumber value. Actual tests have shown that yields can go up significantly when the computer can analyze the interior of the log. Those who think this is just "blue sky" dreaming, should remember that it was not too many years ago when ANY lumber industry use of scanners seemed impossibly foolish. Today, few would build a large sawmill without including scanners. Here again, the operator needs to combine expert knowledge of computers with specialized expertise in sawmill operations. This is a knowledge economy career.

So I think it's true to say that the future of forestry will see a torrent of advanced technologies and information systems. It is also true that the success of any of these information applications depends on getting the mill people or the forest fire guardians properly trained in how the systems work. Training for mill crews, for example, should be in-depth. An expert said it took 12 weeks of training at one mill his firm designed. Further, the training has to be ongoing. As the mill upgrades, managers and workers have to be able to "update themselves" on the innovative techniques. And with these high capital-cost projects, people must have the expertise to be able to judge how well the system is doing. Evaluation requires a high degree of training, in order to properly track performance.

If indeed the forestry sector requires higher and higher levels of training, how are we going to deliver that training?

The key to the process is to use information technology to prepare workers to thrive in an information world.

Using technology-based training is often the most effective way to deliver or transfer expertise. For a major segment of our working population, it is the only way to keep abreast of the knowledge-based world. Yet it is an increasingly vital activity. As ITAC's Investing in People study reveals, our primary task today is to tap the brainpower of value-adding workers.

There is no question that the old methods of training are not sufficient. They are not cost-efficient. They are not the most effective way to deliver training. And they are not the most conducive way to prepare people for a "information technology" economy. Using information technology to teach will reinforce other behaviours that are appropriate in an information economy. In a sense, we will use I.T. to catch up with an I.T. world.

As I am sure the coming speakers will outline in more detail, the forest industry in particular can benefit from many different techniques in technology-based training:

Computer-assisted learning provides simulation training. It is usually used to help workers understand the introduction of new technologies, by running through a typical computer-generated "experience" with the employee.

Hypertext and hypermedia can help people navigate through large amounts of information. Hypertext uses nodal "words", that are linked or related in a topical sense. Its richer cousin, hypermedia, does the same thing, but adds graphics, sound, animation and video.

Expert systems capture the knowledge of the "best people" in the organization. This is a critical capability, as firms today are moving away from product expertise as the competitive lever, to core capabilities of knowledge, held within the company's people.

Interactive video conferences can link an instructor with different students in different locations. Students can ask questions and receive answers. The technology allows for the sharing of information in the form of graphics and data files. Canadian companies are leaders in this field, which sometimes goes by the title: virtual conferences.

Compact disk, read-only memory can store and deliver huge amounts of knowledge. Even limited animation is capable of being stored on the CD-ROM disks. Information can be accessed sequentially or at random. It allows trainers to immediately obtain training specific to their needs, when they need it.

Digital video is a new generation of training technology building on CD-ROM and interactive video techniques. It can deliver a training tool that is as lively as a technology can be, using stored images that "talk to" the students.

Finally, computer conferencing uses "audio-graphics" to deliver a voice instruction with computer screen displays. Its virtue is that it can be used by smaller industries, through the public phone system.

All these techniques can be used by the forestry industry. There are a number of different areas in which they could help:

At the most basic level is the straight educational improvement of our workers. We have already revealed that the "baseline" level of worker education is fairly low in Canada. Investing in People makes clear that if we are to succeed today, we must have the total knowledge involvement of all our workers. There are very impressive interactive programs available to allow workers to teach themselves how to read and interpret documents. Hypertext systems, for example, let each worker learn at his or her own pace, following interest areas appealing to the individual. These programs can either be based on-premises, or can be accessed from the workplace to distance learning centres.

Of equal interest are training programs that upgrade specific in-plant skills through personalized, interactive instruction. The new systems no longer require a mainframe, but can be run on a personal computer. This means that Human Resources managers can access information directly, saving time and increasing organization effectiveness. There are skills training packages that cover everything from product knowledge, to questioning and probing workers' abilities with a view to establishing individual career development programs.

Then there are computer-based repair and maintenance systems. These systems can provide on-site instructions to allow someone to diagnose the problem and provide instructions for correcting the fault. They can vary in complexity from instructions on repairing complex engines to forklift fuel tank exchange procedures. During ITAC's Softworld conference here last year, we saw a number of impressive programs. One used a computer screen to call up a diagnostic check on faulty equipment. While the operator was exchanging information with the computer, a window on the screen displayed the faulty equipment and rotated it to show the areas of possible concern. Ken Harrap, of FirstClass Systems in White Rock, calls many of these programs "Just In Time Training", because employees can receive instruction at the very moment the instruction will be useful. This can be critical in many operations. It includes the field of emergency response team instructions. These programs are accessed in the case of an environmental disaster, or example, to give the procedures and instructions to control an oil spill.

Another training area is full human resources management systems. These use probing techniques and databases on worker experience, to give a picture of all the skills resident in the company as a whole. All of the skills in particular departments, or those required for particular jobs, can also be indexed. These systems tell companies exactly what their training needs are, so that training programs can be tailored. Further, internal company goals, such as spotting employees with drive and talent, can be realized. At their very best, the programs can allow you to take an integrated approach to human resource management. They can link the HR department to the strategic planning process.

In today's world, this is an increasingly important capability. Investing in People suggests that the traditional competitive tools, such as financial resources and access to raw materials, are increasingly being eroded as effective levers of competition. Firms are increasingly focusing on human resources to win in today's economy. And these computer tools give companies "people levers": effective ways to transform a workforce.

There is no doubt that the transformation of a workforce is an enormous effort. It requires changes in many perspectives and activities. Training, for example, has to be tied tightly to market requirements and realities. Not to embarrass anyone, but I've heard of an automotive training program that instructs people on carburettor installation. No carburettors have been put in cars in the last two years. This "close contact to market" area is another advantage of technology-based training. It is readily updateable, widely accessible and mass-useable. Yes, the job of moving our workers into the 21st century is a large one. Fortunately, we have the technology to make it happen.

If the training is available, and we have the will to use it, there is no globally-competitive situation that we have to fear. There are two statistics that really determine our actions in the forest sector. First, Canada has ten per cent of the world's forests. That's a huge number, and we can be thankful that we have access to that resource. Secondly, we have two per cent of the world's population. That's not very much, in terms of the brainpower that we can concentrate on the processes of wealth-creation. We have to make every shot count. Our prosperity will not come from large numbers of people cutting down trees. It will come from a relative handful of clever, flexible and well-trained people. These people will be dedicated to finding new ways of doing things and new uses for our forest products. The resource, after all, is not the forest. The resource is the forester. Let's give our people the best training in the world, because Canada needs it.

AN EXPERT SYSTEM BASED APPROACH TO PROGRAMMABLE LOGIC CONTROLLER TRAINING

by
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OVERVIEW AND SUMMARY

In July 1991, *Pacific Artificial Intelligence Systems Corp.* (Pacific AI) approached the Federal government with a proposal to use industry resources for a pilot project to develop computer-based instructional modules for trades training. With encouragement from the Federal government, Pacific AI began work on the pilot in January, 1992, and expects to complete the pilot project in December 1992. Having previously built the software components for a Programmable Logic Controller (PLC) simulator, Pacific AI (in consultation with industry) decided in the pilot to focus on PLC training for electrical workers. This decision was made after an in-depth survey of industrial training needs throughout the province identified PLC training as the number one priority for electrical workers. In March 1992, BCIT joined the project and contributed resources from its Automated Reasoning Laboratory to assist with the high level programming of the tutor. The primary objectives of the pilot project are as follows:

1. To determine whether a computer-based PLC tutor can be developed which will provide *individualized* training which can be offered on-site whenever an individual's schedule permits him/her access to the host computer, thereby reducing and making more effective the amount of instructor-based training needed to achieve pre-defined levels of competence.

2. To determine the extent to which tradespeople themselves can master expert system technology as it can be applied to their own site-specific training needs, particularly as these needs are related to technological change at the workplace.

3. To determine the cost of producing stand-alone industrial tutors using expert system technology and computer simulation of equipment and processes.

THE PROGRAMMABLE LOGIC CONTROLLER

There are many control applications which require the switching (on or off) of various output devices as a function of the state (on or off) of various input devices. This type of control is referred to as *switching control* or *logic control*, and is useful in practical applications where machines or processes follow a fixed and predictable pattern of operations. An assembly line in which each station performs an operation on a manufactured part, after which the processed part is transferred to the next station and replaced by an unprocessed part is an example of a process suitable for sequential control. Processes in which bulk materials are measured, combined, mixed and then discharged provide other examples of applications suitable for sequential control. Sequential control can be implemented in a variety of ways, such as electromechanical relays and various pneumatic, fluidic, and solid-state devices. There is a clear trend, however, which began at General Motors in the late 1960s, to use special-purpose computers called *programmable logic controllers* in virtually all switching control applications for industry.[1] A well-planned PLC control system offers clear benefits over the inflexible, relay-controlled systems of the past. These benefits include reduced machine downtime, greater flexibility, intelligent diagnostics,[2] reusable software components in the control system, and expandability for the future. It is safe to say that modern standards for quality and pollution control require sophisticated control strategies, of which the PLC is in many instances an essential part.

THE TRAINING CHALLENGE

Traditional electromechanical control was expensive, prone to breakdown, and required rewiring for any substantial changes. The traditional training and experience of electricians prepared them very well indeed for installing and maintaining traditional control systems. This traditional training and experience, however, did not in general prepare electricians for the more abstract challenges associated with installing and maintaining computer-based control systems, making the skills of the workforce a limiting factor in the spread of PLC control systems. Nevertheless, the tremendous competitive advantages which *programmable* control offers to industry guarantees that computer-based

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1 Modern PLCs now include functions to support analog control, as well as discrete logic control. This pilot project, however, concentrates upon the discrete logic control, though there are plans to expand the scope of the tutor to analog control once the pilot project has been brought to a successful conclusion.

2 See Kay, P. and Skosnik, J., 'Intelligent Diagnostic and Control Systems', as contained in: American Association for Artificial Intelligence, eds, *Intelligent Diagnostic Systems for Manufacturing Using Abductive Technology.* (Boston: 1990)

control systems will, in time, replace nearly all traditional control systems. There is a danger in this if training does not accompany the changeover from electromechanical control to computer control. Traditional control methods were well understood in the trade, and subject to inspection by various government agencies. It is important, therefore, to accompany plant modernization programs involving the computerization of operations with substantial retraining programs. The need for such retraining was recently highlighted by a random test of 150 electricians in the forestry and mining industries: in this test, only 25% of the questions relating to safety in PLC circuits were answered correctly.[3]

OUR METHODOLOGY

Before we embarked upon this pilot project, we considered carefully how PLC training is currently being conducted, and we reviewed the various software products currently available for computer-based training. After detailed discussions with tradespeople, their supervisors, and plant engineers, we concluded that the available training methods are falling short of what is required. At the risk of some overgeneralization, it may be said that the instruction provided by professional programers tends to go over the heads of the tradespeople while the instruction provided by tradespeople specializing in PLC work tends to provide an inadequate foundation in structured programming techniques. The most popular training tends to explain the operation of a PLC in terms of analogies to traditional electromechanical control circuits. The advantage of this approach is that it builds upon a pre-existing foundation of knowledge. The disadvantage of this approach is that it tends to limit the electrician's vision of the full scope and power of PLCs. In addition, this approach leaves the electrician very ill prepared to deal with problems in the PLC (*e.g.*, scanning problems) which have no analogue in traditional control systems. In examining computer-based PLC training packages, we found that they were too superficial for our purposes: either they amounted to a mere user's guide to the features of a particular vendor's PLCs and did very little to teach PLC programming as such, or

3 Cautionary Note. These are preliminary results from a two year study of the impact of changing technology upon the training requirements of B.C.'s skilled work-force. This study is being conducted by the IBEW/ECA and BCIT, and was commissioned by Labour Canada. Final results will not be available until next year. The remark in the text above notwithstanding, there is nothing in our preliminary findings to suggest that electricians are engaging in unsafe PLC programming practices, or that the control circuits in B.C.'s industries are unsafe. Worksites tend to rely upon a few highly skilled tradespeople with adequate knowledge for PLC programming or upon outside engineering firms which specialize in such programming. Both labour and management, however, has identified a need to distribute these skills more widely.

they amounted to a mere computer slideshow about PLCs, which did not give the student an opportunity to practice PLC programming on meaningful process simulations. We hope to avoid the pitfalls of these approaches by applying some of the skills we developed in working on an earlier project. In that project,[4] we developed extensive process simulations in order to provide simulated I/O for training on real PLCs. Using process simulations, we avoided the enormous expense of replicating industrial processes while providing realistic training for the control of those processes. In many ways, the present project has its origin in a suggestion from Drug Svetic, P.Eng., an outside evaluator of the earlier project, who suggested that we should have simulated the PLC itself in addition to the processes it controls. Then we could have a complete training system as a stand-alone module on an inexpensive, widely available computer platform (the AT-compatible personal computer). The present project takes the final step recommended by Svetic in his evaluation of our earlier work.

WHY AN EXPERT SYSTEM APPROACH TO PLC TRAINING ?

An expert system is a computer program which is capable of performing tasks normally thought to require human intelligence and specialized skill or knowledge. Certainly, any program which can effectively teach a complex subject like PLC programming *is* an expert system. We know from testing them on our students at BCIT, however, that the computer based PLC tutors commercially available do not teach PLC programming. At best, they acquaint students, in a superficial way, with the various uses of PLCs, or provide them with specific programming examples which help students with a prior foundation of programming skill to "come-up-to-speed" quickly on a particular manufacturer's PLC. The purpose of our pilot tutor is to provide inexperienced students with that foundation of programming skills necessary to write good, safe PLC programs for the real-world using any of the commercially available PLCs. As we have argued elsewhere,[5] virtually any computer based tutorial can benefit from an expert system approach using logic. A PLC tutor lends itself particularly well to this approach because the PLC itself is a logical device. As discussed in the next section, there were technical challenges to be overcome associated with having the simulator do logical calculations in "real-time". Actual PLCs avoid the problems of computational complexity discussed below through the use of hand-coded assembly language search routines which search only in a proper subset of the total search space--*i.e.,* in that part of the logically possible space which is physically

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4 The IBEW/ECA--BCIT Innovations Project: 1986-1990. For details, see the Final Report (April, 1991) available in the BCIT library.

5 See, Skosnik, J., "The Role of Logic in Computer Assisted Instruction", *Proceedings of the Sixth Annual Conference on Instructional Technology.* (Halifax: 1989)

real to the device. We had two reasons for not doing the same with our PLC simulator. First, we did not wish to restrict ourselves to any particular PLC, but wanted to be able to model *any* PLC, real or imagined, with our simulator. Second (and more important), we wanted to be able to use metalogical techniques to evaluate student produced PLC programs under all possible sets of conditions, including component failure. Doing this meant that exhaustive search in the whole logically possible search space would be necessary and that, in consequence, highly sophisticated search algorithms would be necessary to achieve satisfactory performance. Having overcome the various technical problems discussed in the previous section, the tutor is able to examine student produced PLC programs intended for pre-defined processes and determine such things as the following:

1. Is there a shorter, equivalent PLC program? This can be important, given that memory is often in short supply in PLCs.
2. Is this PLC program "fail-safe" (in some sense defined by the expert system) in the event of component failure?
3. Does the student PLC program exhibit logically correct behavior, relative to the design specifications of the problem?

Given the approach we have taken, the simulator can quickly check any PLC program proposed by the student to determine whether it satisfactorily solves the problem at hand in the exercise. The expert system in effect can act as a personal instructor for the student, examining his work in progress and correcting it where necessary. It is not yet clear how far this approach can take us; but it will provide a tremendous aid in developing clear, logical thought by exposing the elementary errors of logic which often infect the PLC programs of beginning students. When we look at the whole problem of plant control using PLCs, there are obviously some mistakes which a PLC simulator by itself cannot detect. For example, (a real example from my experience) one could develop a PLC program for controlling the movement of goods through a bulk handling system and test it by moving an empty crate around the plant--only to discover that, when the crate is full, it is so heavy that the hydraulic system breaks down and the crate does not move at all. This is not a situation which logic alone can correct. But there are certain programming principles, derived from purely logical considerations, such as how emergency stops should be programmed, which our simulator is ideally suited to teach. Many beginning students have a great deal of difficulty with these basic logical principles. We are sure that carefully constructed exercises using our simulator will make it much easier for beginning students to grasp these principles and as a result develop good, safe programming methods.

TECHNICAL CHALLENGES AND DETAILS[6]

Above, we informally characterized expert systems in terms of the tasks they perform. A more careful characterization would also take into account *how* these tasks are performed. From our point of view (which admittedly is biased in favour of one side of a philosophical controversy about the nature of machine intelligence), expert systems should be capable of full logical deduction with respect to the information they store. Supporting this full range of deduction gives our tutor very powerful analytic tools for evaluating and identifying programing errors of our students. But even for a very simple logical device, like the PLC, there are profound problems associated with supporting completeness of deduction with respect to the operations of such a device. For the purposes of our tutor, in its present form, the PLC is simply a device which does boolean calculations.[7] Such calculations are simple in this sense: there are easily understood rules which, when applied carefully, allow man or machine to calculate solutions to any problem expressible in purely boolean terms. There are other logical systems, richer and more powerful than boolean logic, where the rules are much harder to understand or, in some instances, completely inadequate for the solution of whole classes of problems expressible within these systems.[8] The theoretical simplicity of boolean logic concealed an important *practical* problem associated with the use of boolean calculations by computers: given a boolean formula **B** with **n** atomic symbols, 2^n calculations are in general needed to calculate the truth-value of **B**.[9] Thus, given a formula with a hundred elements, calculating its truth value would require 2^{100} finite time units. This is an enormous amount of time, even when the computer's operations are occurring at a rate of millions per second. While the theoretical problems associated with the computational complexity of boolean calculations are probably not resolvable, we have been able to apply some techniques derived from the work of Gerhardt Gentzen to greatly

6 This section is intended primarily for readers with an interest in automated realtime logical deduction. Other readers may skip this section without loss of continuity.

7 Modern PLCs, as mentioned above, in fact do more than this; the pilot tutor, however, will just teach sequential logic, which is boolean in nature.

8 The interested reader is referred to Gödel, K., "Über formal unentscheidbare Sätze der Principia mathematica und verwandter Systeme I", as contained in: *Monatshefte für Mathematik und Physik*, vol 38, pp. 173-98.

9 For a proof of the surprising computational complexity of boolean calculations, see Cook, S., "The Complexity of Theorem-Proving Procedures", as contained in: *Proc. 3rd Ann. ACM Symp. on Theory of Computing, Association for Computing Machinery,* pp. 151-8. (New York: 1971) mitigate their effects in practice.[10] In fact, we have fully implemented a logical abstraction of an arbitrary PLC device, which can easily be customized to exactly reflect the computational behavior of any real PLC. PLCs are for the most part programmed in what electricians call *ladder logic*, which, from a logician's point of view, is simply a very visible presentation of sequences of boolean formulas combined with a mechanism for calculating the truth value of these formulas given the I/O state of the PLC. For a ladder logic diagram seven devices wide and one hundred rungs deep, our PLC simulator running on a 33 Mhz 486 computer with 1 meg of extended memory makes all necessary calculations in less than one second. This level of performance is more than adequate for any tutorial applications; in fact, we have found that even on less powerful AT class personal computers the simulator's performance is satisfactory.

CONCLUSION AND ACKNOWLEDGMENTS

This project raises many issues about the use of automation in industry, not only for training purposes, but also for efficient industrial control. The labour force, particularly the unionized section, is sometimes depicted as being hostile to automation. In this situation, it is particularly gratifying for me to acknowledge all the individuals and organizations helping to make this project a success; they are as follows:

Dennis Duffey, former Training Coordinator for the IBEW/ECA and now BCIT Assistant Dean for the Electrical Trades, who has always led the way in the use of new technology for trades training;

Pacific AI, which provided the *HyperLogik* programming environment used to develop the PLC tutor/simulator and assisted with every phase of the project described in this paper;

The Joint Retraining Apprenticeship and Journeymen Retraining Committee of the IBEW/ECA, which provided the project with three months of labour from Brian Jones, an IBEW electrician with specialized PLC knowledge, who is making an invaluable contribution to the project;

Weldwood Canada, which released Herb Sutter, an experienced maintenance electrician from its Quesnel operation, to work on the development of the tutor; Herb's cheerful help guided us to what is important in PLCs for electricians;

10 See Gentzen, G., "Untersuchungen über das logische Schliessen, as contained in: *Mathematische Zeitschrift*, 1934-5, Vol. 39, pp. 176-210, 405-31.

Martin Litster, a BCIT advanced electrical instructor, who has volunteered to validate the technical content of the tutor;

Drug Svetic, Director of the BCIT Advanced Industrial Control Centre, whose comments influenced both the form and content of the tutor, and who has offered to assist with the more advanced levels of the tutor after the pilot project is complete;

Neil Marnard, Second Vice President of the IWA, whose active interest in the education of IWA tradespeople helped to secure cooperation for our project from various mills in B.C.;

Paul Sourisseau, Training Coordinator for the Interior Forest Labour Relations Association (IFLRA), who arranged for 22 IFLRA mills to serve as test sites for the pilot tutor when it is complete;

Labour Canada, whose Technology Impact Program provided funds to the IBEW/ECA and BCIT to determine the impact of advanced technology upon B.C.'s workforce.

For a project of this type to succeed, it is absolutely essential to secure the cooperation of labour and management, and to work with tradespeople from the beginning on all aspects of the tutor. We are fortunate indeed to have had this cooperation so generously given to us by so many individuals and organizations committed to the use of advanced technology in trades training.

Pitch Expert System - A Case Study of a Knowledge-Based System for Pitch Control in the Pulp and Paper Industry

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Introduction

In the next few minutes, I am going to tell you about an expert system which we have been working on and testing over the last four years. It has been called the Pitch Expert System and it is designed to help kraft pulp mill personnel to solve a certain kind of problem they can encounter, called pitch problems.

During my talk, I'll give you a little more detail on pitch problems and their economic significance, I'll describe the expert system we built and then I would like to share with you the results of our evaluation of this technology and describe the benefits of it.

I should make it very clear from the beginning that today you are hearing it from the expert's point of view. I have had 20 years of experience with research and consultation on pitch problems. My co-author, Alan Kowalski, was the knowledge engineer - the brilliant chief architect of the system.

Kraft Mill Pitch Problems and Their Economic Significance

Let's begin with a definition. Pitch, or wood resin, as it is sometimes called, is the material in wood which is insoluble in water but soluble in organic solvents. It comprises 1 - 4% of the weight of wood after the bark is removed. It is a very sticky material.

The nature of kraft mill pitch problems can take a number of forms, but the one most frequently encountered is as follows: the pitch or wood resin is partially liberated from the wood during pulping and tends to deposit on the surfaces of the process equipment. These deposits grow in thickness until they reach a size at which they break away from the surfaces of attachment. When this happens the chunks of deposit are carried with the pulp and are broken up by the pulp agitators and pump impellers. The result is small dirt particles in the final product. This is the most common kind of pitch problem, but one can also have sticking problems on rolls and problems in subsequent paper manufacture.

It is difficult to place an exact figure on the cost of pitch problems even for a given mill. However, kraft mill pitch problems are estimated to cost, on average, several million dollars per year per mill in Canada. This is a lot of money. It could be worse, though; I've encountered mills in third world countries losing $10 million per year.

Components of the cost include: sale of off-grade pulp contaminated with pitch-dirt, premature replacement of machine clothing, time lost for clean-ups, and the cost of additives to control the problem. The additives may include detergents and solvents for cleaning surfaces, pitch dispersants for stabilizing the resin in suspension, and talc, for detackifying the deposits.

If we use the round figure of 50 kraft pulp mills in Canada, then the problem costs our Canadian pulp industry approximately $100 million per year.

Technology of Pitch Control

There are quite a large number of factors important in determining whether or not a kraft pulp mill has pitch problems. Some of these are listed in Table I.

The species of wood is very important; for example, pine usually processes relatively easily, whereas aspen is more prone to give pitch deposition. Bark removal is very important, as the bark itself has a high resin content. Ordinarily, for softwoods, the less time the wood is stored, the fewer the problems. Conversely, for some species such as birch and aspen, some storage time is highly desirable to ease the propensity for problems. The purity and concentration of the cooking liquor is of paramount importance, as suspended materials, such as calcium carbonate or carbon, tend to co-deposit with the resin. Washing of the pulp is an ideal way to remove the pitchy materials, so good washing is very important. The foam control agents that are usually used in kraft mills have a tendency themselves to co-deposit with the pitch. It is therefore important to use them judiciously. The pH of the process and water hardness are key variables in determining whether or not hard water soaps, a type of pitch, deposit at some points in the process. Temperature can also be important. Screening and cleaning of the pulp, if done properly, present opportunities for removing pitch from the system. Certain elements of the bleaching process can have an influence on deposition. The chemical additives, especially talc and pitch dispersants, if used skilfully, can help to control resin. Used blindly, they add to the mill's cost accrued from pitch problems and may even aggravate the problems.

Chemical analysis of pitch deposits is often an important key to solving pitch problems. There are numerous tests for pitch and analytical chemical methods for determining the composition of the deposits. In a trouble-shooting situation, this leads to a better knowledge of what is depositing and usually points to a course of action to solve the problem.

The Continuing Need for Training

One reality of life in a kraft mill is that over the years, there is a constant influx of new engineers. Because pitch control is often a responsibility assigned to the younger staff, there is a constant need for training. Good training of young engineers in Canadian mills might cut the estimated $2 million per annum cost of pitch problems by as much as 30%.

The Kraft Pitch Expert System

We started work on the Pitch Expert System four years ago with three objectives in mind: to build an expert system to help kraft mill personnel solve pitch problems (independently of the expert), to evaluate expert system technology, and to enable our staff to pick up skills in the expert system area.

The Kraft Pitch Expert System was undertaken as a joint project with CRIM, the Centre de Recherche Informatique de Montréal, a largely provincially funded computer research institute. The costs of the development were shared by the Institutes, roughly on a 50:50 basis.

The Kraft Pitch Expert System was patterned after my approach to solving pitch problems in a consulting situation. That is, it begins by asking questions of the user. Usually 80 - 100 questions are asked, and the exact number depends on the answers given to the system. The system then draws deductions on the likely causes of the problem and proceeds from there to make recommendations.

One thing that the expert system cannot do, that a consultant can, is inspect the mill. In solving problems, the expert system is therefore entirely dependent on the user providing correct answers to the questions. In my experience, this is usually something one can count on; however, there have been occasional exceptions.

To give you an idea of the size of our expert system, it contains 1,200 rules, 2,800 schemata, and 150 functions and daemons. This makes it one of the largest expert systems completed to date in Canada. For hardware, we chose a Sparc workstation with 32 megabytes of RAM and 800 megabytes of hard disk storage. Implementation of the system was done with ART, using the programming language LISP.

With such a large expert system, testing and fine tuning was a challenge. Initially, the testing was done by giving the expert system scenarios and verifying that it gave the correct answers. Since January, 1991, we have run trials with a dozen different Canadian kraft mills using real data.

Testing and Performance of the Pitch Expert System

For the expert system to be functioning correctly, it must give accurate deductions and recommendations.

Table II shows the chronological progress in fine tuning the system. In July of 1991, 60% of the answers were accurate and it delivered only 70 - 80% of the total number of recommendations that should have been given. By October of 1991, the accuracy of the deductions and recommendations had reached the 80% mark. In February of 1992, this had improved to a point where 90% of the deductions and recommendations were accurate and 93% of required recommendations were delivered, on average. Needless to say, we are hoping to fine tune the system to a point where we surpass 95% for both accuracy and completeness. Only time and hard work will reveal whether or not this is possible. Obviously, with such a large system, it is difficult to achieve perfection, but we are delighted with the progress so far and consider it to be more than adequate. In fact, it has greatly exceeded our expectations for expert system technology.

Benefits

The cost savings accrued to our mills from use of the Pitch Expert System have been impressive. Table III shows cost savings realized in three of the mills where the system was trialed. These figures were provided by mill personnel. The total projected annual savings in these three mills alone exceeds $2,300,000, which in turn exceeds the total cost of development of the Pitch expert system to date ($1,007,000, as of November 1991). The savings cited are a combination of the benefits of improving quality and quality uniformity, reduced defoamer usage and reducing machine clothing costs.

It is very important, in manufacturing and selling kraft pulp, that the product be consistently free of dirt. Sporadic appearances of dirt in the product can lead to loss of customers and consequently of business. Quality improvements for the same three mills as in the preceding table are shown in Table IV. The percentage of total production which is off-grade because of pitch-dirt is shown for Mills 2 and 3. For Mill 2 it decreased 4% and, for Mill 3, 2%. The kind of pitch problems that Mill 5 was experiencing were not causing quality problems, so this kind of consideration is not relevant to this mill. The quality benefits in Table IV are indeed impressive.

Shown in Table V is a summary of the benefits of the Kraft Pitch Expert System. Since we began testing the Pitch Expert System with mill trials, I have had approximately half as many consulting calls to mills. This has saved me considerable time and enabled a greater fraction of my efforts to be directed to research. In addition, the mill personnel who have tried the system have been delighted with the teaching aspect of the system. By interacting with the expert system, mill personnel learned what the important variables are for pitch control. Not only do they learn from the questions that are asked, if they need help with the question, they can consult a **HELP** feature which will ask the question using different words, direct them on how to get an answer, and explain the significance of the question. Mill personnel can also learn by playing "What if" games with the system. Finally, in Table V the cost savings and quality improvements have impressed industry personnel.

Concluding Remarks

In concluding, I would like to say that, as an expert, I have been impressed. The logic networks for this Pitch Expert System, if typed in ordinary type on pages 4 feet high, would stretch around an average-sized gymnasium. This has been necessary to capture the subtleties of the subject so that the expert system does not give awkward or trivial answers. The Pitch Expert System has been a resounding success for expert system technology. In being fortunate enough to participate in the project, I feel I've had a privileged glimpse of the future. This is a future in which expert advice for directing mill staff towards the solutions of dozens of routine mill problems is contained on mill computers. Surely this is the way it will be and has to be. Simple logic says that the industry and country which can adopt and use this technology the fastest will have a considerable competitive edge.

Table I - Some Important Factors in Pitch Control

Some Important Factors
Species of wood used
Bark removal
Seasoning (storage) of wood
Purity and concentration of cooking liquor
Washing of pulp
Use of foam control agents
pH of process, at some points, and water hardness
Temperature of process, at some points
Screening and cleaning of pulp
Bleaching process
Chemical additives used for pitch control

Table II - Accuracy and Completeness of Recommendations

Date	July 1991	October 1991	February 1992
Accuracy	60%	80%	90%
Completeness	70-80%	-	93%

Table III - Typical Cost Savings

Mill Number	2	3	5
Annual Production (tonnes)	170,000	360,000	450,000
Annual Estimated Savings ($)	527,000	1,080,000	742,000

Table IV - Typical Quality Improvements

Mill Number	2	3	5
Off-Grade Before	5%	2%	n/a*
Off-Grade After	1%	0%	n/a*

*n/a - Quality was not a problem in this mill

Table V - Benefits from Kraft Pitch Expert System

Half as many consulting calls to mills for the expert
Mill personnel delighted with teaching aspect
Cost savings at mills
Quality improvements

KD Expert: A Computer-based Training Program in Lumber Drying

By

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1.0 INTRODUCTION

The increasing demand for high quality products requires significant processing changes when compared to the traditional manufacturing of construction lumber. The drying operation is clearly one area where major modifications will have to occur in order to meet new quality requirements.

In addition to improved technology, the lumber drying sector will also have to rely on a well established quality control program in order to guarantee high grade recovery and therefore determine the success of the operation.

With all the technological advances that the lumber drying activity has been experiencing over the years, specialized training in lumber drying has certainly become a priority.

In order to address this training need, Forintek Canada Corp. in conjunction with Softwords Research International Ltd. have designed a computer-based training program in lumber drying. Due to its user-friendly characteristics, no previous experience in either computers or kiln drying is required.

KD Expert was developed with the NATAL Authoring Language in combination with Softwords own expert shell system, OCAM1. The program combines NAPLPS graphics technology with NATAL's interactive graphics capabilities. The expert system technology allows the user to simulate situations in which process variables must be adjusted so that drying degrade can be avoided.

It is hoped that the instructional material of the program associated with the simulation capabilities, may serve as a valuable learning tool to anyone interested in lumber drying.

2.0 THE KD EXPERT PROGRAM

The main parts of the program are illustrated in Figure 1. There are six basic sections, namely:

1. How to run the course
2. Test
3. Lessons
4. Simulation
5. Glossary
6. Report

In the first part, the user is presented with a brief summary of the other parts. Whenever possible, an example illustrates the purpose and characteristics of each part.

The "Test" section is divided into: a) pre-test and b) post-test. The pre-test is intended for those with some wood drying experience willing to evaluate their overall knowledge. The post-test on the other hand, was designed to be taken at the end of the training program. In both tests, questions are randomly selected and there is enough flexibility so that the tests can be interrupted and resumed at any time. Also, in either type of test, it is possible to select a particular topic on which to be tested. The feature allows the user to concentrate on specific areas where, for example, a greater emphasis may be needed.

The section on "Lessons" is where the contents of the course are organized. A logical sequence takes the user from very basic concepts of lumber drying to useful discussions related to quality control. The section is quite lengthy but well illustrated so that more complex concepts can be visualized and better understood.

The "Simulation" section is where the expert systems technology is used to a great extent. The basic approach is to change certain process variables in order to avoid a specific drying degrade. When the user simulates a drying process by "running the kiln", the program using the expert system strategy, analyzes the set of pre-established kiln conditions and decides whether or not a particular drying degrade is likely to occur. If it finds something incorrect with the process variables that were selected, the program returns a message pointing out what is wrong as well as some hints as to why the problem has occurred.

The "Glossary" is a very useful part of the KD Expert. It contains more than 130 terms associated with kiln drying. Most definitions are illustrated so that they can be easily remembered in a number of situations. The glossary is especially useful when studying concepts introduced in the "Lessons" section.

The last part shown in the main menu is the "Report" section. This section presents the results by lesson of both the pre-test and the post-test. The user can find very useful information in this section such as where more study in a particular subject is needed.

3.0 MAIN LESSONS

The main lessons contained in the KD Expert program are:

- Drying Factors
- Moisture in Wood
- Shrinkage
- Types of Degrade
- Quality Control
- Kilns

Although independent, the lessons were arranged in a logical sequence so that the user is progressively led from fundamental concepts of wood physics to practical aspects of industrial kiln drying. A detailed view of the lesson structure is presented in Figure 2.

The lesson on "Drying Factors" is divided into four main sections. In the introduction, the user has the opportunity to learn essential terms related to kiln drying which will be extensively used throughout the course. In addition, the lesson presents a very comprehensive discussion on drying stages, drying mechanisms and physical elements influencing water removal in each stage of the drying process.

The main objective of the "Moisture in Wood" lesson is to provide detailed information relating to the available technology for measuring moisture content in wood. The user will find information on laboratory procedures for moisture content determination as well as industrial devices used for sorting lumber on the production line.

The lesson on "Shrinkage" discusses basically the causes and effects of shrinkage due to moisture loss. By discussing mechanisms of shrinkage development, the user is given the opportunity to study the consequences of a particular drying schedule on degrade. The lesson ends with a section on shrinkage control which serves as background for the lesson on degrade.

The lesson "Types of Degrade" presents all forms of drying related degrade. The section is fully illustrated so that the user will be able to easily recognize any type of drying degrade. In order to provide a thorough understanding of the subject, the basic strategy of the section is to present information about a particular degrade by answering the following questions:

Drying Degrade

WHAT IS IT?	This will lead to illustrated questions about particular degrades.
WHAT CAUSED IT?	This will lead to a submenu listing 6 factors which most contribute to the occurrence of degrades
HOW TO PREVENT IT?	This will lead to detailed information about drying conditions, their effect on degrade and how kiln drying adjustments can prevent or reduce degrades.

By studying the answers to these three questions, the user will readily relate the new information to the knowledge obtained in the previous sections.

The lesson on "Quality Control" presents information on basic statistics applied to lumber drying operations. The section is well illustrated and the practical examples allow the concepts to be easily understood.

Finally, the section on "Kilns" is intended to provide an overview of what is currently available in terms of equipment for drying lumber under a number of different processes.

4.0 SIMULATION

The main purpose of the "Simulation" section of the program is to let the user explore how changes in the drying process will affect the results in terms of quality. The simulation presents scenarios of different drying stages. After selecting a particular drying degrade, the user has to point out probable causes. In order to assist the user, the program presents a list of possible causes for the selected degrade. The program will even help the user select the most important causes. With the causes correctly selected, the user is directed to the section "How to prevent it" where changes in the drying conditions can be made and ultimately the simulation of the drying run can be performed.

From the simulation, it is possible to access the glossary at any time so that a particular concept can be reviewed. This is a very powerful feature since definitions and basic concepts can be found here.

After setting the variables, that is, changing kiln conditions, the user runs the kiln, which means, simulates the drying process under the conditions that were set.

By "Running the Kiln", the program will produce a diagnosis of the drying on the "Explanation" screen and indicate whether or not the selected degrade has been corrected. If not, the program displays an explanation for why the degrade was not corrected by highlighting one or more causes. In addition to viewing the explanation, the user may obtain more information through the "Further Explanation" option.

The KD Expert training program will hopefully become a very useful tool for those dealing with lumber drying on a daily basis. Powerful graphics capabilities combined with user-friendly characteristics will certainly make the program very attractive to anyone, independent of having previous experience in either kiln drying or computers.

LESSON Structure

- **Factors Affecting Drying**
  - Introduction
    - The Lesson
    - Moisture Distribution
    - Common Terms
  - Early Stages
    - Evaporation
    - Vapour Pressure
    - Air Pathway
    - Air Velocity
  - Later Stages
    - Drying Rate
    - Moisture Gradient
    - Preventing Damage
    - Vapour Pressure Gradient
    - Summary
  - Physical Elements
    - Humidity and Temperature Properties
- **Moisture Content**
  - Introduction
  - Determining Moisture Content
    - Formulae
    - Examples
  - Electrical Moisture Meters.
  - Resistance-Type Moisture Meters
    - Function
    - Correctness
    - Meter Types
  - Moisture Gradients
    - Surface to Core
    - End to Middle
  - Green End Moisture Sensors
    - Pre-sort Lumber
    - Function
    - Applications
  - Continuous Moisture Meters
    - Purpose
    - Function
  - In-Kiln Moisture Meters
    - Introduction
    - Resistance Method (RM)
    - RM for Kiln Control
    - Capacitive Admittance
- **Shrinkage**
  - Introduction
  - Cause of Shrinkage
    - Structure
    - Drying
  - Shrinkage and Moisture Content
    - FSP and Zero MC
    - FSP and Shrinkage
  - Shrinkage and Wood Shape
    - Radial and Tangential
    - Type of Cut
    - Shape Changes
    - Size of Cross-Section
  - Shrinkage Measurement
    - Example 1
    - Example 2
    - Example 3
  - Wood Types
    - Reaction Wood
    - Compression Wood
    - Tension Wood
    - Juvenile and Other Wood
  - Other Effects
    - Drying Conditions
    - Swelling
  - Shrinkage Control
    - Methods
    - End Damage
- **Degrades**
  - Casehardening
    - What Is It?
    - What Caused It?
    - How to Prevent It?
  - Bow
  - Crook
  - Cup
  - Twist
  - End Check
  - Internal Checks
  - Surface Check
  - Knot Damage
  - Collapse
  - Loosened Grain
  - Raised Grain
  - Fungal Stain
  - Chemical Stain
- **Quality Control**
  - Introduction
    - The Lesson
    - Lumber Drying
  - Quality Control Problems
    - Wood Quality
    - Moisture
  - Statistics
    - Purpose
    - Normal Distribution
  - Histograms
    - Definition
    - Example 1
    - Example 2
    - Average and Variance
  - Confidence Intervals
    - Concept
    - Confidence Intervals
    - Sample Size
  - Kiln Performance
    - Maintenance
    - Air Velocity
    - Temperature
- **Kilns**
  - Definitions
  - Characteristics
    - Construction Materials
    - Loading Systems
    - Progressive and Compartment
    - Air Circulation
    - Heat Sources
    - Operating Temperatures
  - Steam Kilns
    - Types of Steam
    - Steam Coils
    - Steam Traps
    - Buckets
    - Heat Maintenance
    - Humidity Problem
    - Steam System
    - Humidity Maintenance
    - High vs. Low Pressure
  - Direct Heated Kilns
  - Dehumidifier Kilns
    - Use in Canada
    - Operation
    - Controls
    - Economics and Quality
  - Heat Loss and Corrosion
    - Heat Loss
    - Vapour Movement
    - Maintenance
  - Additional Concepts
    - Power Venting
    - Recorder-Controllers
    - Procedures
  - Alternative Drying
    - Introduction
    - Vaccuum Drying
    - High Frequency Drying

Main Menu

- HOW TO RUN THE COURSE
- TEST
  - Pretest
  - Posttest
- LESSONS
  - Drying Factors
  - Moisture In Wood
  - Shrinkage
  - Types of Degrade — Refer to Page 18
  - Quality Control
  - Kilns
- SIMULATION
  - What Is It?
  - What Caused It?
    - Airflow
    - Restraint
    - Stacking
    - Temperature
    - Humidity
    - Storage
    - Cancel
    - Done
  - How To Prevent It
    - Airflow
      - Right Top Baffle
      - Left Top Baffle
      - Right Bottom Baffle
      - Left Bottom Baffle
      - End Stickers
    - Restraint
      - Sticker Interval
      - Top Restraint
      - End Stickers
    - Stacking
      - Wood Size
      - Wood Length 1
      - Wood Length 2
      - Piling
    - Temperature
      - Early Stage
      - Middle Stage
      - Late Stage
    - Humidity
      - Early Stage
      - Middle Stage
      - Late Stage
    - Storage
      - Covering
      - Humidity
    - Run Kiln
  - New Degrade
- GLOSSARY
- REPORT
  - Pretest
  - Posttest
  - Simulation
  - Print
    - Pretest
    - Posttest
    - Simulation

Forintek
Canada
Corp.

Condition Monitoring and Fault Diagnosis of Complex Equipment: Possible Paprican—NRC Collaboration*

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I. Introduction

In principle numerous opportunities exist for collaboration between research organizations and pulp and paper companies. The question that arises is: what benefits would be derived from involving two research organizations — NRC and Paprican — in a knowledge-based systems project with a pulp and paper company? This question can perhaps be best addressed by considering the specific strengths that each could contribute to a project.

Paprican is known worldwide as a canter for scientific and engineering research relating to the pulp and paper industry. This concentration of expertise is a priceless resource for any project involving application of leading-edge technologies in the industry. In addition, Paprican staff have an extensive network of contacts in the pulp and paper industry and in other research centres and universities.

It is particularly worth noting that Paprican has been very active in the application of advanced systems and control engineering techniques in the pulp and paper industry [1,2,3]. The challenges and opportunities encountered in this field are very similar to those encountered when implementing AI systems, and in addition, process control itself is a promising AI application area.

The Institute for Information Technology of NRC conducts R&D in the software- and systems-related areas of information technology with the aim of improving the competitiveness of Canadian industry. This broad computer expertise constitutes a resource which could be an essential contribution to a joint project. The Knowledge Systems Laboratory in this Institute focuses on R&D in AI. Its activities canter on Intelligent Advisors, Diagnostic Systems, and Machine Learning. Working together with external partners and other NRC Institutes, the Laboratory is applying these technologies within industrial settings.

While both Paprican and NRC engage in a broad spectrum of research, from long-term fundamental investigations to short-term contract work, the long-term focus receives somewhat more emphasis at NRC, whereas at Paprican there has been more stress recently on near-term industry usefulness. This distinction would allow partitioning a joint project with both long- and short-term components, so that each institution could undertake that part most consistent with its overall orientation and goals.

2. Current AI applications

Although the pulp and paper industry both in Canada and abroad is very important economically, there are surprisingly few deployed applications of AI technologies in pulp and paper mills. There is more activity at the research and prototype stages, but most of this has taken place only in the last few years. This situation exists in spite of outstanding opportunities for economic and operating benefits and successes in other process industries.

The ongoing recession must certainly bear part of the blame for the slow penetration of AI technology

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into the pulp and paper industry. Yet a reluctance to adopt this technology was noted even in better economic times. Many companies remain hesitant to invest in specialized computer hardware or software, to hire highly qualified technical personnel, or to commit themselves to long-term projects without quick and guaranteed payback.

One greatly under-utilized source of information and expertise is work that has been done in other continuous process industries (such as mineral processing or chemical manufacture [4,5]) or in other industries reliant on heavy, costly, and safety-critical equipment such as electrical power generation [6]. The pulp and paper industry has traditionally paid little attention to the potential of such technical cross-fertilization. Effort would be required to adapt solutions from other industries to pulp and paper, but the benefits of being able to build on the experience of others would almost certainly outweigh these difficulties.

2.1. Examples of successful AI projects

The earliest practical application of AI technology in the world pulp and paper industry was probably the Recovery Boiler Tutor (RBT) project undertaken by the American Paper Institute (API) to improve recovery boiler safety by better training of operators [7]. The recovery boiler is a critical and expensive component of a kraft pulp mill which may at times enter a dangerous operating condition, possibly leading to explosion, major damage, and loss of life. The RBT is essentially an operator training simulator which can respond with a degree of intelligence to the trainee's actions and direct the course of training appropriately. As of late 1990 the system had been installed in close to 100 mills [8].

LINKman, developed by Sira and Blue Circle Industries of the United Kingdom, is a rule-based supervisory control system originally designed to control and optimize the cement kilning process [9]. As of November 1988, over 60% of the cement output of Blue Circle in the United Kingdom was being produced under LINKman control 70–90% of the time. Some economic benefits derived include an estimated savings of several million pounds a year, fuel savings in the range of 5 to 10%, output increases exceeding 10%, reduction of the average burning zone temperature by approximately 100 to 200 degrees C, and improvement in product quality and plant stability. Other qualitative benefits include enhanced knowledge of the kiln process and process dynamics, improved working practices, more consistent control, and better management of the process and its operation. It has since been found that LINKman is general enough to benefit other processes and has been applied to the manufacture of petrochemicals and glass. It is estimated that payback for cement-based applications is three months.

MIP, developed by the Knowledge Engineering Institute of Madrid (IIC), is a realtime expert system that monitors, diagnoses, and gives advice on how to optimize and stabilize a petrochemical plant [10]. It has been deployed in an acrylonitrile plant of REPSOL QUIMICA, S.A. in Tarragona, Spain since March of 1991. It is expected to increase productivity by at least 1% because of better control of important parameters. It has also already helped to avoid a plant shutdown, saving more than $400,000.

2.2. AI projects at Paprican

Paprican's experience in AI technology is recent but fast-growing and strongly oriented towards technology transfer to industry. In 1988, Paprican undertook its first expert system building project in collaboration with CRIM (Centre de recherche en informatique de Montréal). Pitch Expert, a diagnostic expert system to help process engineers diagnose and correct pitch deposition problems in kraft mills [11], incorporates the problem-solving expertise of Dr. Larry Allen, a pitch scientist at Paprican. In test diagnostic sessions involving 13 mills, its conclusions were in approximately 90% agreement with those of the human expert. It is now available to Paprican member companies for human-assisted telephone consultation sessions and should shortly be accessible via modem. Two other expert systems in the paper and board quality area are also under development at Paprican.

2.3. AI projects at the Knowledge Systems Laboratory

The Knowledge Systems Laboratory conducts R&D in the knowledge-based area of AI. It has three main programs focusing on technologies in Intelligent Advisors, Diagnostic Systems, and Machine Learning.

The Intelligent Advisor program, started in 1987, is aimed at developing technology that supports the creation and implementation of advisor systems. Current prototypes include an Entity-Relationship Modelling Advisor, which serves as an intelligent interface between the user and a database design tool [12], and an Electromagnetic Hardening Advisor, which helps engineers create systems hardened against electromagnetic interference [13].

The Diagnostic Systems program aims to develop tools and methodologies for the design of diagnostic, planning, and control systems. This program is divided into two projects: Engine Health Monitoring and Realtime Expert Systems. JETA, a prototype jet engine troubleshooting assistant, has been developed to help technicians diagnose faults in the General Electric J85-CAN-15 jet engine [14]. Current activities in this project include the application of machine learning to data analysis and the development of tools for knowledge browsing. The Realtime Expert Systems project is investigating the application of AI techniques to industrial process control plants. Project activities include the development of laboratory prototypes to investigate (1) the blackboard control architecture, (2) fuzzy sets and fuzzy logic [15] and (3) qualitative modelling and simulation [16].

The Machine Learning program is applying this technology to the development of knowledge acquisition tools. Activities in this program include the Intelligent MAnufacturing FOreman (IMAFO), the data analysis activities related to JETA, and the application of machine learning to crime analysis. IMAFO uses machine learning techniques to analyze and explain plan failures in an industrial process planning environment [17]. Work is being done with General Electric's Aircraft Engines plant in Bromont, Québec, to use IMAFO to optimize an electrochemical machining operation. A prototype is being developed for the crime analysis activity to support the investigation of residential break and enters.

3. Some promising application areas

This section identifies possible application areas to consider for a joint project with NRC, Paprican, and pulp and paper companies.

3.1. Machine and process diagnostics

Pulp and paper processes are characterized by complex material flow patterns with important recycle flows. The operation of the process is influenced by a host of continually varying physical and chemical factors, many of which are imperfectly known and inadequately measured or controlled. Malfunctions tend to be costly, taking major production lines out of service, compromising product quality and possibly damaging equipment or even presenting safety risks.

Much problem-solving in mills today is done on the advice of experienced personnel. However, turnover can be rapid, especially in remote areas, removing these people and their fund of knowledge from the mill, and in hard economic times attrition and layoffs take their toll. Senior people also tend to work the day shift, meaning that at night and on weekends less experienced operators may have to cope as best they can or else call in someone more knowledgeable. Troubleshooting handbooks and manuals are often used, but finding the required information is often a problem and the manual may not address multiple or more unusual problem occurrences.

Artificial intelligence technologies have a clear role to play in the preservation of problem-solving experience and the dissemination of problem-solving knowledge to remote areas and to all shifts. Soon equipment may be supplied with its own diagnostic expert system. A more challenging but potentially more fruitful contribution would be the effective use of basic cause-effect process knowledge in an intelligent system. Incorporating strategies to evaluate and combine multiple pieces of evidence and work around missing information would produce systems with more "expert-like" reasoning.

3.2. Maintenance

Maintenance is an interesting candidate for AI technology application because it has a direct impact on mill up-time and profitability and because decisions on scheduling and priorities involve evaluating multiple factors in non-obvious ways. The trade-off is normally between taking a piece of equipment out of service in a scheduled shutdown now or keeping it in service and hoping it does not break down. A more sophisticated analysis includes evaluating the risk of breakdown and the cost of production losses. Variations in production schedules and crew availability may further influence the decision. A related problem is the decision on repair vs. replacement of equipment.

A number of mills now have maintenance databases and may use project management software to assist in maintenance scheduling. These make more information available to the decision maker and may pre-process it to some extent (for example, identifying resource availability bottlenecks) but do not yet support the entire maintenance decision-making process. An opportunity therefore exists for intelligent systems to perform multi-criterion comparisons of proposed maintenance schedules, in particular evaluating the degree of risk and expected cost of each.

3.3. Manufacturing automation and process control

Conventional process control has achieved major improvements in process operation in the pulp and paper industry, but is limited by the non-availability of sensors for key properties, the harshness of the mill environment, the need for rigorous loop tuning and system maintenance, and limited training and experience of mill personnel in process control.

The tuning of basic control loops and the maintenance of final control elements such as valves are frequently neglected in the mill, with the result that existing control systems seldom achieve their design effectiveness [18]. An intelligent system could codify approaches to robust loop tuning, providing a computer assistant to instrument technicians in the mill or an automated trainer for new or under-qualified personnel. The identification of faulty sensors or control elements through identification of signature patterns in process data is another prime candidate for AI systems applications.

Many advanced process analysis techniques output spectral or trend data instead of single readings. The interpretation of these outputs to yield useful information about the process is currently a fine art practised by engineers with advanced mathematical training. Intelligent systems could assist people with less mathematical background to make these interpretations.

4. Conclusions

In the area of knowledge-based systems, a joint project between NRC and Paprican with the cooperation of some pulp and paper companies will benefit not only the eventual users of the resulting system, the pulp and paper companies, but also the research organizations involved. The NRC will benefit from Paprican's expertise in the industry and Paprican will benefit from NRC's expertise in the area of information technology. This mix of expertise should provide a smooth transfer of technology from the research centres to industry. In this paper some possible application areas that may form the focus of a future collaborative project have been identified. These areas were specifically chosen because of their importance to the pulp and paper industry and the potential benefit of the use of AI technologies.

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Total Millwide Control of A Green Field LWC Line

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Introduction

Caledonian Paper plc is a wholly owned subsidiary of the Kymmene Corporation, Finland, and was built on a totally Green Field Site in Irvine, Scotland.

The site clearance at Meadowhead Farm started on February 1 1987 and the Mill started up on April 1 1989 on the planned date.

The Mill was built using the latest available proven technology at the time including Millwide Control and Information systems. Different from mature Mills who add this long after startup. We have had to make it work, because without it we could not have run the Mill effectively.

Line Technology

Kone Woodhandling and Debarking.

Kone Pulpmill Feedsystem.

Tampella Pressurised Groundwood 280tpd.

Canadian and Finnish bleached softwood kraft.

Valmet Symconcept PM Balance Speed 1500m/min
Normal Operating Speed 1200m/min

Beloit Walmsley off Machine Coater Balance Speed 1600m/min
Normal operating Speed:
SDTA : 1300 - 1350 m/min
RA : 1200 m/min

Kleinewefers Supercalenders (12 roll stacks with Hydrein top and bottom)
Design and Operational Speed : 800m/min

Valmet JR 1000 Winders Operating Speed 1800 m/min

Valmet Streampack Wrapping Line:
Operating Speed 40 sec/customer roll

Current Annual Capacity 225000 tpa
(First 5 months 1992 average)

Control Systems:

Altim DCS Millwide

Tamsec/"Grinderman" for PGW

Measurex. PM, Coater (3), Supercalenders (2)

Jetmatic - PM

Impact - PM and Coater

ABB Selma. All Drives

Siemens PLC

Erdman, Supercalenders
Windcontrol Winders

Information/Measurement System

PQM + FS 200	Pulpmill/Stock Prep control
Robotest	PM Autolab
Sensodec	Condition Monitoring/PM stability control
Ulma (ABB)	Fault detection
Autospec (ABB)	Coater Fault detection

Management Control

Auto Quality	(ABB Afora)
Prod Control	" "
Marketing Control	" "
Papershed (trim optimisation)	"
Engineering Drawing	CAD
Finance/Purchasing	Ross
Engineering Preventative Maintenance and Stock control	Idhammer
Office Automation	Wang
Data Analysis	RSI (BBN)

In addition to all of the above at Caledonian, the Kymmene Corporation have a Marketing Network which we are linked directly to, as well as a Corporate Office Automation System.

These systems are all connected up as you can see in the illustration (1) and despite the apparent mass of inter-connecting lines - this actually works extremely well, although it took us maybe 12 months more than we had anticipated to remove corrupt files and data from the systems and make the whole package so reliable that people started believing in it.

The other decision we took was to "Compartmentalise" Access, i.e. behind your own password you only have access to the part of the system that you require to do the job. Total access only starts at Director level.

The construction process of this system started 2 years before startup and was extremely detailed and time-consuming. In many cases we had to make "Guesstimates" on how Caledonian would function - since we had nothing like it in the Group and in many cases we just made mistakes - so the "mopping up" process after startup was formidable.

We continuously register in the Millwide Information System upwards of 9500 variables and we keep the data for around 18 months before tape Archiving.

In summary then, we couple together in this IT package 8 separate functions.

Process Control

Quality Assurance

Roll Handling and Tracking

Marketing : Order Entry
Deckling
Warehouse
Shipping

Production Control

Maintenance Control

Purchasing

Finance

We also have two separate - free standing personnel systems, one administrative and the other operational.

It is worthwhile to just briefly go over these areas to establish how the systems work and interact.

Process Control

The main distributive control system is Altim, which - bearing in mind the extensive and complex system at Caledonian - has performed very well from the start.

The Mill is split into 5 main Process areas, all of which have additional computer control systems interfaced with the Altim system. These are:-

Pulpmill:	Tamsec "Grinderman" Control system.
Papermachine:	Measurex, Valmet headbox control, Impact Caliper Control, Ulma fault detection, Sensodec continous monitoring.
Coater:	Measurex, Afora Autospec Coating fault detections, Sensodec (Lubrication and bearings only) continuous monitoring.
Supercalender:	Measurex, Erdman bow control.
Winders:	Valmet Slitposit control.

Below this level and into the field instrumentation, a high degree of continuous measurements are employed, as well as a continuous sampling regime where the measurements/test results are automatically downloaded to the Mill Information BUS, where Altim (or the next level down) fetches the information at the frequency it requires.

Quality Assurance

Quality Control at Caledonian is entirely in the hands of our operators.

They do all the sampling and the testing required for their own area and monitor all automatic sampling/testing. The principle is that the next step in the process is their most important customer.

The Millwide information system (designed by Afora) carries around 9500 different variables which are continously updated, and the Control Room menus are configured that those variables apertaining to that control room are easily accessible for the Operators.

The philosophy extends to all areas of the Mill from the Woodyard through to dispatching the finished products to our customers.

Quality Assurance is run as a separate function where a number of important aspects are overseen.

- Extensive calibrations to ensure data to machine crews are reliable.
- Finished product sampling and testing
- Offset Printing of finished product
- Analytical Services
- Troubleshooting Services
- Quality System Auditing
- Raw Material Auditing and tracking
- Customer samples
- Archiving

All these services bar customer samples and archiving, are maintained in the Millwide information system with continuous access to updated data.

A separate computer system (RSI) has also been added, capable of accessing most of the aforementioned 9500 variables.

This system is used for two main purposes:

- Advanced analysis of Quality and operational performance.
- Creating easily accessible control charts for each control rooms so that Statistical Process Control may be performed on the most important variables.

  This project really only got off the ground 1 year after startup but is now running in all the Control Rooms, mostly using Standard Control Charting (General Electric) Rules but choosing very carefully the critical variables to control.

- **Roll Handling/Marketing/Production Control**

  These three functions are all very closely linked and the starting point is that all the jumbo reels in the plant are tracked through the production line by a laser beam - barcode systems.

  This enables instant status to be available to Supervisors and Operators alike and assembles all quality data against the "batch" of a jumbo reel up to the point where the winders slit the paper into customer reels.

At this point, a separate barcode - for each customer reel is printed out and attached to the roll core.

This is then read by a separate laser reader on the weighing stations - prior to the wrapping line.

Width and length measurements is tracked all the way through enabling very close monitoring of area efficiencies.

The Marketing system having received the orders and fed these through a deckle optimisation programme, will send these signals to core production and winders enabling automatic setting of these machines to conform with customers requirements.

At the Wrapping stage, when net good production is produced, the Marketing System will be automatically updated to show good paper in stock (as well as locations in the Warehouse) enabling loading and shipping plans to be generated.

The total system has therefore several important functions:

- Total trackability
- Accurate and reliable Warehouse and Stock Status
- Accurate and reliable Production and Efficiency data for each process stage
- Accurate and reliable raw material and energy reports for each process stage as well as throughout the Mill.
- Effective shipping and customer communications.

Maintenance Control is achieved through extensive use in all areas of the Idhammer System, and responsibility for ensuring the system is up to date is extended down to Senior Operator level, with a separate planning function in Maintenance controlling the backlog generated.

The already mentioned Sensodec continous condition monitoring forms an integral part of this, but additionally a separate system of systematically visiting all critical moving parts with hand held instrumentation, logging and analysing vibrations/pulsations, thus building up an extensive history where the accent stays firmly on preventative maintenance.

The Idhammer system sends continuous updated information to the Ross Purchasing System, thus enabling good control of spare parts to be achieved.

SUMMARY

The overriding Philosophy developed at Caledonian is one of Total Quality.

To this end, we have in this Greenfield Project developed the following strategy.

1. Hire first class people at all levels.

2. Devolve responsibility to enable all Operators to have control of their quality.

3. Install State of the Art continous Measurement and Field Instrumentation.

4. Develop a truly Millwide approach to all our information flow.

5. Install and connect to the Millwide BUS, an advanced range of freestanding systems handling.

   - Maintenance
   - Purchasing
   - Company Wide Marketing
   - Personnel
   - Forestry
   - Finance
   - Advanced Analysis (RS1)

6. Develop a method of Analysing and controlling quality in all Operational Areas using Statistical Tools (SPC).

EXPERIENCE SO FAR

We have, within the normal startup time been able to bring the operations up to design output of 225000 tpa.

The system of Quality Management and Total Millwide Control has ensured that our customers received very good LWC from the start.

Clearly, the Total Quality approach and aggressive use of Statistical Tools has enabled equally, very good development in each area of the Mill, both in terms of Quality and Operating Efficiency.

ThF/MaT/11573/PROD
11.5.92

Advanced Tools for Analysis of Paper Making Process Variations

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Introduction

The application of modern, computer-based analysis tools to paper machine processes is providing new opportunities to reduce process variations, improve quality and reduce costs. These tools provide the paper maker with a "window" into their processes and supply the means to identify and eliminate the source of product variations. The tools reduce the vast amount of information on a modern paper machine to manageable form and provide a simple user interface. This paper discusses analysis tools in general and offers two case studies into the application of analysis tools to paper machine processes.

Analysis Tools

In this paper, analysis tools refer to computer-based tools used to analyze and understand process variations. These tools provide:

- Mechanisms to help optimize process performance
- Methods to monitor performance over time
- Devices to speed the diagnosis and correction of processes and controller problems
- Devices which "boil" information down to manageable, easy-to-use and interpret displays

These tools help the paper maker to:

- Reduce down-time
- Improve quality
- Lower costs
- Improve maintenance

Most importantly, analysis tools empowers operators and process engineers with the means to continuously improve their processes.

Analysis tools must satisfy, amongst others, the following general requirements:

- Provide a simple user interface (using menus, windows,etc.) with good use of graphics
- Present data in as simple a form as possible
- Provide access to both "real time" and historical data
- Be configurable by the user for the user
- Provide quality hard copies of reports

There are many fine examples of analysis tools developed by both suppliers and end users in the pulp and paper industry. This paper reviews two specific analysis tools, SafeControl and PROFIT and discusses the application of these tools to paper machine process control.

SafeControl

SafeControl offers complete monitoring of critical process elements in formation, pressing and calendering. This tool allows the paper maker to identify the source of product variability and establish cause and effect relationships. SafeControl consists of both a process monitoring system and a condition monitoring system. The condition monitoring system monitors the state of critical process elements (bearings, rolls, etc.) and provides indications of potential failures before they occur. This paper will focus on the process monitoring system which consists of three elements:

- SafePulsation
- SafeNip
- SafeQuality

SafePulsation monitors the wet end of the paper machine with the goal of identify the relationships between the formation elements and measured paper parameters. SafePulsation uses pressure sensors, accelerometers, vacuum sensors and rotational phase detectors to determine the effects of headbox, pumps, screens, rolls and vacuum elements on final paper properties. SafePulsation has been successfully applied to identifying, amongst others, the following cause and effect relationships:

- Headbox manifold pressure variations cause by pressure screens
- Basis weight variations caused by forming board vibrations
- Basis Weight variation caused by fan pump oscillations

SafeNip provides nip monitoring in press sections, size presses, breaker stacks and calenders. SafeNip uses nip gap sensors, roll and felt rotation phase detectors, accelerometers and vacuum sensors to determine the effect of nip variation on final paper properties. These sensors are used to "synchronize" the measured variation with each element using the Synchronized Time Averaging technique. Using this method, the variation in the paper product of interest (ie. the basis weight) is "synchronized" to the element of interest (ie. by using pulses from the press roll) and the rest of the variation in the paper product which is not related to the element is averaged out over time. This allows the paper maker to quickly quantify the amount of total product variation from each monitored element and identify the most significant contributor through a "pareto-like" analysis. This is a good example of reducing information to a form which is directly interpretable by the paper maker.

SafeNip has successfully been used for many applications, some of which are:

- Identification of a press section suction roll failure before it failed
- Identifying the source of press section variation related to an improperly stored felt
- Relating measured caliper variation to calender roll eccentricity
- Identifying a corrugated granite roll
- Identifying and removing felt-induced product variation

SafeQuality provides fast collection (512 hertz) of process measurements such as single-point scanner data, scanning process measurements, and measurements from sensors such as rotational phase detectors, etc. on screens, pumps, rolls, etc.. This tool provides frequency analysis of process and sensor data and reduces the collected data to manageable form (key numbers) which can be monitored over time. Often just being able to see the nature of process variations with higher resolution can lead to the identification of potential sources. With displays of the nature of process variation, including its magnitude and frequency, the operator can quickly determine the effect of each change made to the paper machine.

SafeQuality has successfully been used for many applications, some of which are:

- Relating high-frequency moisture variation at the reel to a press section felt
- Relating fast basis weight variations to headbox pressure variations
- Identifying the relationships between sheet forming arrangements (ie. jet angle, jet impingement, etc.) and final paper properties (weight, formation, etc.)

PROFIT

PROFIT stands for Profile Improvement Toolkit. It is a "windows-based" package for optimizing machine direction and cross-machine direction control systems. PROFIT provides an interactive tool which allows the paper maker to maintain control performance over time. PROFIT provides tools to align paper profiles to cross-directional actuators. Once the profiles are aligned, PROFIT automatically determines controller tuning parameters based on input-output data (actuator step response tests). All tuning and control optimization is provided using simple menus and point-and-click user interfaces.

PROFIT provides on-line control performance monitoring with Statistical Process Control (SPC) trends of critical elements. Through these screens, paper makers can quickly identify and correct "out-of-control" situations. With statistical displays of variation across the machine and down its length, the operator can identify regions of poor profile control or process problems and take appropriate action.

PROFIT provides on-line histograms and variance analysis which summarize the nature of the total variation in the sheet and help the paper maker identify the source of the variation. Through the histograms, the operator can obtain a summary picture of how profile variation is distributed around the target. By fixing the scale of the histogram, the effect of automatic controller changes and process changes can be immediately determined by a visual assessment of the shape of the histogram. Colours can be added to further enhance the information the histogram provides to the paper maker (tight distribution within quality limits is green, wide distribution with regions outside quality limits are red). Through on-line variance analysis, the paper maker can see a "pareto" analysis of the total variation in the sheet. This analysis attributes total variation to machine-direction, cross-machine direction and residual components and provides a quick, graphical assessment of the effect of control and process changes.

PROFIT provides frequency analysis of both cross- and machine-directional variation to determine the nature of the variation present in the statistical displays like the histogram, etc.. These displays provide the paper maker with the tools to isolate the cause of paper variation and quantify improvements made through process and cross/machine direction control changes.

PROFIT provides a graphical, user friendly environment using windows technology. It is a product designed to empower the paper maker with tools to setup, tune and maintain the performance of control systems without requiring continuous on-site service. It also provides many, easy-to-use-and-interpret graphical tools to monitor, identify and eliminate the source of paper variations.

Conclusions

Analysis tools are providing a "window" into process variations as never before. These tools focus on managing information and presenting it to the paper maker in a concise and meaningful format. The burden of providing these tools for paper machine applications has been accepted by suppliers as demonstrated in this paper. Analysis tools are being used today to improve product uniformity, reduce down-time and lower overall costs.

Operations Management For Complex Industrial Systems: Dynamic Simulation and Design of Pulp and Paper Mills

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Introduction

Prior to starting any human endeavour, we must establish a clear vision of where we are going. Designing and building a pulp and paper mill is no different from any other endeavour in this regard. At Simons we have a vision of how mills should be designed and built so that clients can start-up, operate and maintain their facilities in a cost effective manner. Two of the key elements of that vision are dynamic process simulation and three dimensional physical design. Though design tools, they ultimately result in better facilities and operations management.

The Design Process

When we design complex industrial systems, our starting point consists of a business decision to build or improve a process. That new process is first conceived as a series of unit processes strung together in a schematic manner. The design steps that follow consist primarily of adding greater and greater detail and complexity to that specific string of unit processes. Once a facility is in operation, we as designers must then audit its performance in order to optimize current operations and improve future processes.

With the advent of object oriented programming, these activities can be conducted in a much more flexible manner. Since some people may not be familiar with object oriented programming I will briefly discuss some of the key characteristics of object oriented programming that are useful for the designer and how this approach allows us to create a better design.

An Object Oriented Approach

The four key features of object oriented programming that I will describe are: encapsulation, the ability to send and receive messages, classes and inheritance.

1. Encapsulation

This feature allows a portion of a program and the data specific to that program to reside in one object. The advantage of this over more traditional approaches is that one can change specific elements of a unit process, such as controller setpoint or valve characteristics, without changing those characteristics in other unit processes. This feature also allows specific objects to be run on separate CPUs. This is particularly important when there is a need to run a complex process in real time, as part of advanced control or a decision support system. It also allows particular descriptive information like specifications to be tied to a specific object. This is particularly useful in the physical design process for material takeoff.

2. The Ability To Send and Receive Messages

In a traditional fortran type environment, when we re-run a model it must execute all modules. With an object oriented approach we can construct a large process work sheet with a number of unit processes represented by objects that are only executed when there is a specific request to do so. This allows the overall program to execute faster and perform in a more realistic manner. For example the sampling rate of a particular sensor can be mimicked within the context of a continuous process. This allows the program to only execute a module that utilizes that sensor output when new information is available.

3. Classes

Objects that respond the same way to the same message are grouped into classes. A good example of a class is a pump. Due to their common operating characteristics, pumps all require similar inputs (input stream characteristics) and produce similar outputs (required flow and pressure). This logical subdivision simplifies the design process. For example, if we decide to substitute one type of pump (variable or constant speed), or size of pump for another in a particular unit operation, we need not change any of the "process linkages".This allows process equipment modifications to be made very quickly.

4. Inheritance

If we add a new object in a class, it can inherit characteristics from another. For example if we want to create another pump for our list of available pumps in our parts catalogue, it can inherit specific primary elements types including flow, pressure, and horsepower. This allows the designer to create and very quickly specify new pieces of equipment. For these reasons we have adopted design programs that utilize object oriented approaches for both the process design and the physical plant design.

Process Design

The physical behaviour of plant processes for a facility are usually designed through use of simulation. Simulation is a mathematical model of processes and equipment. These models are either steady state or dynamic.

1. Steady State Process Simulation

With steady state models, neither the inputs nor the outputs change for a particular "model run". This allows the models to execute faster for a given model complexity because the time dimension is missing. However they represent an idealized snapshot of the real world, and thus cannot be used for determining how a process will run when subjected to upsets, etc.

2. Dynamic Process Simulation

With dynamic models the inputs and outputs change with time. This complicates the model, but increases the degree of realism. When accurately created they allow causes and effects to be determined. At Simons we use steady state simulation to establish a high level view of the plant during initial process design. We use an object oriented dynamic simulation tool for more complex problem solving. It includes:

- realtime process links
- the ability to link across multiple processors
- high quality graphic display
- the ability to handle deadtime
- the ability to handle multiple non-linear inputs
- learning capabilities

These features allow Simons to use the tool both to solve problems on existing processes and for the development of new processes. An example of the first is computing the over-run of a setpoint during the start-up of an existing unit operation. With steady state simulation these problems are masked and can result in design oversights such as too small of capacitance tankage to handle the surges associated with the start-up. An example of the second type is using pilot plant data as the basis of a model to conduct performance reviews. This activity provides part of the risk analysis of a new process. It allows multiple scenarios to be run efficiently and cost effectively which helps ensure key potential performance issues are not overlooked.

In both these circumstances the degree of accuracy with which the models can be created depends on key process characteristics. If there is a restricted amount of mechanical internals to a unit process, the chemistry and the physics govern process performance, and these can be readily modelled. For instance, steam tables and Bernoulli equations are well known, and thus can be used to accurately predict steam flow etc. When trying to model equipment characteristics such as a valve response, a valve curve can be digitized and an equation developed.

From an overall project process point of view, the dynamic model is the thread that links the stages of process design, process control design, staging and checkout, advanced process control, decision support and training simulation. From an operations management perspective, it is the last three categories that are most important.

To maximize the performance of any complex process operation requires advanced control. Advanced control based on an adaptive model of the process tends to be superior to a number of other approaches. For this reason, developing a dynamic model at the design stage and evolving that model for control purposes is highly effective for operations management. In a similar way, it is valuable to use the model for decision support and training. For decision support, scenarios can be applied to solve current operations problems and test potential plant modifications. For training, the understanding of process and process controls by engineers and operators can be improved. For this purpose high fidelity dynamic simulators are ideal.

Physical Plant Design

With the possible exception of the use of plastic or wood models, plants have historically been conceived in three dimensions but the design has largely been output on paper in a two dimensional format. This approach forces the designer and constructor to constantly switch mentally from a two dimensional representation back to a three dimensional reality. This is not only time consuming, but results in errors. Worse, once design and construction are complete, two dimensional paper representations are all that are available to the operations and maintenance personnel. Since operations and maintenance personnel are often not as skilled in reading drawings, this can cause considerable misunderstanding. Such confusion is costly. Also, numerical codes are usually provided on drawings to allow a manual link to specifications. They are by no means dynamic and certainly not convenient. This limits the accessibility and hence the usefulness of the specification during the design process. This in turn can result in errors in design. Further it makes it difficult at the operations and maintenance stage to find key information.

At Simons our design tool PASCE has object oriented characteristics that allows us to design and view in three dimensional space. In addition PASCE attaches all pertinent design specifications to a given item, and manages this textural data in an integrated manner. The three dimensional holistic approach for all geometric elements allows interference checking at the design stage on all geometric components from multiple disciplines (structural steel vs piping vs equipment vs heating and ventilation ducts). This minimizes field interference. It also allows such items as piping isometrics or process system plots to be easily produced as a byproduct of the design process.

The integrated characteristics also provide for consistent design through the establishment of project specifications for a wide variety of elements. The most important are for piping and structural components. Piping can be based on piping standards such as Ansi, Canadian Thinwall, or DIN. Similarly structural specifications such as AISC, CISC, or DIN can be used.

A key element in our use of this tool concerns the component libraries for a broad assortment of equipment. This further increases design efficiencies by reducing the requirements to create new objects. Accurate material takeoffs can be readily generated. Once the design process is complete, both the geometric representation of the model and the attached specifications are available as the foundation data for the maintenance management system. With the plant walk capability we can use the three dimensional physical model to orient both operations and maintenance personnel prior to the plant being commissioned. This can be in "live" demonstrations for an area or activity. The former can be used to check actual equipment removal or repair activities. The later can be a perspective drawing showing a particular unit operations equipment and piping with all structural steel etc. removed. This capability extends the tool's usefulness from design and construction into the areas of maintenance, plant operations and training.

Benefits

Overall the benefits of these tools are well established. They include improved communication of design concepts, faster drawing production, more accurate and more detailed materials list, a major reduction in field changes, and a visual method for construction monitoring. When properly applied these capabilities result in improved design, lower construction and capital costs and reduced start-up and operating costs.

OPERATIONS MANAGEMENT FOR COMPLEX INDUSTRIAL SYSTEMS:

Dynamic Simulation and Design of Pulp and Paper Mills

SIMONS

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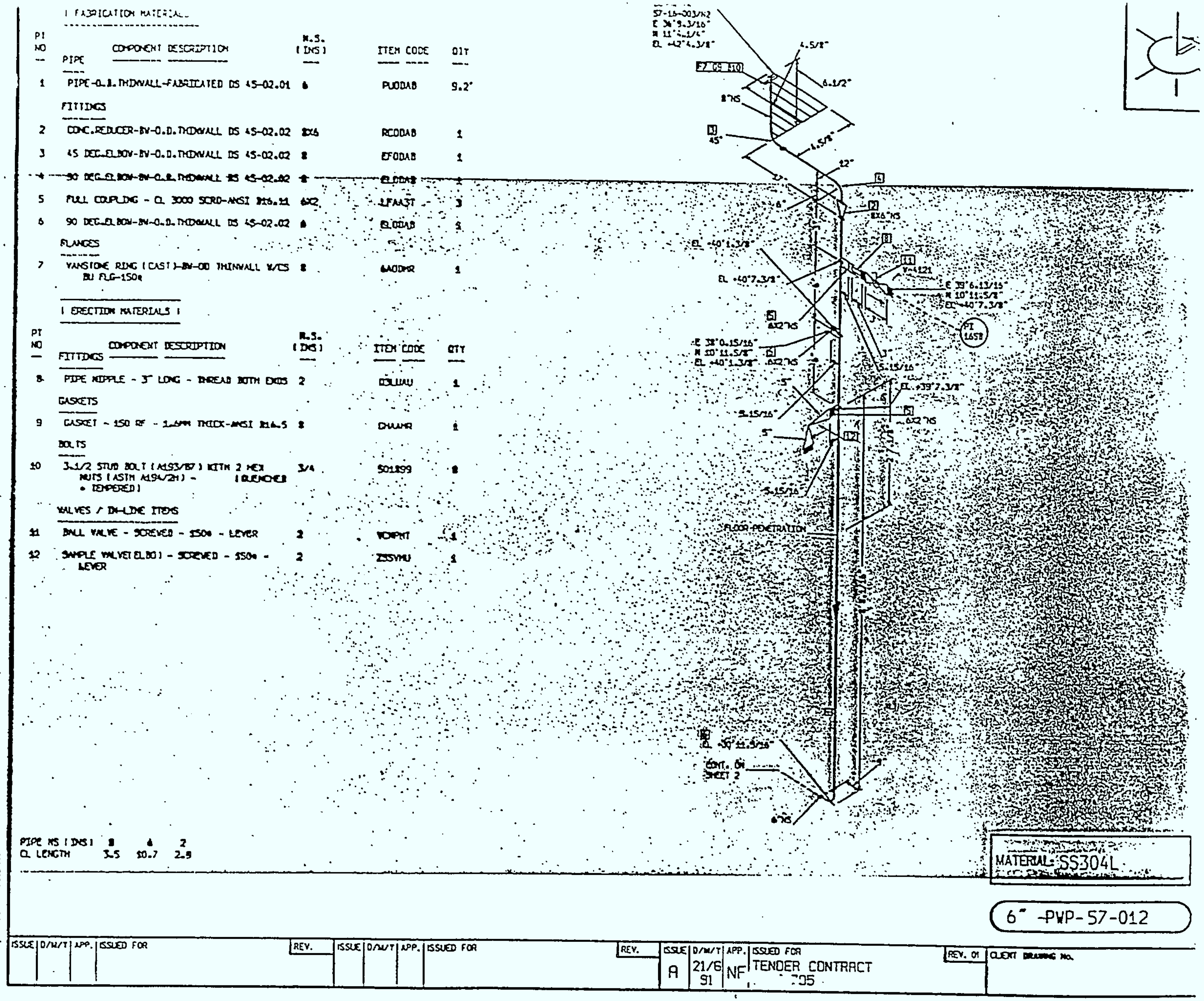
FABRICATION MATERIALS
PT NO | COMPONENT DESCRIPTION | N.S. (INS) | ITEM CODE | QTY
PIPE
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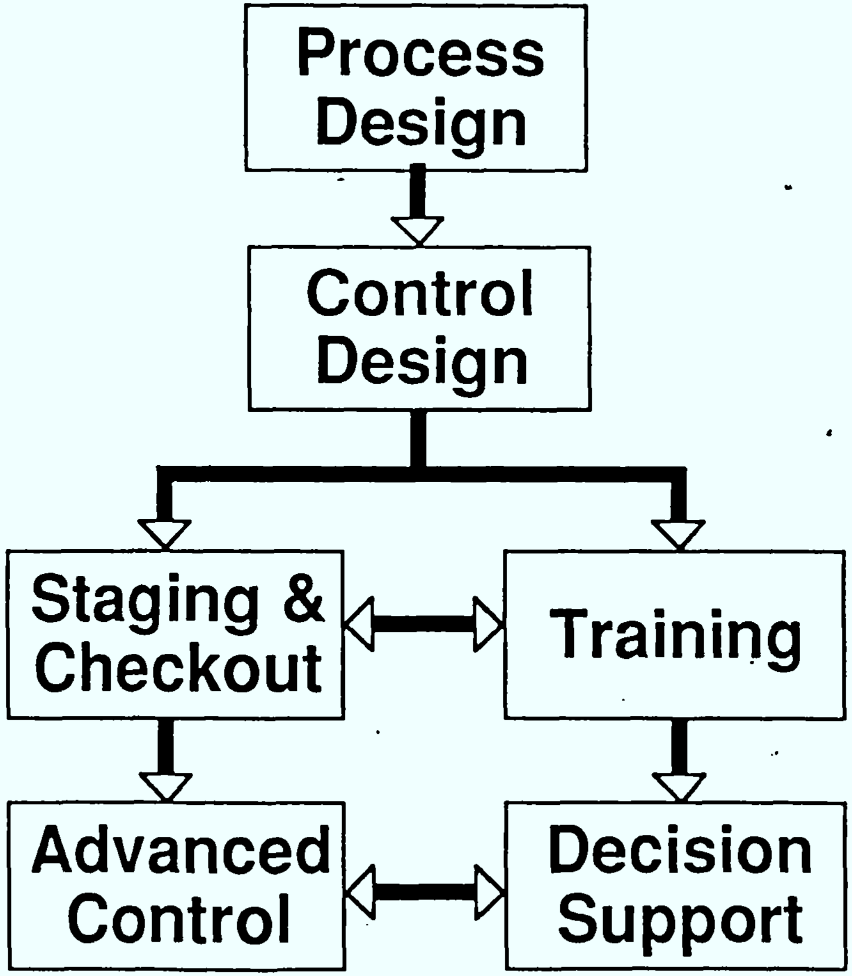
FITTINGS
2 CONC.REDUCER-BV-O.D.THINWALL DS 45-02.02 8X6 RCODAB 1
3 45 DEG.ELBOW-BV-O.D.THINWALL DS 45-02.02 8 EFODAB 1
4 90 DEG.ELBOW-BV-O.D.THINWALL DS 45-02.02 8 ELODAB 1
5 FULL COUPLING - CL 3000 SCRD-ANSI B16.11 6X2 LFAA3T 3
6 90 DEG.ELBOW-BV-O.D.THINWALL DS 45-02.02 6 ELODAB 5
FLANGES
7 VANSTONE RING (CAST)-BV-OD THINWALL W/CS BU FLG-150# 8 6AODMR 1
ERECTION MATERIALS
PT NO | COMPONENT DESCRIPTION | N.S. (INS) | ITEM CODE | QTY
FITTINGS
8 PIPE NIPPLE - 3" LONG - THREAD BOTH ENDS 2 DDLUAU 1
GASKETS
9 GASKET - 150 RF - 1.6MM THICK-ANSI B16.5 8 DHAAMR 1
BOLTS
10 3-1/2 STUD BOLT (A193/B7) WITH 2 HEX NUTS (ASTM A194/2H) - (QUENCHED + TEMPERED) 3/4 S01899 8
VALVES / IN-LINE ITEMS
11 BALL VALVE - SCREWED - 150# - LEVER 2 VCMPNT 1
12 SAMPLE VALVE(ELBO) - SCREWED - 150# - LEVER 2 ZSSYMU 1
PIPE NS (INS) 8 6 2
CL LENGTH 3.5 10.7 2.9
24-JUN-1991 14:14:17.10
EL -40'1.3/8"
EL -40'7.3/8"
FLOOR PENETRATION
CONT. ON SHEET 2
MATERIAL: SS304L
6" -PWP-57-012
ISSUE | D/M/Y | APP. | ISSUED FOR | REV.
A 21/6 91 NF TENDER CONTRACT
REV. 01
CLIENT DRAWING No.

The Dynamic Model is the Thread



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Control and Management Systems for Process Control

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Alberta

SLIDE 1 INTRODUCTION

A.1 Introduction - Background

Good afternoon. I'm pleased to be here today to offer some perspectives from a company in the petrochemical industry on 'Control and Management Systems for Process Control'
What my talk today will really be about is one Chemical Company's perspective on changes to manufacturing processes and on changes to the control of these processes.

The early communication between Dow and Dr. Efford, requested from Dow. 'An exciting presentation that demonstrates the application of advanced technologies - at the leading edge industrial use - in order to accelerate their commercial adaptation for enhancing global competitiveness of the Canadian forest sector'

I'm not sure I've gotten past the intimidation of the challenge to provide 'excitement' let alone deliver on the rest!

Well , what perspectives might Dow offer, from its experience base in the Petrochemical Industry, that might be of interest to the Forest Industry?
There seem at first look to be a number of differences?
Dow's product mix is quite different. Dow is involved in Industrial Specialty chemicals, plastics, agricultural chemicals, pharmaceutical chemicals, consumer chemicals.
What might this offer that would be relevant to this conference?
But there are also a number of similarities:

We both utilize complex manufacturing processes that involve chemicals, fluid flow, and complicated industrial equipment.
We both utilize a lot of water chemistry and must deal with waste issues.
Both of us 'live in Canada' yet must compete by selling our products into a global marketplace.

A.2 INTRODUCTION- WHAT FACTORS ARE DRIVING THE CHEMICAL INDUSTRY

On reflection, it seems that many of the factors driving change in the Petrochemical Industry are the same as those for the Forestry Industry. What are some of these?

SLIDE 2 SOCIETAL ISSUES

'Ozone Hole', 'Acid Rain', Waste Dumps', 'Ground Water Contamination'

These topics are heard so often now in the press that they need no explanation. Society is demanding that industry do better! The Montreal Protocol Chemical ban is an example of how this impacts. Does society have any good alternatives for replacing the Freons ? This kind of issue has hit home with Dow -- resulting in our withdrawal from the Chlorethene* cleaning solvents businesses!

Zero 'waste' like zero safety incidents may be hard to accomplish but must be our vision.

If we do not do better, will we be allowed to build future plants, or even run the plants we have? At each of Dow's manufacturing sites in N. America, we are committed to reducing atmospheric emissions of NOXes and 'Volatile Organic Carbons' by 50% by 1995 relative to 1989.

SLIDE 3. COMPETITION

And in this framework, we must be globally competitive to survive against ever more competitors such as the Japanese, Koreans, Saudis ...

Each company must realize that it must do better to survive
- Do better in creating quality products and marketing them
- Do better in our manufacturing processes
- Do better in our management of these processes

My talk today will focus primarily on doing better in our manufacturing processes and in the control of these processes, with some reference to some of the changes that are occurring in the management processes as well.

* Dow trademark

B. THE STARTING POINT -- THE MANUFACTURING PROCESS

B.1 MANUFACTURING PROCESS TRENDS

What are some of the trends that these driving forces are leading to?

SLIDE 4a, 4b

1. More clever processes with 'no wastes' -- or at least, way less wastes to minimize costly treatments.

A major commitment has been the elimination of use of disposal wells for waste chemicals, and has been accomplished at the site. A current major Dow goal is the reduction in all existing plants in N. America of 50% of volatile organic and Nitrogen Oxide emissions from 1989 to 1995.

The designs used in our Ft. Saskatchewan, Alberta, Ethylene Plant under construction will result in the lowest waste/lb. of product from any known Ethylene plant. It utilizes both Dow and purchased knowledge. The plant process changes and extensive plant recycle have resulted in an order of magnitude reduction in the volume of liquid wastes. Also this plant has built into it the investment of $25MM for final treatment of these wastes within the plant's battery limits, that totally eliminates water based effluent to the river. The basis of this approach is not that it is impossible to return acceptably clean effluent to the river, but that it may be the cheapest long-term solution to totally eliminate it!

SLIDE 5a, 5b

2. Lower risk plants - with minimal hazardous material inventory.

Because of the flammability / explosivity nature of hydrocarbons or some chemicals such as ethylene oxide, or because of the toxicity such as with isocyanates that were part of the Bhopal disaster, a significant trend is to eliminate intermediate and even raw material and product tankage. In addition, the trend in towers to use packing rather than trays significantly lowers the tower inventories.

All potential vent sources such as PSVs are increasingly connected to process headers . These headers and clean-out systems recycle/handle materials back into the process , further adding to the process complexity. It is ever less acceptable to have any emissions from manufacturing plants even in 'emergency' situations.

B.1 MANUFACTURING PROCESS TRENDS (con't)

SLIDE 6a, 6b

3. More Energy Efficient Plants

Historically, chemical plants had considerable cross-exchange, but on the whole, the reboiler heat and the condenser cooling were thought of as utilities. The much higher cost of energy and the desire to reduce waste has resulted in much more extensive cross-exchange with one columns' condenser being another's reboiler. The impact is for extensive coupling together of previously unrelated parts of the process -- introducing additional impacts from any upsets.

SLIDE 7 REDUCING LONG-TERM COST OF OWNERSHIP

4. Reducing 'Long Term Cost of Ownership' Plants

To remain competitive, each capital project (new plant or modification) must be done at the lowest possible capital cost. New construction techniques are coming into practice today. In the past, a tower might have been shop fabricated , but after being put in place, it required costly scaffolding and costly field labour, to add ladders, platforms, conduit, insulation ... In today's plant the tower is lifted into place with all of these items complete. Even pipe-racks are being shop fabricated in long sections with all of the pipes, tracing and insulation in place.

Can an equipment item be made reliable enough so that we are willing to live without spares? We have always done this on some kinds of equipment -- but , for example why not a reliable pump, needing no spare?

In fact, why not purchase equipment that can run say five years, reliably without any shut downs? Is an annual shutdown really necessary? And can shutdown time be reduced? Experience in several of our plants is that through focused team effort, that shut-down time can be reduced by the order of 1/2 when more thoroughly planned.

New plant process instrumentation costs are being lowered and flexibility gained by going to ever more distributed and interference free digital systems with ever better intelligence and diagnostics. At the same time, extensive redundancy is added. Buried cable can be a safer approach than the historical cable trays for signals.

What is the result of all of this to the control management issues in running manufacturing processes ?

B.2 MANAGEMENT PROCESSES AND EVEN ORGANIZATIONS MUST CHANGE

The following are some of the responses at Dow to these trends:

SLIDE 8 MANAGEMENT PROCESSES MUST CHANGE - MORE ANALYSIS , MODELING, and TQM

1. Much more Analysis and Use of Modeling Techniques

   Processes are analyzed using complex steady-state simulators with real physical properties and realistic unit operation models.

   Dynamic modeling is being done on selected critical units although this is by no means common place.

   Reactor models are being expanded to include secondary as well as primary reactions. It is often in the understanding of such previously unexplored fine details that real innovation is possible.

2. 3-D Modeling of the Physical Plant

   Engineering is starting to utilize common integrated data bases across all disciplines. '3-D modeling has gone from being a curiosity less than 5 years ago to being a significant technology being used in the Ethylene plant design and construction -- a first in Dow for a project of this size. The intention is to keep this computer model up-to-date throughout the plant's life, by using it in doing maintenance.

   A major thrust is to re-engineer parts that have failed. This may mean replacing a vessel with a different alloy, or replacing a metal pump shaft as in one large pump situation with a fibre-reinforced composite as in one recent plant.

3. Adoption of a 'Total Quality Management' or TQM philosophy for the entire company.

   I won't go into this today, except to say that some of the very significant thrust of this is :

   Data-Based Decision Making
   More Teamwork and cooperation across line functions
   Empowerment of people to get the job done.
   Re-engineer organizations to align to these new directions

SLIDE 9 IMPACT OF CHEMICAL PLANT PROCESS CHANGES

C CONTROL OF MANUFACTURING PROCESSES

What do these changes in our chemical plants mean to the control of these processes ..... less mass flywheel, less intermediate inventory, heat balance interconnections of unrelated parts of the process, SQC demands from customers, high turn-down needs .....

In a nut-shell, every one of the changes is making it much more difficult to control these manufacturing processes.

I would like to briefly discuss what is happening in the control area at Dow under five categories:

AUTOMATION
CONTINUOUS CONTROL
PROCESS INFORMATION
ARCHITECTURE
MANAGEMENT PROCESS CHANGES

C.1 AUTOMATION

SLIDE 10

C.1.1 AUTOMATION OF DISCRETE PROCESSES

Automation implies running a manufacturing process without human intervention. The sense that I'll use this today is for non-continuous process, such as those characterized by a discrete and sequential nature.

The first category shows some ways currently being introduced by the use of bar coding technology. The first example depicts a bar code label used on a sample to uniquely and accurately identify the sample. The payout is that by reading the bar code as the sample goes through one or more analyzers, the data is accurately and automatically recorded. And as a bonus, sample storage is much simplified. As environmental demands require ever more sampling and record keeping, automation in this area is highly desirable.

A second example is the bar coding of waste drums as they are filled to help guarantee accurate handling of the drum until proper disposal. Over the years, there have been a lot of minor reactive chemical incidents by poorly marked drums and subsequent incorrect handling as more and different people are involved. In Dow's incinerator facilities in Texas, Louisiana and Germany, this bar code is read automatically as the drum is processed and the incinerator firing conditions automatically adjusted to the correct values. Accurate management of wastes and their ultimate disposal/destruction is a growing demand.

C.1.1 AUTOMATION OF DISCRETE PROCESSES (con't)

The final example is one that is being piloted at Dow in the states -- the use of bar codes to identify the thousands of flange gasket and valve packing potential sources of fugitive emissions, which must be 'sniffed' and documented to meet pending legislation. It is hoped that bar coding will enable an operator to quickly and accurately identify a source, do the sniff test, and enter the result to a portable device, greatly reducing the workload associated with this kind of coming legislated requirement.

SLIDE 11

C1.2 AUTOMATION OF PLANT PROCESS CONTROL

The most significant automation that is done is that associated with the operation of the manufacturing process itself. In a chemical plant at Dow, process control is organized into units that categorize the normal sequential steps - start-up, batch sequencing process steps, and normal shut-down. In addition a variety of emergency situation units are developed that handle the sequential activities that are needed to handle any such identified emergency. The sequences may require equipment shut-down, or start-up of back-up equipment and the like, as needed. The key is that all such units are part of a SINGLE integrated control program.

For a batch plant, automation control is all that is needed.

SLIDE 12

C.2 CONTINUOUS PROCESS CONTROL

For plants that run in a mostly steady-state manner, it is important to utilize a different kind of control. The traditional PID controllers are still the engines for most chemical plant control, with some considerable extensions utilizing ratio and cascade control. The main thrust in this area is to standardize and simplify the ability to quickly tune loops. Amazingly enough in hindsight, we are only now introducing a systems approach to automate the identification of out-of-tune loops through a simple monitoring of the cumulative PID error variance as the indicator.

The hottest category for large continuous plants, is the implementation of what is called 'Advanced Control'. This technology gets into using heuristic or even better, mechanistic process models to be able to better handle upsets and run in control nearer the constraint points. Last year, in a large continuous plant in Texas, use of multivariable predictive control techniques allowed a separation tower that was the plant bottleneck to handle a greater throughput with no off-spec re-processing required -- worth several hundred thousand dollars per year. The expansion of this kind of control to applications is not yet heavily implemented, but is fast growing.

The top layer, economic model control, is not currently practiced at Dow in an on-line manner. Economic models are run in some instances with some regularity, the results interpreted, and any changes needed made to the control system settings. The economic models developed to date have not had the 'robustness' needed, although no doubt such problems will be successfully addressed in the future.

SLIDE 13

C.3 OPERATOR CONTROL - PROCESS INFORMATION

The final form of process control historically was the first -- operator control. In today's complex plant, it is as important as ever that the operator understand what is going on and be able to intervene as needed. As a philosophical point, Dow does not see going to 'lights out manufacturing' -- even as a visionary goal. The operators role is seen as evolving to include trouble-shooting and simple maintenance but also present in the traditional oversight role.

What becomes essential, then, is for the plant operator to be able to see everything in the process that the control equipment sees, and in addition gets a series of secondary information through the process information system to diagnose equipment problems. This can be through gas detector head zone readings, through secondary analyzers and the like.

The typical system used in a new plant is to have panels to show critical alarms, but essentially to see the rest of the process via 'computer work stations' called operator stations. The ergonomic design of control rooms is a big issue. In general, the control rooms are getting smaller for a given size plant, and the PI systems are getting much more 'user friendly'. Typically the plant support staff are also able to access all of this information from their offices, although in a read-only manner.

SLIDE 14a 3 PARALLEL CONTROL MODES

Historically, the three modes of plant control were parallel and somewhat separate. The continuous control portion was done on a variety of 'boxes' hard wired to plant sensors and plant control valves. The automation portion was implemented using relays and later on PLCs sometimes tying into the continuous sensors/valves and sometimes utilizing separate sensors and valves. Process information was a process of monitoring all the continuous 'boxes', the PLCs and any other miscellaneous 'boxes' around .

C.3 OPERATOR CONTROL - PROCESS INFORMATION (con't)

SLIDE 14b ONE INTEGRATED CONTROL MODE

A modern plant ties together all three modes in the most seamless and integrated way possible. So strong is the belief in this integration that at Dow, the same control programs actually do both the automation and continuous control for all control loops. This has been found to be a significant advantage in achieving the highest degree of control possible.

A trend worth noting is the evolution of redundant systems. The conflicting goals of 'Never miss a needed shutdown' and 'Never take a false trip' are being addressed with the approach of going to a 2 of 3 voting strategy on a redundant control system.

The process information system runs on one (or more) separate computer(s), but is designed to access ALL information - primary (from the control computer) and secondary data inputs as well. This allows the operators and engineers to be able to conveniently get at all data and to collect history on all data. The PI system can not only track field sensed data, but can also display and keep calculated variables if desired -- such as for example, a heat transfer coefficient.

SLIDE 15 TECHNOLOGY ARCHITECTURE

The parts that I've been discussing are examples of what at Dow has become an increasingly more formalized approach to handling information flow - namely a Technology Architecture. In a nut-shell, this architecture is the framework and the standards that need to be used throughout a company to be effective. It encompasses choosing technology architecture standards , vendor products, and can even include the choice of 'supplier partnerships' vendors.
As practiced, it is a trade-off between having too few vendors versus too many, too few technologies to do the job right, versus too many technologies that everything is too complex.
The reason that I mention Technology Architecture today, is that I believe that it is an important management tool in addressing the future complex world, right from the sales order to the manufacturing plant through to delivery to the customer.

C.3 OPERATOR CONTROL - PROCESS INFORMATION (con't)

SLIDE 16. MANAGEMENT PROCESSES MUST CHANGE

I've discussed very briefly the technology architecture framework in which process control is implemented. It is important to touch on some of the management and organizational processes that must evolve.
In common with the manufacturing process itself, there is a need for much better modeling. In the case of process control, this is mostly dynamic modeling although steady-state simulators can be a great help in analyzing the before and after steady-state more accurately and in defining some of the relative gain parameters needed to achieve the best design.

SLIDE 17. BETTER SYSTEM ANALYSIS LEADS TO BETTER CONTROL

It is tempting to think that a given kind of equipment can best be controlled by one 'best' control strategy. Managers are often given to this kind of thinking.
But depending on the flow rates, and physical properties of the fluids going into, in this case, the tower, the 'best' control strategy can be quite different. Analysis can often show that simple, low cost changes, such as a different pairing of controllers and valves can yield big improvements.
I'm no expert on this topic, but I've been told that there are many analogies between a paper-making machine and distillation towers in the impact of reflux (recyle slurry) and reboiler energy (water removal).

C.3 OPERATOR CONTROL - PROCESS INFORMATION (con't)

SLIDE 16. MANAGEMENT PROCESSES MUST CHANGE

The eventual best model is the plant itself. Today's plants are very heavily into monitoring the key parameters and keeping SQC and SPC charts -- and tracking plant statistical 'capability'. Statistical experiments have been utilized successfully to optimize some of the operational parameters.

The management of process control in a plant is not a one pass activity - it is an ongoing process, ever looking to improvements ...

I've shown the 'TQM' major points once before today, but it bears repeating. The essential change needed is to put all of the various management sub-systems into this TQM framework: Customer oriented, with data-based decision making, utilizing teamwork across all lines, and empowering people to do the job. I don't have the time today to expand on this, but TQM is not just a passing fad or a lot of 'motherhood' but an essential part of a successful company's culture.

A core concept in all TQM management processes is the PLAN, DO, CHECK, ACT cycle. To a knowledgeable control engineer , this is pretty old hat -- a combined feedforward, with feedback control strategy.
Maybe management is just discovering what good process control engineers have for a long time known and practiced.

D. SUMMARY

A lot of change is occurring in the Chemical Industry -- Driven by Environmental/Societal Issues and by World Competition.

Changes in Chemical Process Plant Design are making control of these manufacturing processes more difficult.

Process Control of a manufacturing process is the first-line and most critical manufacturing process. The three traditional control modes, automation, continuous control and operator control need to be seamlessly integrated into one system within a technology architecture framework.

Analysis and use of modeling is a powerful strategy to meet this challenge, both in original design and throughout a plant's lifecycle.

The management systems that make all this most effective are part of an overall TQM approach -- Data-based decision making in a teamwork environment.

SLIDE 18

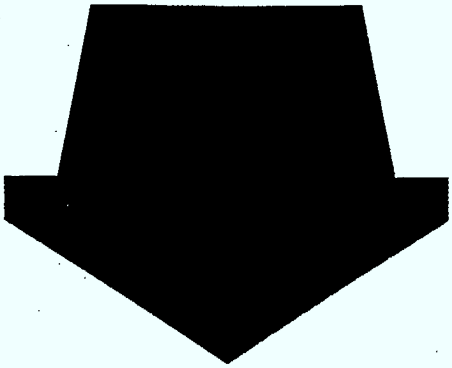
A final comment. I've had the opportunity to visit many of Dow's manufacturing sites in the US and in Europe. Everywhere I've gone, I've been impressed with the quality of the people. It is a tough, competitive world.
I'd also like to say that Dow Canada people are not out of place. To build a facility in Canada, a site must win out over other Dow projects and indeed demonstrate that Canada is the best location for the project -- global competition inside the company as well as in our products!

Given that all levels of government create a level playing field in terms of taxation, I have faith that Canadian industry can compete, tough as it is.

The $800 million dollar investment currently under construction at Ft. Saskatchewan, Alberta for a Fractionator, an Ethylene Plant and a Polyethylene expansion, seem to me to be a statement by Dow Chemical on its view of Canada's future.

Thank you for your attention today.

CONTROL AND MANAGEMENT SYSTEMS FOR PROCESS CONTROL



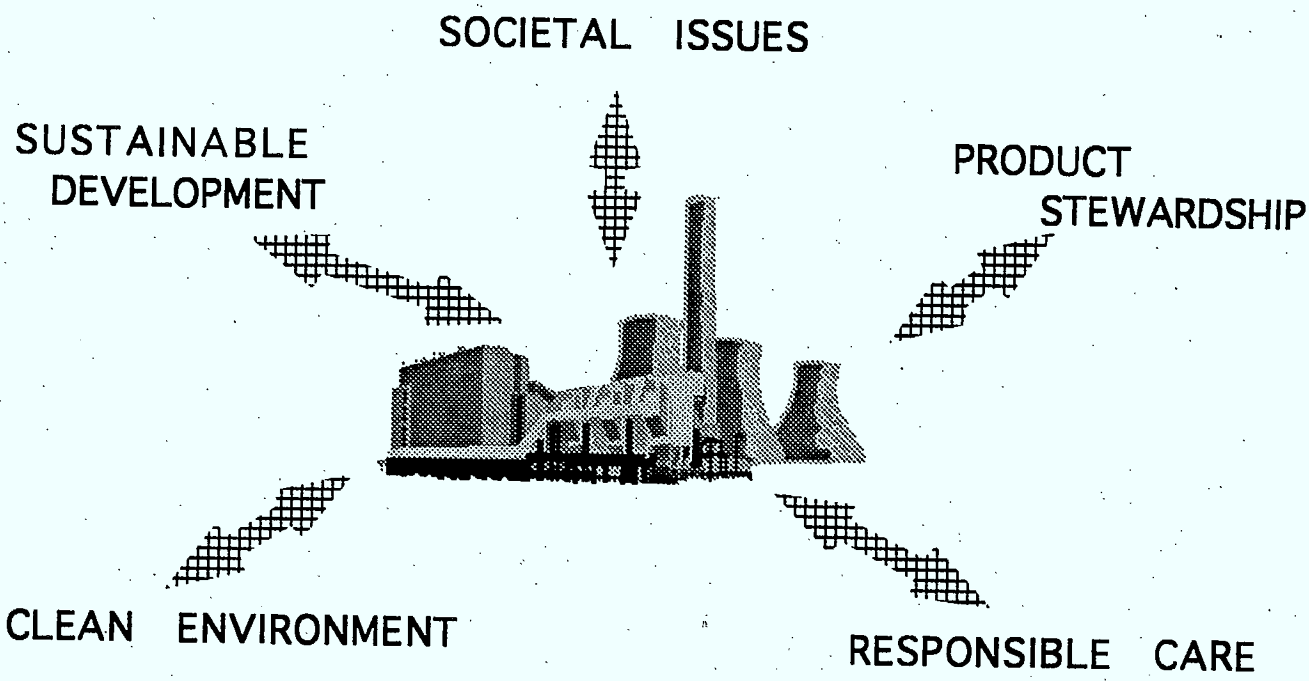
A CHEMICAL COMPANY PERSPECTIVE

- ON CHANGES TO MANUFACTURING PROCESSES

- ON CHANGES TO THE CONTROL OF THESE PROCESSES

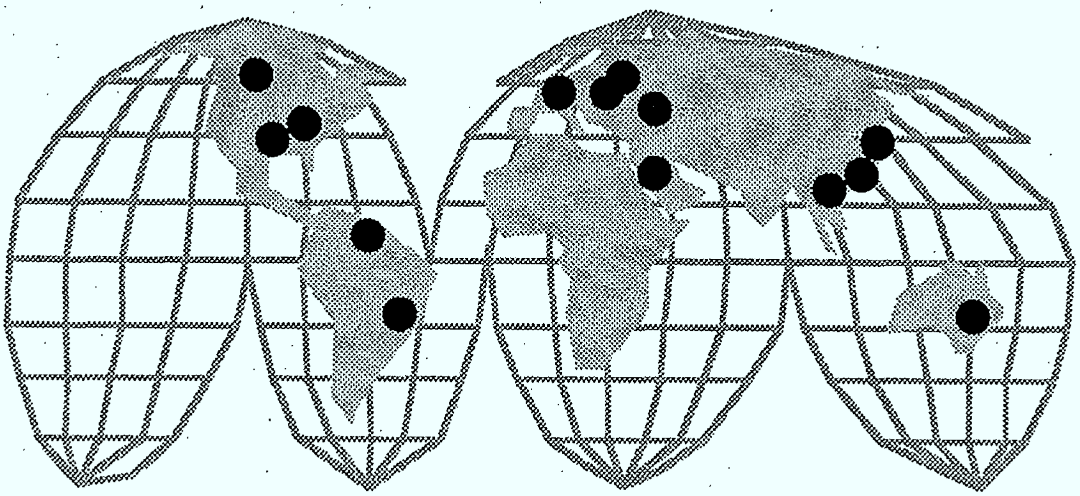
J.D. YALLOP
MANGER OF PROCESS ENGINEERING,
PROCESS CONTROL & COMPUTER SERVICES
DOW CHEMICAL CANADA INC.
FORT SASKATCHEWAN, ALBERTA SITE

JDY 9205
SLIDE 1



JDY 9205
SLIDE 2

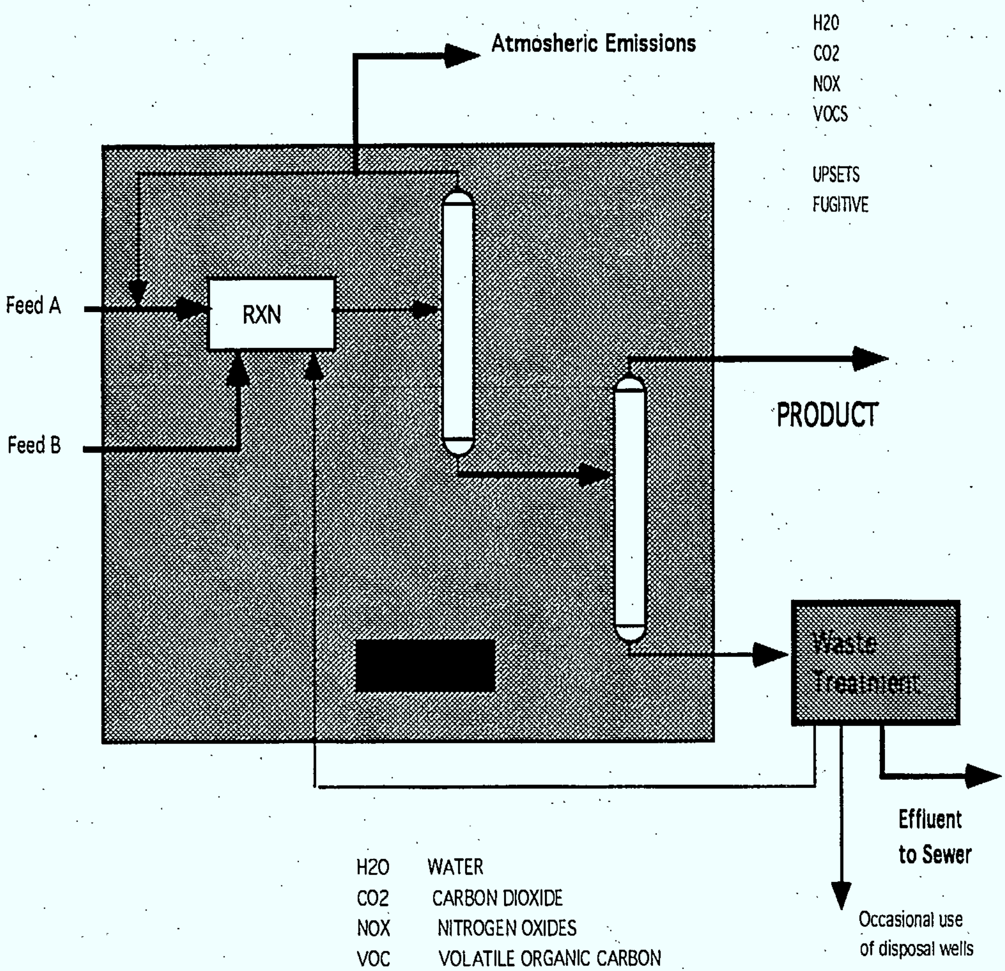
WORLD COMPETITION



- **More Competition than ever**
- **Global marketplace**

JDY 9205
SLIDE 3

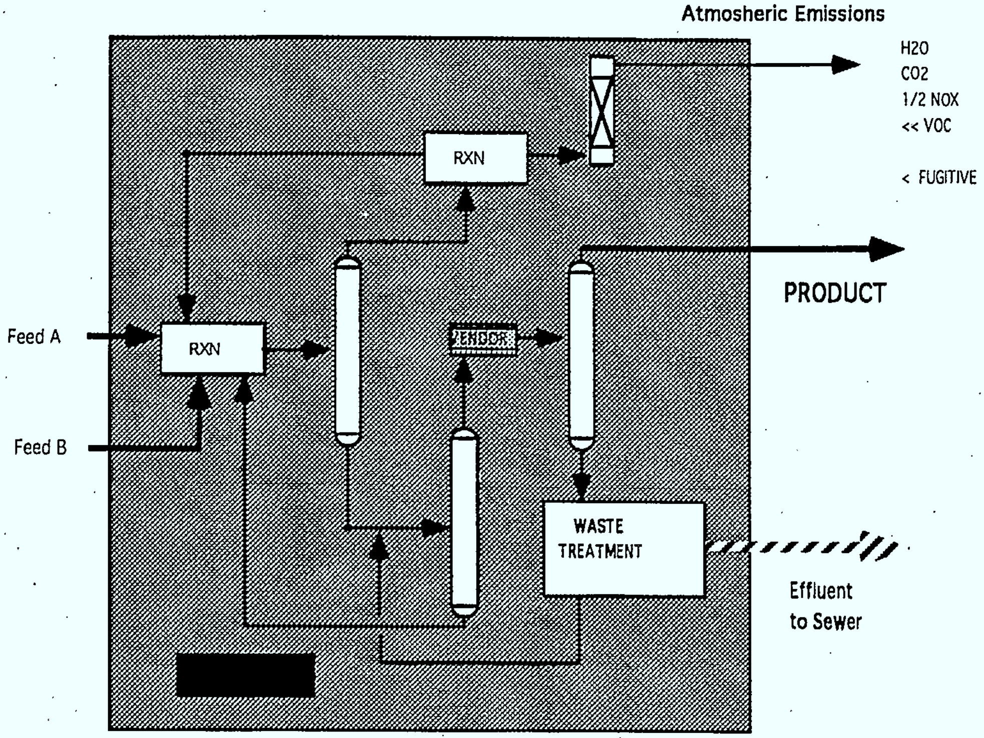
HISTORICAL PROCESSES



H2O	WATER
CO2	CARBON DIOXIDE
NOX	NITROGEN OXIDES
VOC	VOLATILE ORGANIC CARBON
UPSETS	ANY PROCESS CHEMICAL EMITTED IN AN ABNORMAL MANNER
FUGITIVE	FLANGE LEAKS AND VALVE PACKING LEAKS

JDY 9205
SLIDE 4a

MORE CLEVER PROCESSES



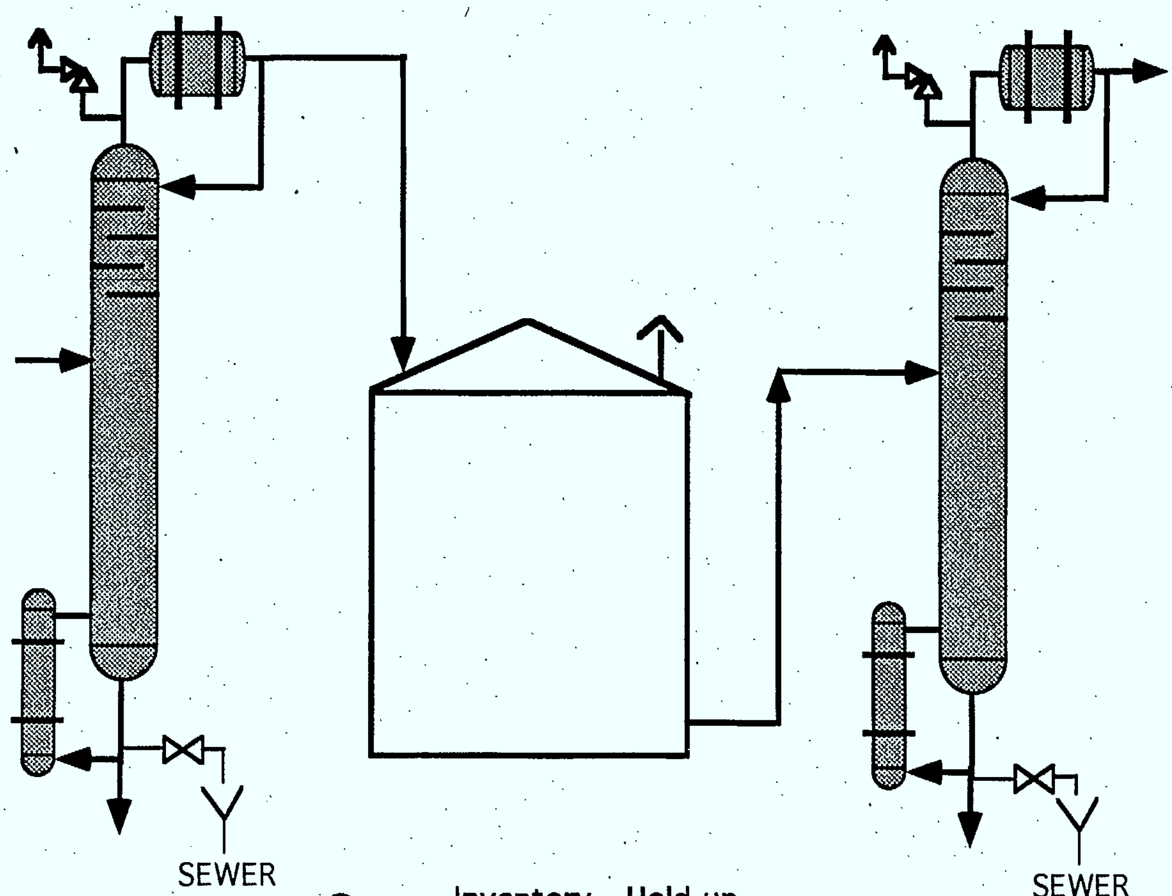
H_2O	WATER
CO_2	CARBON DIOXIDE
NOX	NITROGEN OXIDES
VOC	VOLATILE ORGANIC CARBON
UPSETS	ANY PROCESS CHEMICAL EMITTED IN AN ABNORMAL MANNER
FUGITIVE	FLANGE LEAKS AND VALVE PACKING LEAKS

- Less Byproduct/Waste Generation
- More Recycle
- Waste Treatment Designed into process - not added later
- Better Utilization of top vendor technology
- Total Elimination of effluent to sewer is seriously considered as an economic alternative
- Elimination of use of disposal wells

JDY 9205
SLIDE 4b

HIGHER RISK PROCESSES

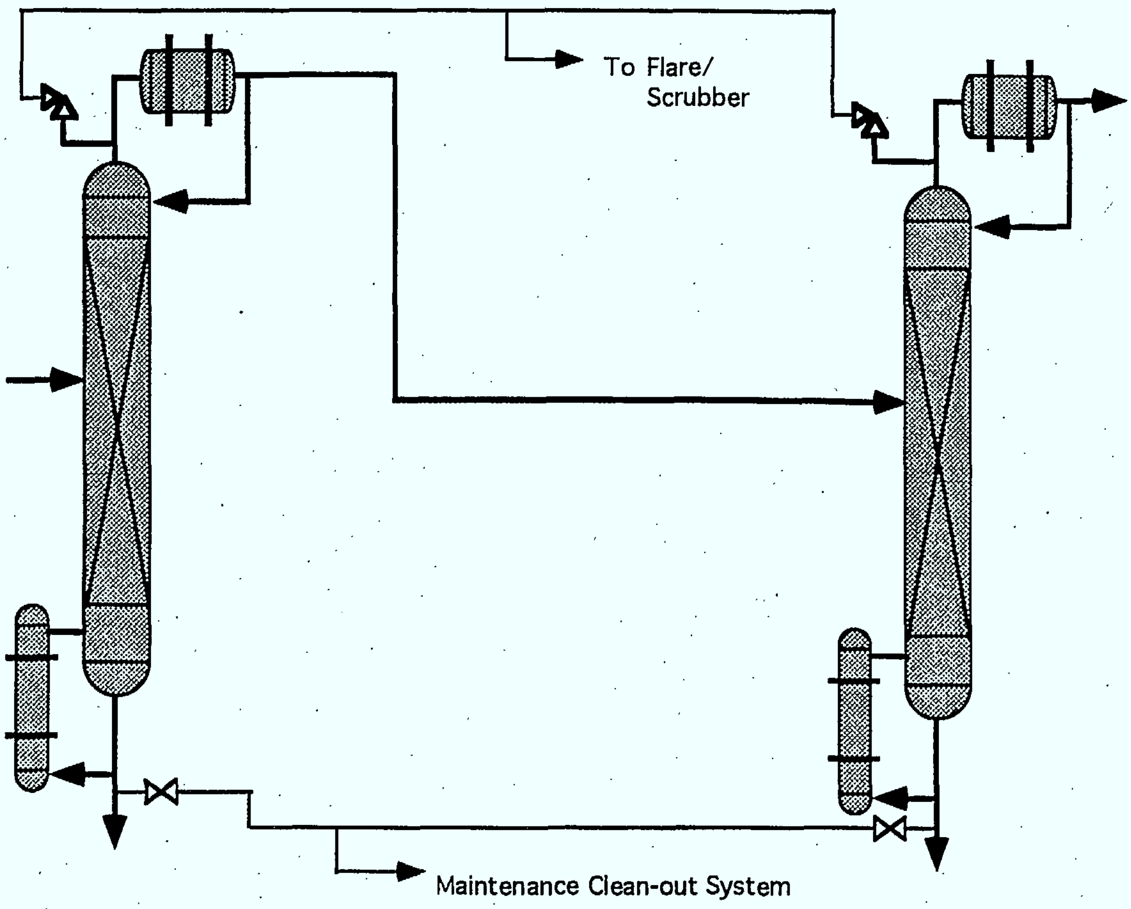
Historical



- Inventory Hold-up throughout process to smooth upsets
- Relief Devices vented to atmosphere
- Clean-out connections drained to sewer

JDY 9205
SLIDE 5a

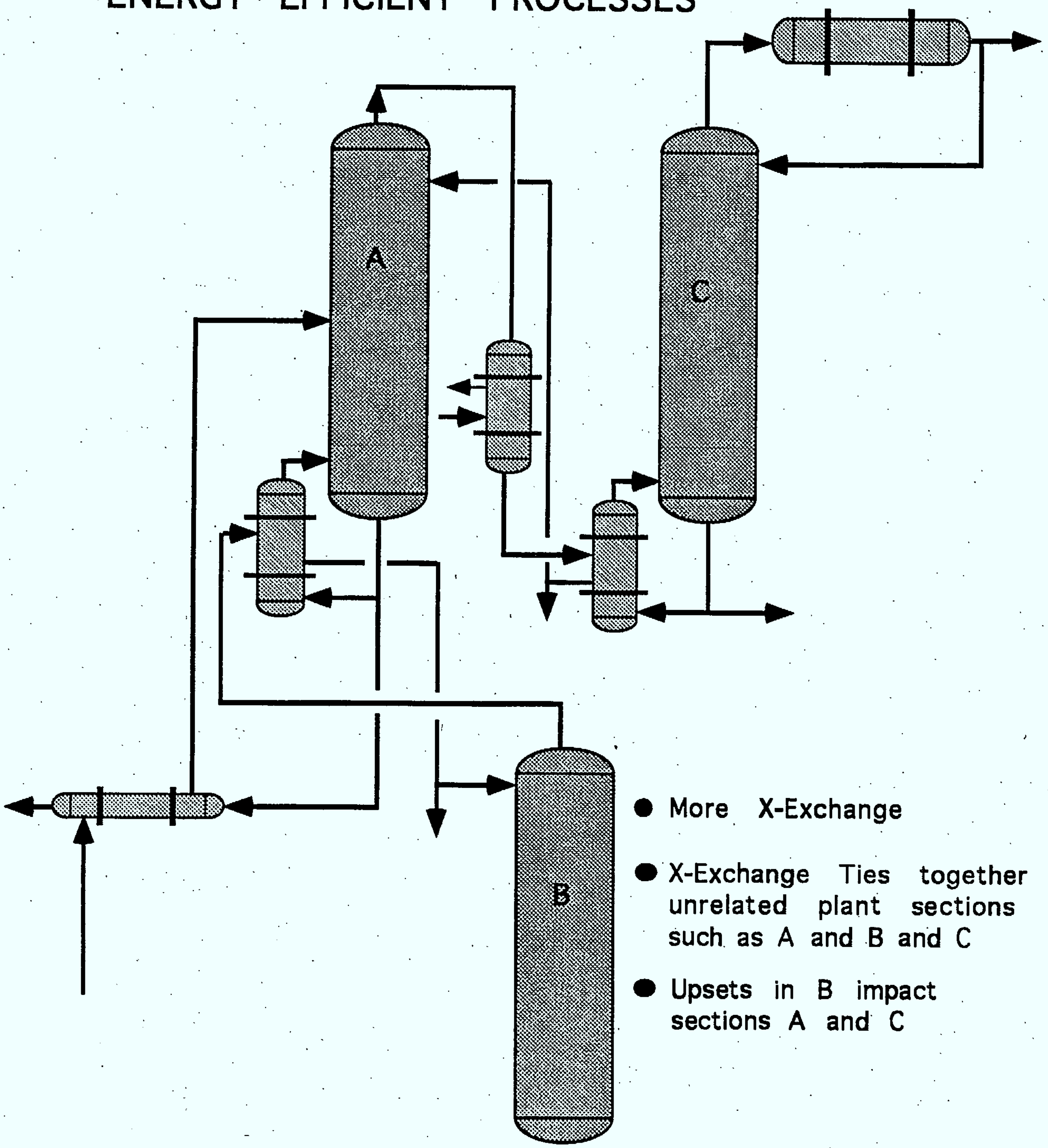
LOWER RISK PROCESSES



- Minimum Inventory of hazardous chemicals
  - No Vessels
  - No tray inventory
- More contingencies handled without emissions
- Upsets propagate quickly
  - no mass flywheel

JDY 9205
SLIDE 5b

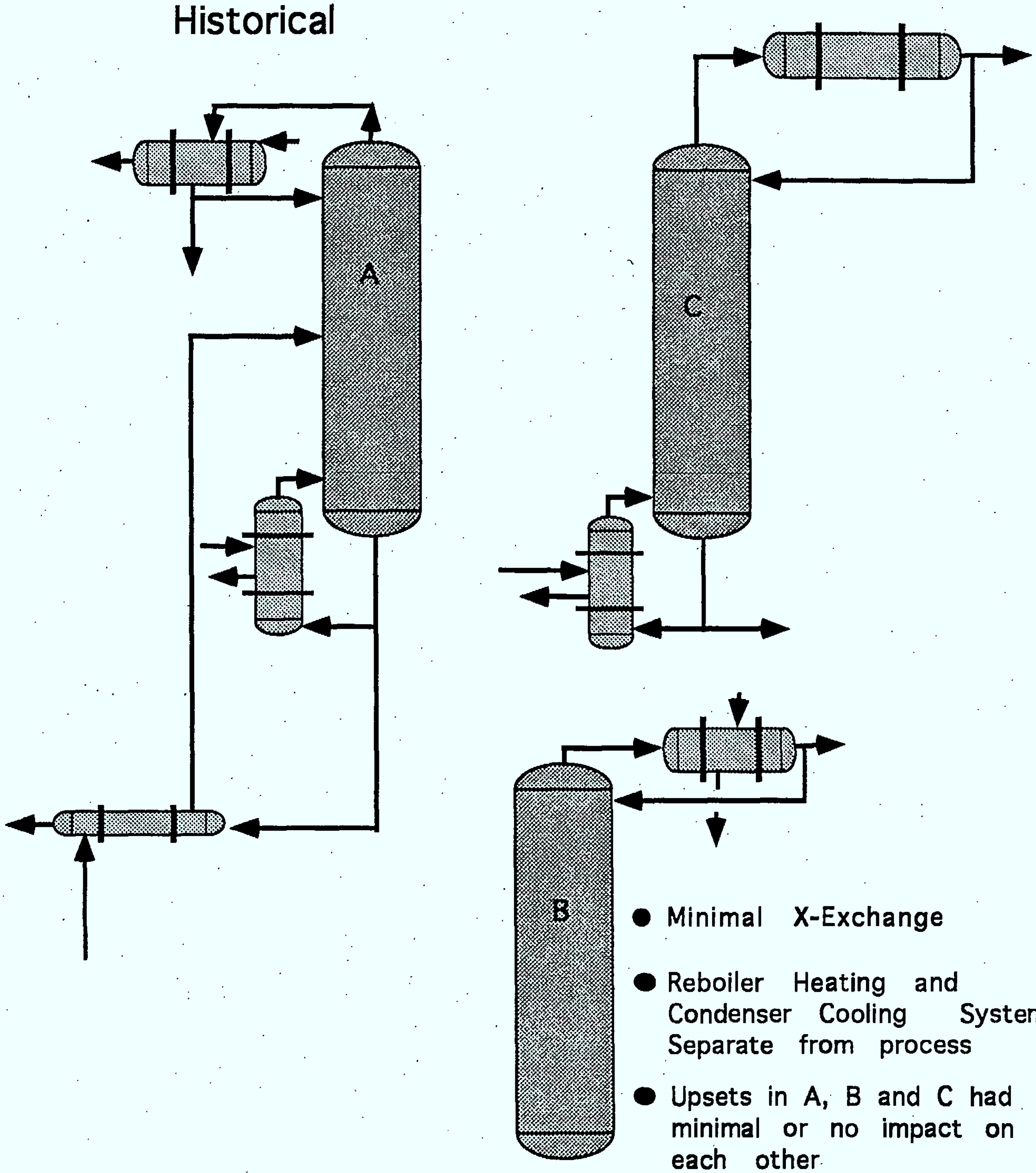
ENERGY EFFICIENT PROCESSES



- More X-Exchange
- X-Exchange Ties together unrelated plant sections such as A and B and C
- Upsets in B impact sections A and C

JDY 9205

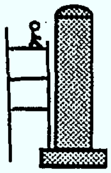
ENERGY EFFICIENT PROCESSES
Historical



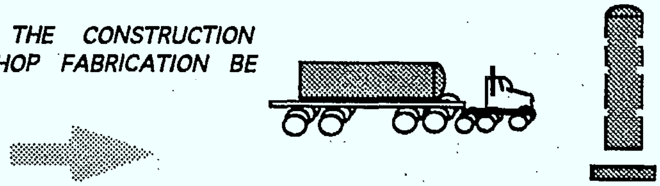
- Minimal X-Exchange
- Reboiler Heating and Condenser Cooling Systems Separate from process
- Upsets in A, B and C had minimal or no impact on each other

JDY 9205
SLIDE 6a

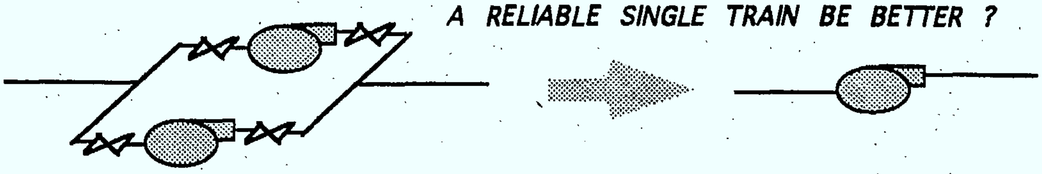
REDUCING LONG-TERM COST OF OWNERSHIP

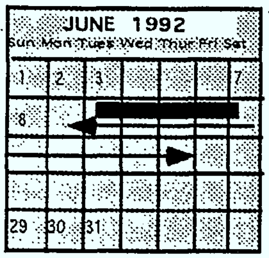


CAN ENGINEERING THE CONSTRUCTION SUCH AS MORE SHOP FABRICATION BE UTILIZED

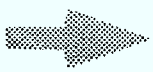


ARE ALL SPARES NEEDED OR WOULD A RELIABLE SINGLE TRAIN BE BETTER ?

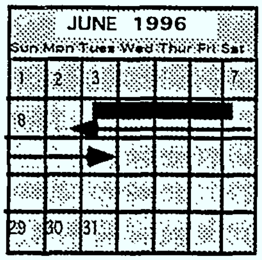




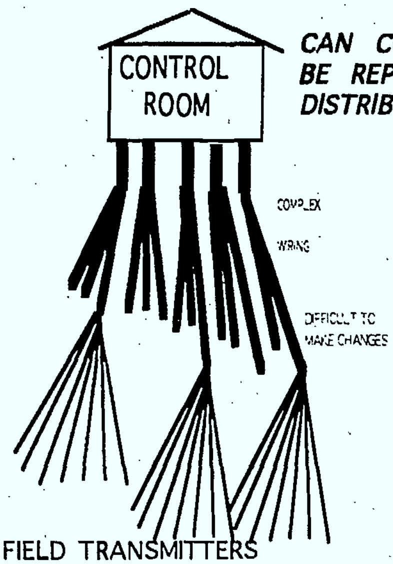
IS AN ANNUAL SHUTDOWN NECESSARY OR CAN THE PLANT BE IMPROVED TO RUN MUCH LONGER ?

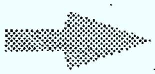


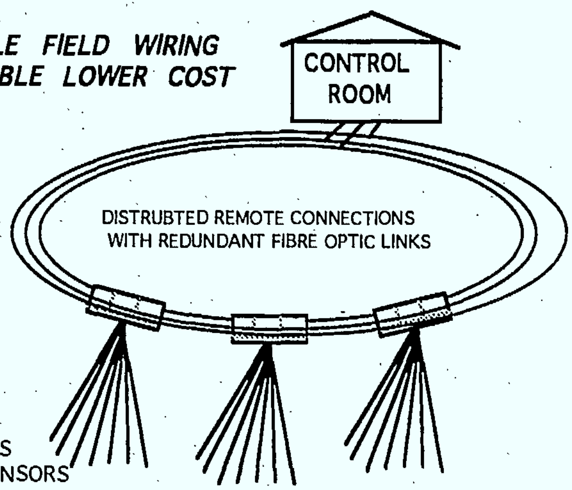
CAN THE SHUTDOWN LENGTH BE REDUCED ?



CAN COSTLY AND INFLEXIBLE FIELD WIRING BE REPLACED WITH A FLEXIBLE LOWER COST DISTRIBUTED SYSTEM ?







SMART TRANSMITTERS
AND OTHER FIELD SENSORS
REDUCE MAINTENANCE COSTS

REDUNDANCY ELIMINATES FAILURES

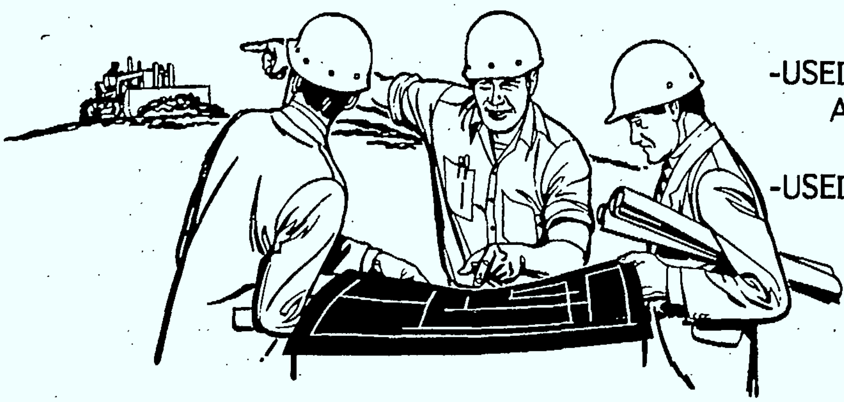
JDY 9205
SLIDE 7

MANAGEMENT PROCESSES MUST CHANGE

MUCH MORE ANALYSIS AND MODELING OF PROCESSES

-BEFORE CONSTRUCTION
-THROUGHOUT LIFE

3-D MODELING OF THE PHYSICAL PLANT



-USED TO DO DESIGN AND AID CONSTRUCTION

-USED TO ENGINEER MAINTENANCE

ADOPT A 'TOTAL QUALITY MANAGEMENT' APPROACH

Customer orientation -external and internal

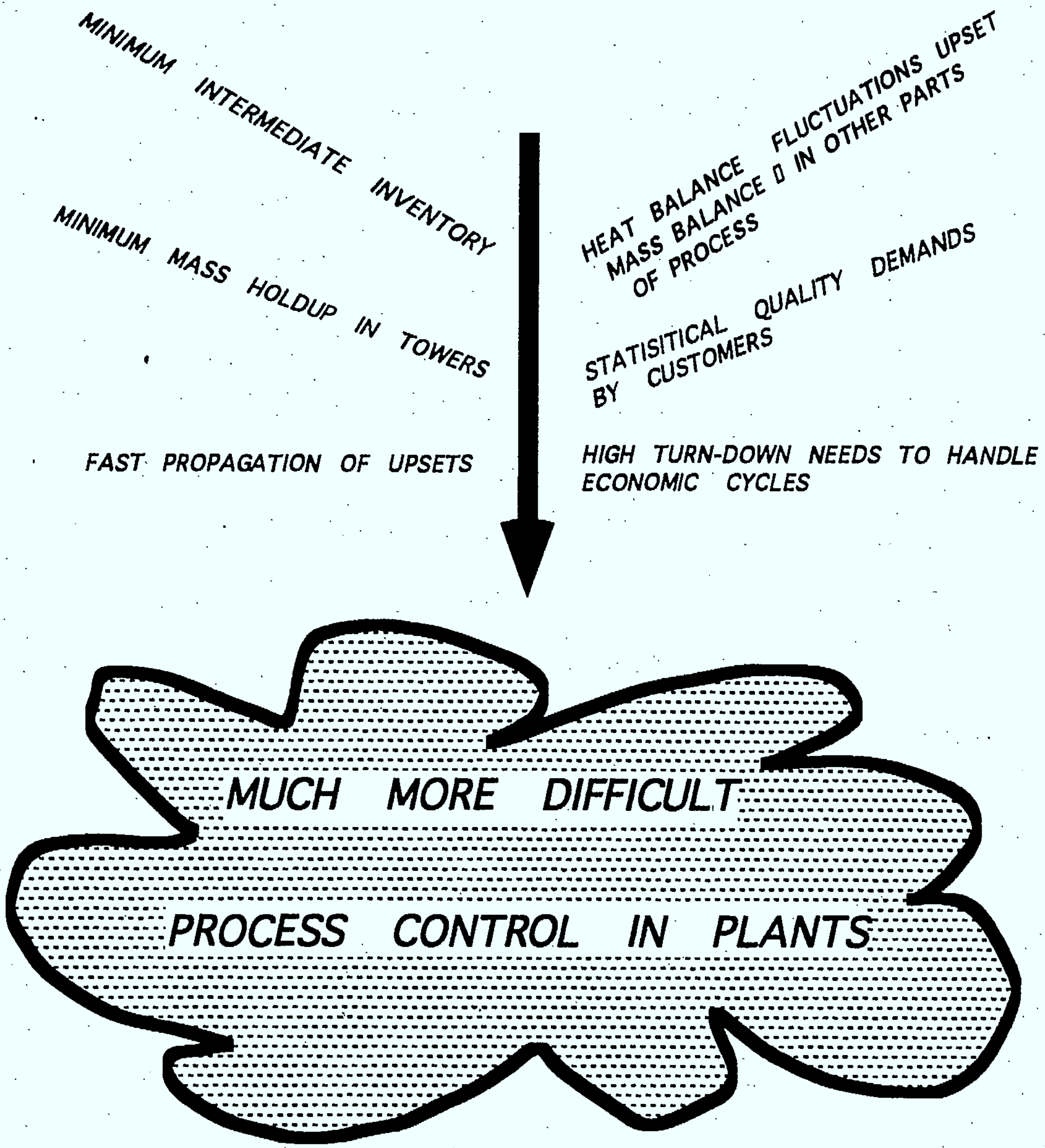
Data-Based Decision Making

Teamwork crossing all lines

Empowerment of people

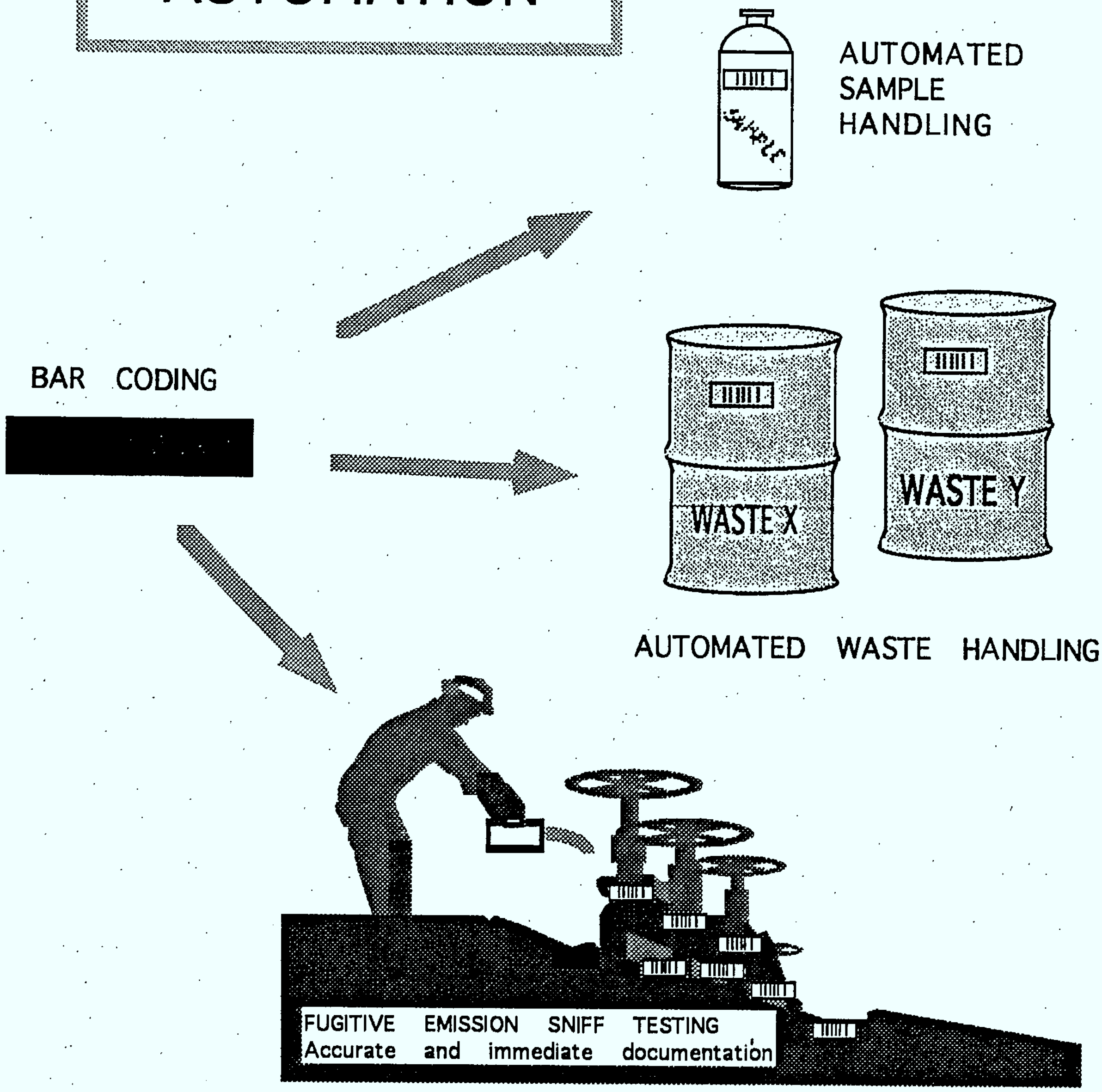
JDY9205
SLIDE 8

IMPACT OF CHEMICAL PLANT PROCESS CHANGES



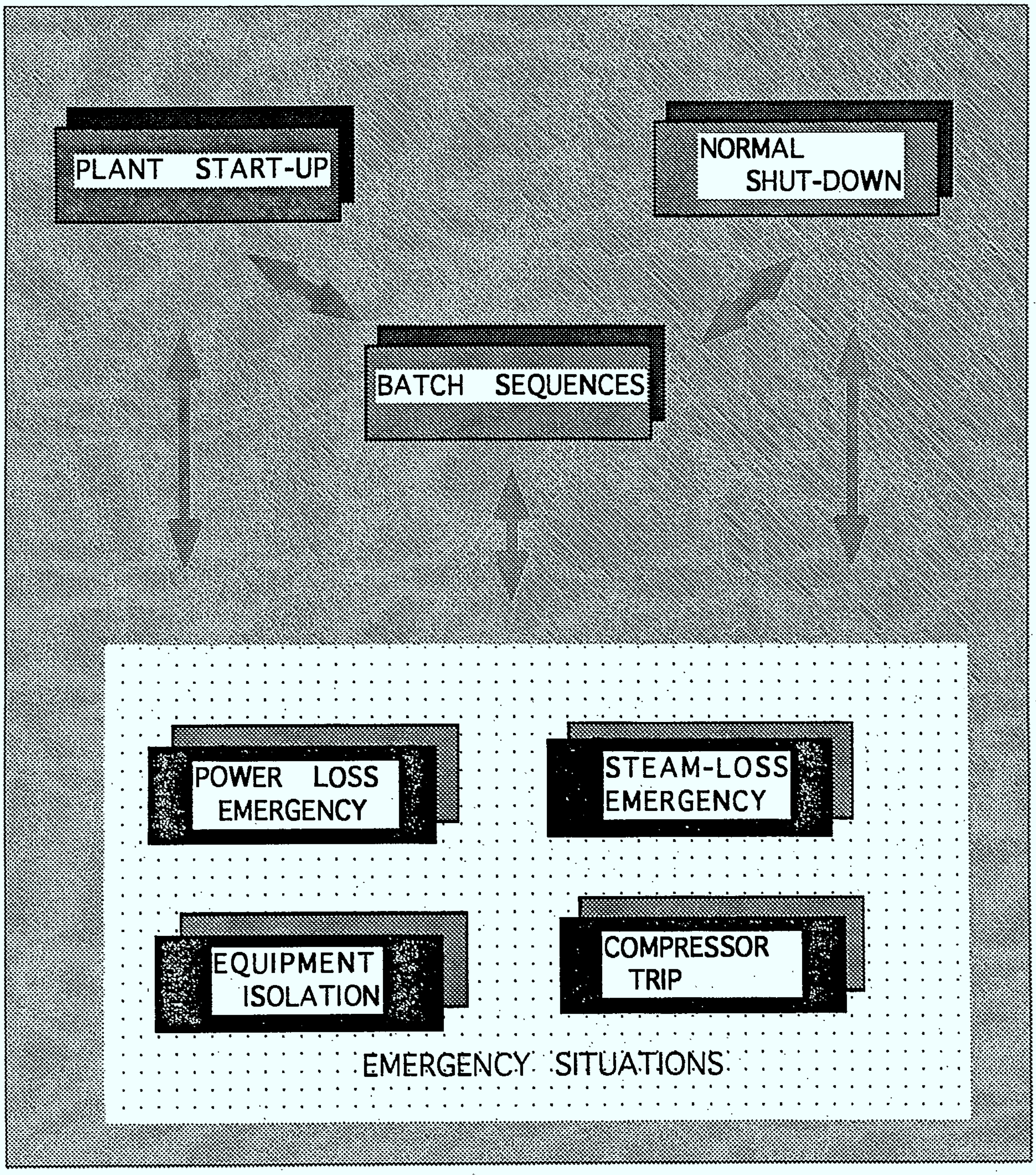
JDY 9205
SLIDE 9

AUTOMATION



JDY 9205
SLIDE 10

AUTOMATION -- Plant Process Control



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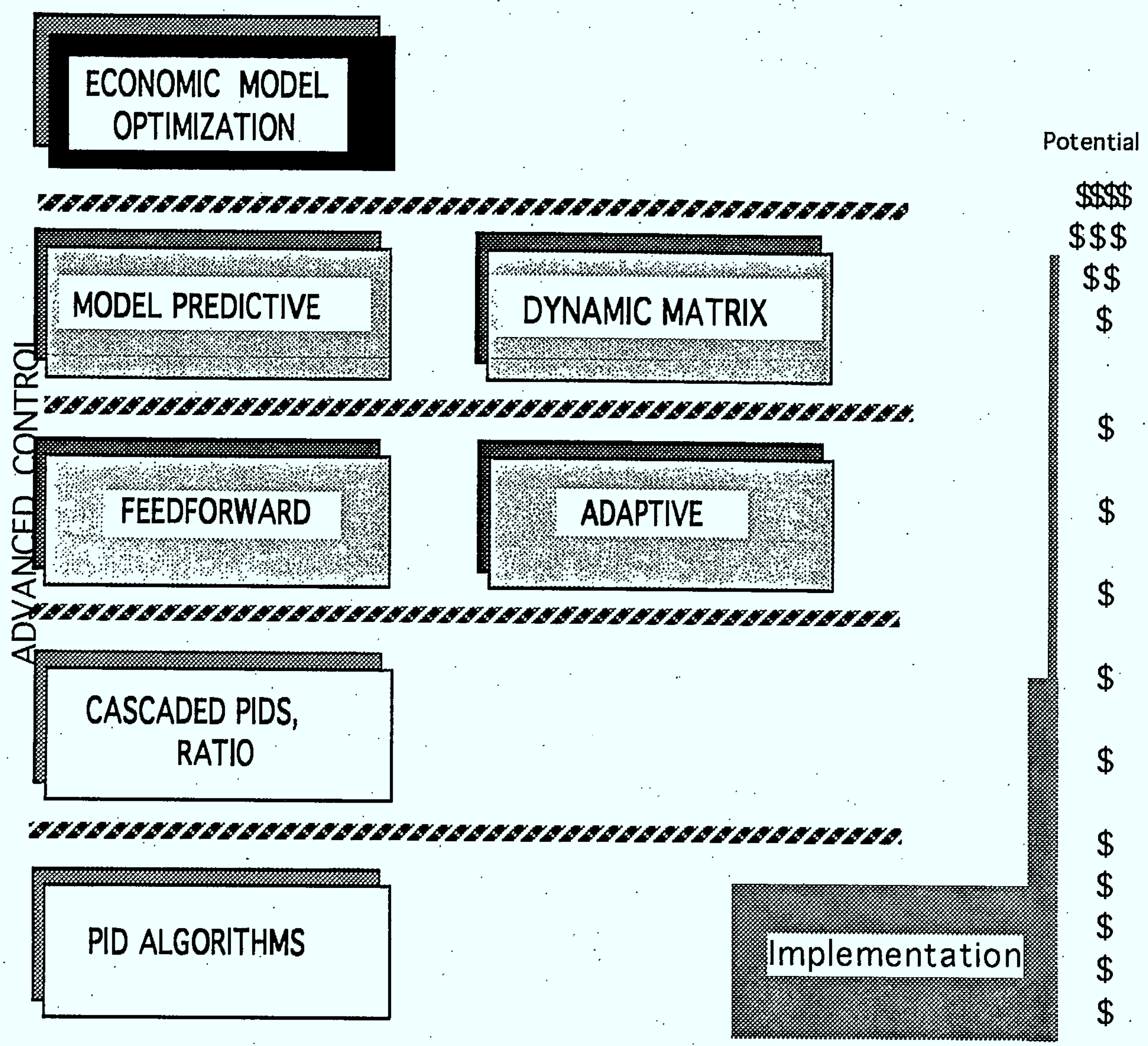
SLIDE 11

CONTINUOUS PROCESS CONTROL



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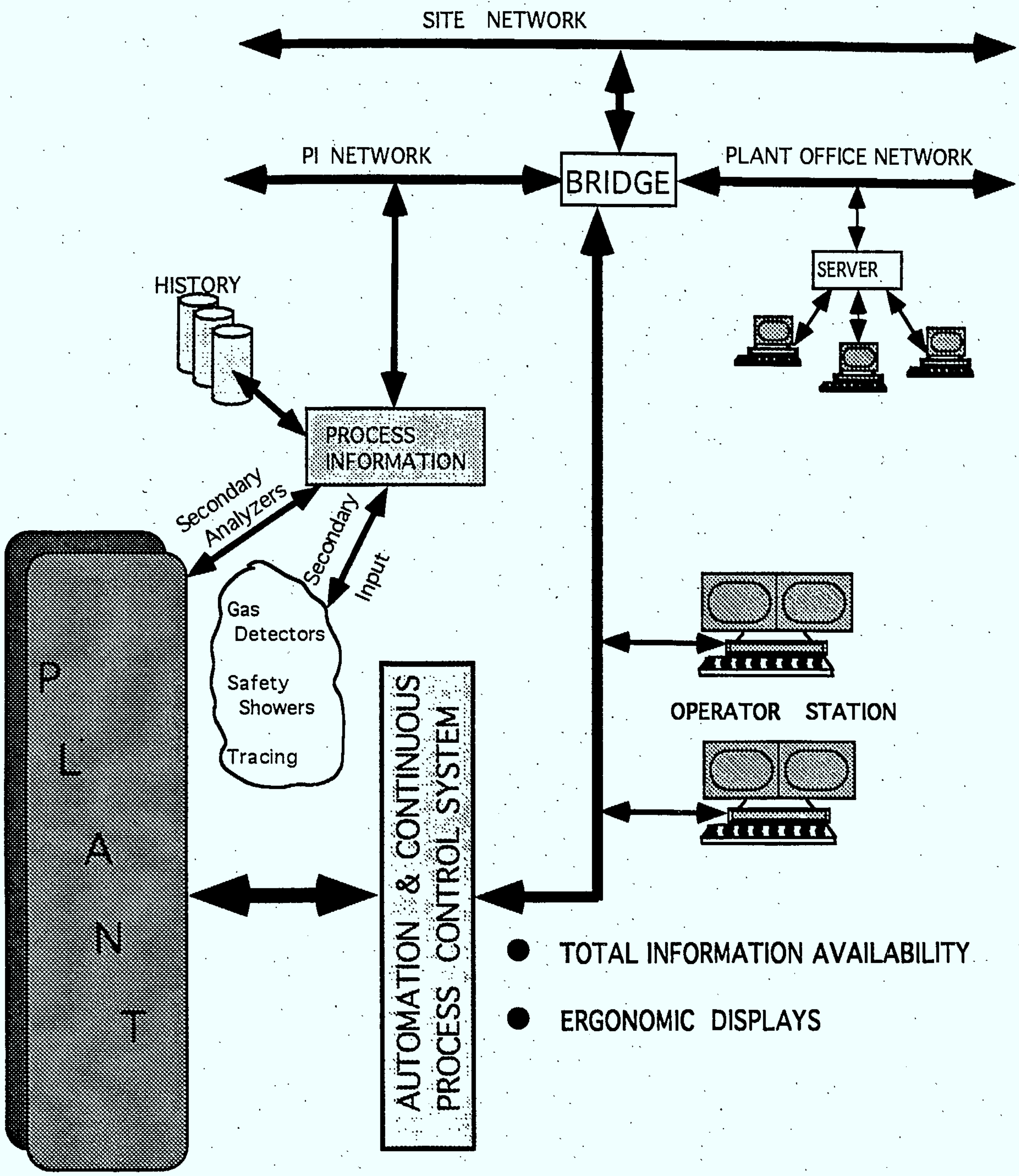
SLIDE 12

OPERATOR CONTROL - PROCESS INFORMATION



- TOTAL INFORMATION AVAILABILITY
- ERGONOMIC DISPLAYS

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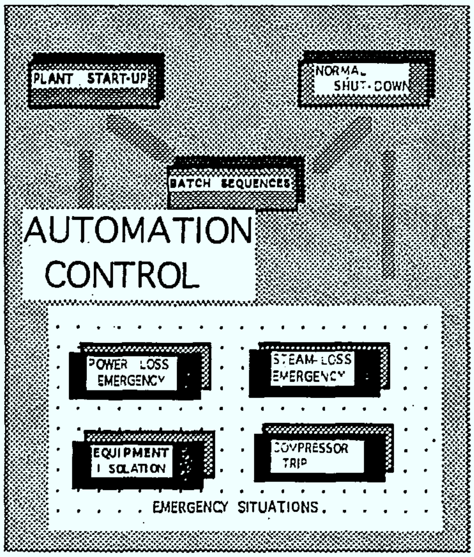
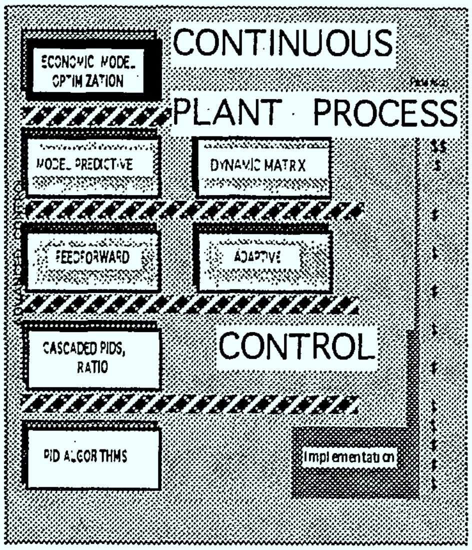
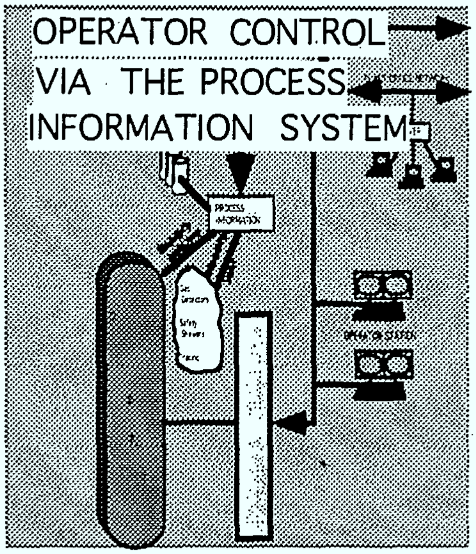
SLIDE 13

HISTORICAL PLANT CONTROL

- Three separate semi-related processes







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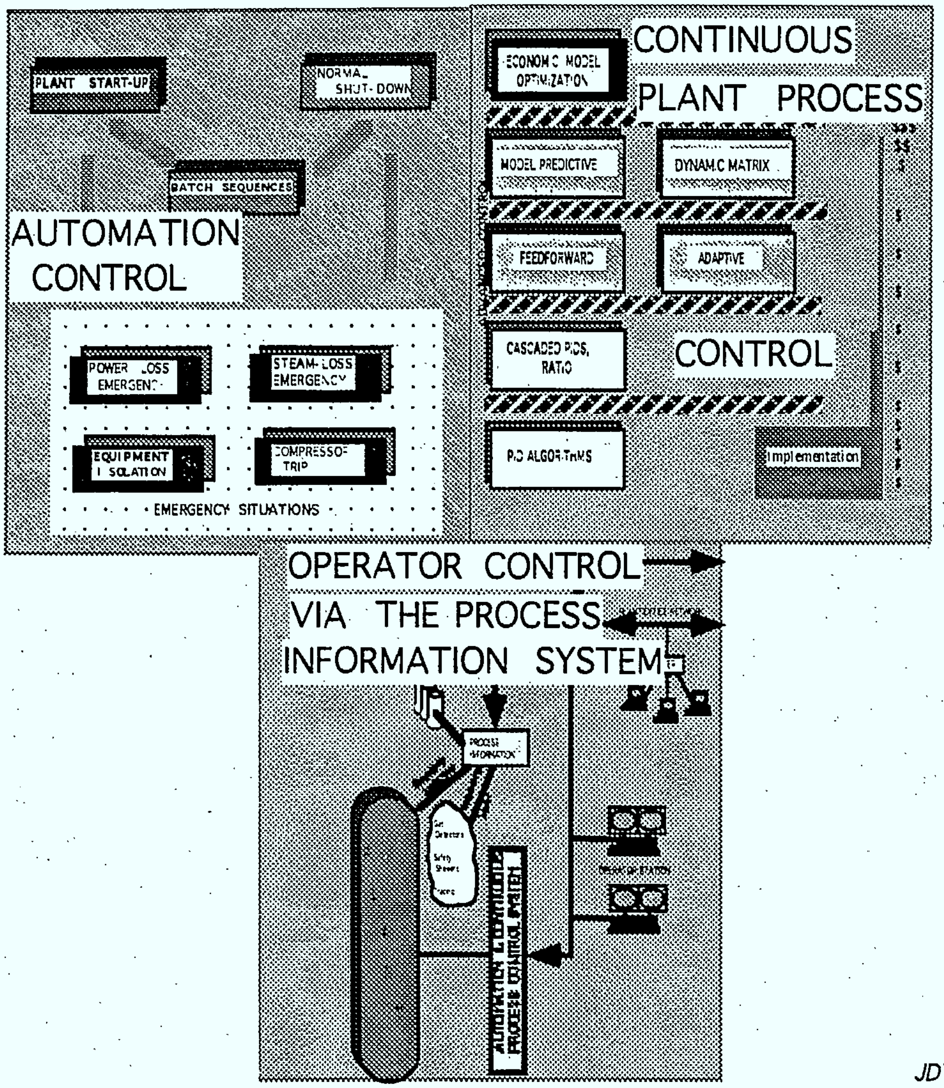
SLIDE 14a

NEW PLANT PROCESS CONTROL

- Automation Control completely integrated with Continuous Plant Control

- Total Process Information of Combined Control

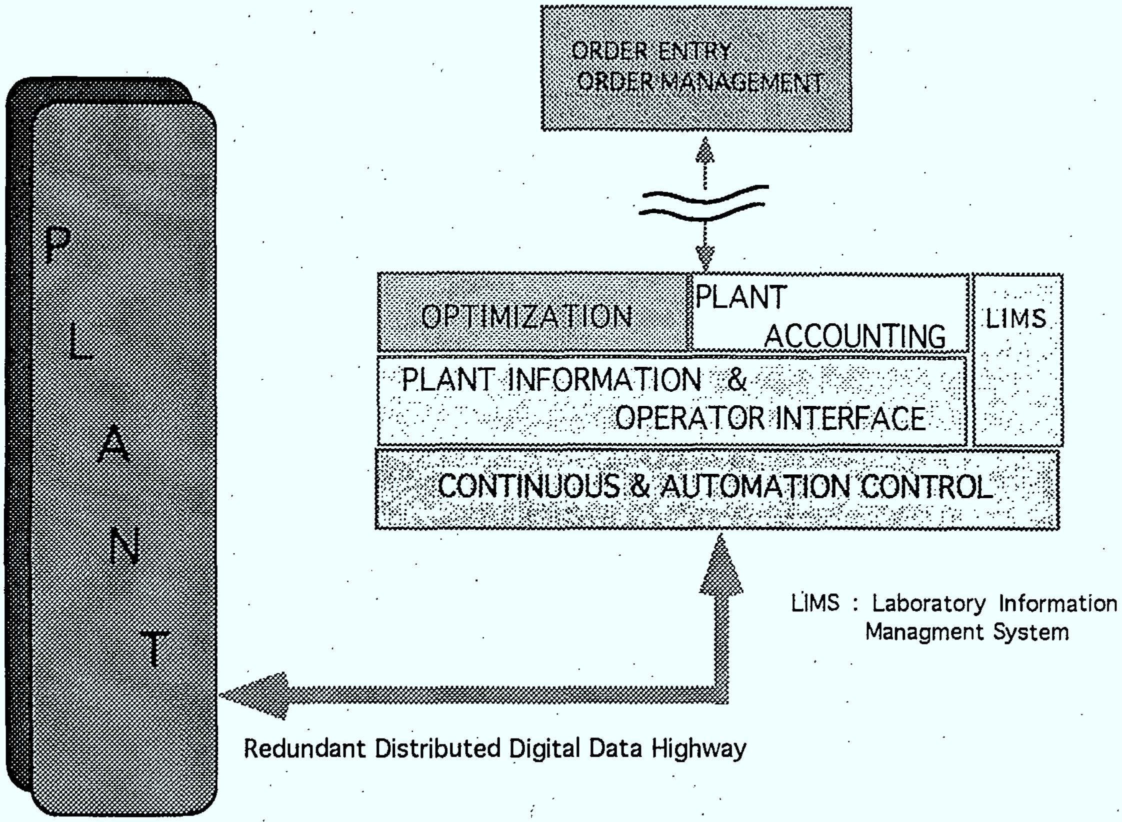


JDY 9205
SLIDE 14b

TECHNOLOGY ARCHITECTURE FOR A NEW PLANT

DEFINES FRAMEWORK FOR ALL SYSTEMS WITHIN MANUFACTURING

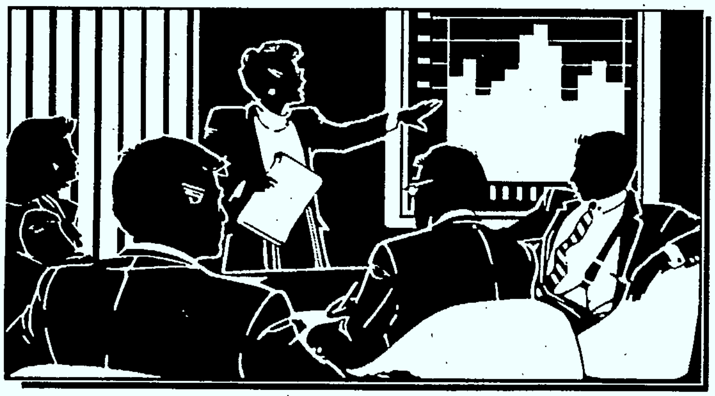
DEFINES FRAMEWORK TO TIE TOGETHER MANUFACTURING WITH OTHER BUSINESS PROCESSES



JDY 9205
SLIDE 15

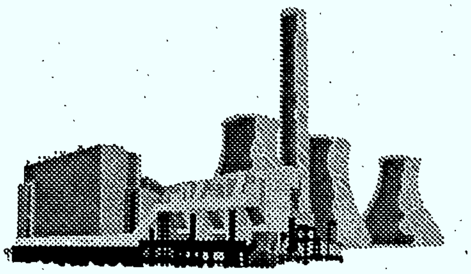
MANAGEMENT PROCESSES MUST CHANGE

MUCH MORE ANALYSIS AND DYNAMIC MODELING OF SYSTEMS , TO ACHIEVE THE BEST CONTROL STATEGEY



-DURING DESIGN
-THROUGHOUT LIFE

STATISTICAL PROCESS CONTROL, STATISTICAL QUALITY CONTROL, STATISTICAL PARAMETER OPTIMIZATION



-DATA-BASED IMPROVEMENTS
-CONTINUOUS IMPROVEMENTS
-THROUGHOUT LIFE

ADOPT A 'TOTAL QUALITY MANAGEMENT' APPROACH

Customer orientation -external and internal

Data-Based Decision Making

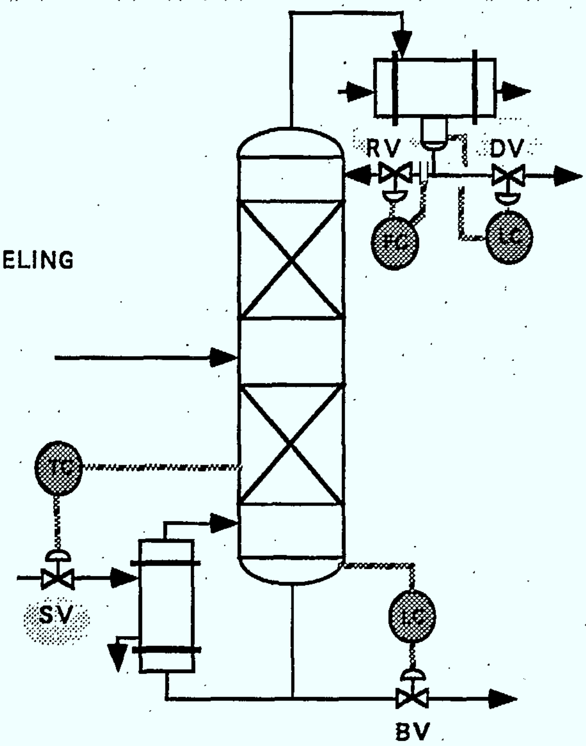
Teamwork crossing all lines

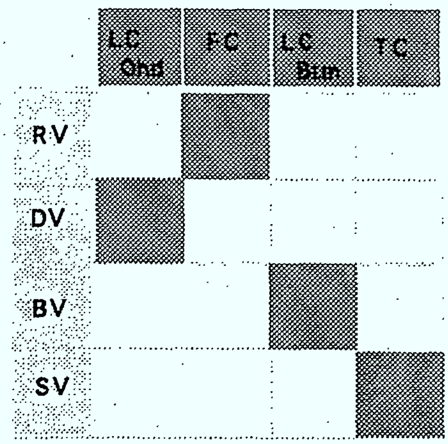
Empowerment of people

JDY9205
SLIDE 16

BETTER SYSTEM ANALYSIS ➡ BETTER CONTROL

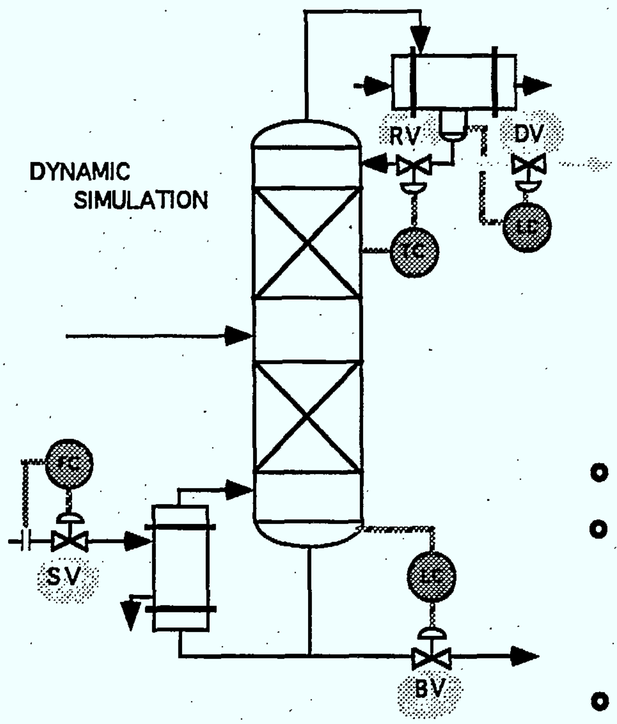
MODELING

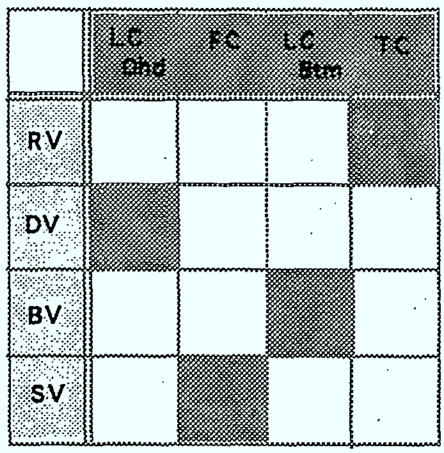




PLANT DATA EVALUATION

DYNAMIC SIMULATION





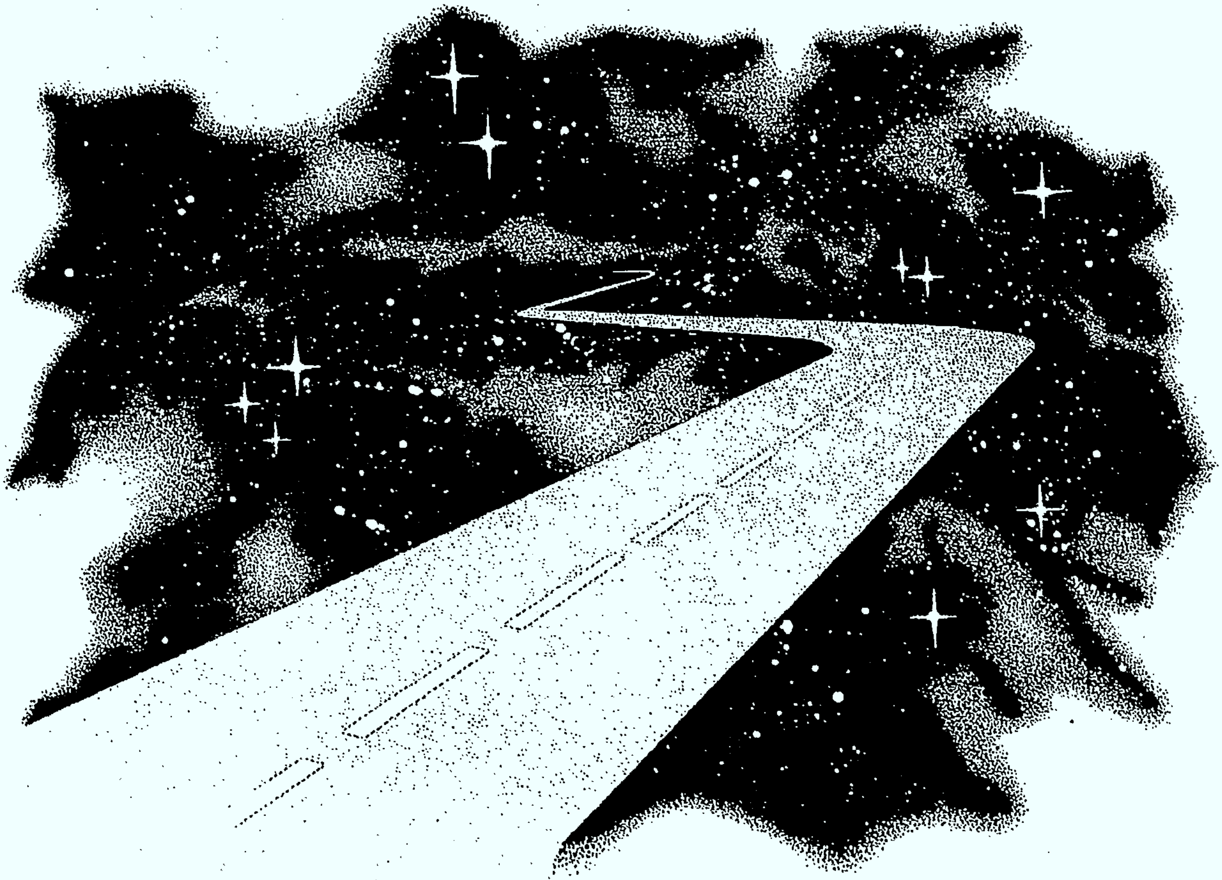
- NO ONE SCHEME COVERS ALL TOWERS
- ANALYSIS MAY LEAD TO BETTER DE-COUPLING OF LOOPS (And better control) BY SIMPLE CHANGES
  - -Different Location of Sensor
  - -Different pairing of valves for loops
- MANY BENEFICIAL CHANGES ARE LOW COST

JDY 9205

THE FUTURE IS A GLOBAL MARKETPLACE

- COMPETITION FROM ALL AROUND THE WORLD

- CUSTOMERS ALL AROUND THE WORLD



CANADIAN MANUFACTURING

CAN COMPETE AND SUCCEED

JDY 9205
SLIDE 18

Process Variability, Control and Competitive Position

W.L. Bialkowski
EnTech Control Engineering Inc.
Toronto, Ontario
Canada

Introduction

This paper is based on the experience gained over the last five years by a Canadian consulting company which specializes in the optimization of process control performance and staff training in the pulp and paper industry. It is the only such company in North America and its services are in demand in both Canada and the U.S. Demand in the U.S. being much greater than that in Canada.

Nearly 100 process variability audit and optimization programs have been carried out. They have linked final product uniformity and process variability to control loop behaviour, thus initiating equipment repair and loop tuning to improve product uniformity. The control engineering training programs provide the process control engineer with the modern concepts of model based control, robustness and variability, all of which need to be understood (e.g., (1)) in order to reduce process variability effectively in a pulp and paper setting. Over 400 engineers have been trained to date. The technicians' program focuses on nonoscillatory, robust tuning methods as a primary foundation for effective process control. About 600 technicians have been trained in North America and off-shore.

Pulp & Paper Mill Process Variability Audit Results

Pulp and paper mills vary significantly and may have between 500 automatic control loops in a small mill and 10,000 in a large mill. Audits have been carried out throughout North America on various unit operations, in various segments of the industry and in both brand new mills with the latest distributed control system (DCS) technology and old mills using pneumatic controllers. Generally the audits have revealed much higher process variability than expected, in virtually all sectors. Audit data is usually based on time series analysis (2). Audit results have been presented previously (3,4,5,6). Some of these results are represented (courtesy of TAPPI) to illustrate the type of problems which appear to exist very widely throughout the industry.

The first example is shown in Figure 1 and illustrates a consistency or fibre slurry concentration control loop which feeds a paper machine and cycles on 'automatic'. It contributes 2.2% to process variability. The cycle is a result of poor loop tuning. Figure 2 shows a fibre saveall tank level on automatic. The reclaimed fibre is recycled to the paper machine and hence destabilizes final product. As in most level controllers, there is a cycle due to poor tuning. Figure 3 shows a bleach plant brightness loop in manual mode. Figure 3a shows the process variable against time while Figure 3b shows the power spectrum. Figure 4 shows the same loop in automatic mode. It is clear that the variability has increased on automatic and that the control loop causes a cycle at about 80 seconds/cycle. These last five figures illustrate the impact of loops which are badly tuned. Figure 5 shows a Thermo-Mechanical Pulp (TMP) stock flow to a paper machine blend chest. The 8 second/cycle oscillation with an amplitude of 12%, is caused by valve positioner overshoot which originates from an excessive positioner gain. Figure 6 shows a ClO_2 flow to a bleach plant chlorine dioxide stage. The square wave like limit cycle is caused by a sticky valve. The last two figures illustrate loops which cycle due to instrument related maintenance problems. This category of problem is of great importance to control performance, since it is maintenance and operating life related. Its impact is generally underestimated.

Figures 7 and 8 illustrate both control strategy and process design problems. Figure 7 shows a paper machine white water chest level cycle with a period of about 14 (820 seconds) minutes/cycle. This cycle destabilized all the consistency dilution control loops which feed off this chest and, as a result, the whole paper machine was destabilized. Figure 8 illustrates the process and control diagram. Root locus stability analysis shows that this control strategy tends to be inherently unstable and is likely to cycle (Figure 9). PI or PID tuning of the level controller cannot easily stabilize this level loop. The solution to this problem required both piping changes and a control strategy redesign.

Process Variability Impact on Product Uniformity

Paper machine audit results have typically found that product uniformity as measured by basis weight (paper mass/unit area) variability is often 3% and higher - some 3 or more times higher than what papermakers have usually believed to be the case based on the averaged data that is usually reported. Figure 10 shows paper machine basis weight variability on automatic control. The data shows the variability as it is typically shown, based on 30 second full sheet scanned averages of the basis weight sensor over 1 hour of operation. The variability is 1%. Most of the variability is faster than the basis weight control loop cut-off period of about 20 minutes/cycle, as is evident from the power spectrum of Figure 10b.

Figure 11 shows instantaneous (as opposed to averaged) basis weight variability over some 4 minutes on the same machine. The variability actually being shipped is 4%. Much of this variability is caused by upstream control loops such as consistencies, headbox total head, dilution header pressure, saveall level, and many others. It is of interest to note that many of these loops are considered by most people to be 'just simple base-regulatory' loops which are thought to require no great sophistication or tuning effort.

A Case Study

A major US daily had informed a paper mill that the product from one of their paper machines was currently rated last on the basis of web breaks per 100 rolls in the pressroom and that they only had one chance left to improve, before their contract was cancelled. This was the paper machine's primary customer. During the resulting audit and optimization program, 10 valves were replaced and 25 loops were tuned. The paper machine rated 3rd in the same pressroom the following month. Its contract was extended and its manufacturing efficiency also rose by over 20% after it was found that the previously established production targets could easily be exceeded.

Control Engineering in the Pulp and Paper Industry

Historical Perspective

Control engineering is the science and discipline of dynamics and control. It is taught at the introductory level in most engineering programs. Unfortunately, traditional undergraduate exposure has, in general, been inadequate to prepare the engineer for practical work in an environment such as pulp and paper. As a result, most people have given up on the theory and have resorted to trial and error. As a consequence, the pulp and paper industry has not recognized the need for people with formal training in control engineering, since, in effect, none have been available. Only recently has this been changing, and then only in a few mills. The process control activity has evolved as the domain of the instrumentation trade throughout most of the industry and control practice has been governed by trade practice. Within the trade, Quarter-Amplitude-Damping (7) is the only formal control tuning method known. Unfortunately, this method deliberately causes loops to cycle and is extremely destabilizing to product uniformity. Hence, for most people, control loop tuning is an 'art' not a science. 'Scientific' or 'mathematical' loop tuning is almost unheard of.

Production Department Performance Expectations

The production departments are the industry 's users of process control systems. They have been conditioned to expect the type of control performance generally available. To illustrate, one paper machine superintendent was heard to say: "I expect my loops to cycle! That way I know that they go both up and down!". However, now that the market pressures are increasingly stressing product uniformity, not just tons of production, leaving process control to tradesman trial-and-error cannot lead to 'excellence in manufacturing'. A fundamental understanding of the critical control engineering issues is now required and each mill must strive to out-perform each competitor at solving its own problems.

Control Engineering Skills - Today

Most engineers completely forget control theory once they graduate, as they quickly learn that in industry this knowledge is seldom used. It is estimated that only 5% actually use automatic control fundamentals in their work. Hence, rather than providing a foundation for practice, automatic control theory has been rejected as 'impractical'. To some extent, the theory available only twenty years ago did not adequately address problems such as those associated with reducing variability in a noisy environment in which the process parameters are constantly changing. This is exactly the pulp and paper situation. Hence the practitioners of the past can be excused for their lack of enthusiasm for control theory.

New Theory, New Hope

There are four major recent developments in control theory that offer substantial new hope for improved manufacturing of uniform pulp and paper products. These include: Lambda tuning; internal model control (IMC); robust control; and minimum variance control. Lambda tuning (8) uses a simple dynamic model of the process and allows the user to specify a desired control loop time constant (called 'Lambda'). The control algorithm "knows" the process dynamics from the model and is able to negate (or invert) the natural process behaviour and force the control loop to behave as desired. The pulp and paper industry has used the method since being introduced in a 1984 (9) training course. The internal model control (IMC) concept (10,11) uses a general dynamic model of the process and, in essence, is a generalization of Lambda tuning. A systematic tuning procedure is produced as a by-product. It is a powerful control engineering concept which offers a structured approach to control algorithm design, selection and tuning.

By today's standards, a control loop is considered robust (10), if it can deliver a minimum level of acceptable performance over the normal working environment of the process . In pulp and paper manufacturing, where the impact of oscillatory loops is so damaging to final product uniformity, combining IMC and robustness concepts has substantially helped in providing consistently stable control. Minimum variance control (12) is a critically important concept in pulp and paper, where uniform product must be manufactured in the face of randomly varying raw materials and chemicals. Hence the real job of a loop is to control out all of the non-random process variability possible leaving only purely random noise. This is the essence of minimum variance control. In practice, minimum variance is a very difficult goal to achieve but an excellent performance yardstick to use.

Minimum Variance Example

As an illustration, Figure 12 shows a stock consistency control loop feeding a paper machine. This loop determines the uniformity of paper stock and thus directly affects final product uniformity. The loop has been Lambda tuned to near minimum variance control. The top left graph shows the consistency against time. The top right graph shows the probability distribution histogram which appears to be near 'normal'. The bottom right graph illustrates the power spectrum, which shows frequency content of the signal. The bottom left graph shows the autocorrelation function. Minimum variance control is achieved when the autocorrelation function lies within the confidence limits for all lags in excess of the process dead time. The process dead time in this case was four seconds, hence the result is essentially minimum variance as the autocorrelation function is seen to vanish inside the confidence limit in about five seconds. This means that feedback control cannot improve on this result and the resulting 2-sigma of 1.3% of consistency signal is the best achievable result - short of making process modifications.

Impact of Training

After training 400 engineers and nearly 600 technicians in modern process control concepts the following comments apply. In a four day course it is possible to train technicians to use robust and effective control tuning rules for flow loops, level controls and consistency controls. In a two week course, it is possible to teach engineers the elements of practical control engineering needed to address modern control loop tuning, dynamics, stability, IMC, robustness, minimum variance and the concepts needed to optimize pulp and paper product uniformity. The combination of training programs and audits has provided the impetus for many pulp and paper companies to embark on mill optimization initiatives, some of which have become major successes. In all cases, these initiatives have involved restructuring of existing organizations and staff assignments to provide for on-going mill optimization tasks.

The Competitive Challenge

The traditional pulp and paper manufacturing paradigm is: "If the hourly tests for fibre are okay, if the fibre blend is okay, if the equipment is working okay, then the paper test at reel turn-up should be okay". The concept of process variability over seconds and minutes is not often connected to product uniformity. The causes of such problems are seldom connected to process control loops and valves. To most people in the mill, control loops are looked after by the Instrument Shop. Loops are tuned only if an operator complains, and he seldom does. They are tuned by 'feel' - loop tuning is an 'art' not a science. It is assumed that once they work, they will work forever. The concept that loops have constantly changing dynamic process behaviour is foreign. The concept that valves wear and stick, is known but mainly ignored until failure occurs.

Variability and control audits shatter these concepts. Product variability is tied to process variability, which in turn is tied back to control loop tuning and control valves. Loops can be tuned using the basis of IMC, robustness and minimum variance concepts to minimize variability. Logic, science and mathematics are involved. This represents a substantial paradigm shift. Unfortunately, mill people seldom have the skills to address these issues, hence training is needed for both technicians and engineers. Few mills have engineers dedicated to process control. Some mills have union jurisdictional issues which may prohibit engineering staff from working directly on control loops. Add to this the fact that process dynamics are constantly changing and that an on-going effort is needed to stay competitive. Most mills have already trimmed their staffing back to the minimum levels possible. Most maintenance staff spend most of their time 'fire-fighting' and feel that they have no time to 'do-it-right'. There usually is no staff available program. To address all of these issues requires a substantial shift in pulp and paper mill management thinking and is a real challenge for most companies.

Audit programs have sparked such organizational change in over a dozen North American mills in the last few years. They have resulted in staff training, management training and various attempts to bring about the necessary organization and staffing to allow on-going optimization. They have met with various degrees of success. Some have been complete failures. Others continue as on-going successes. A common problem is that the effort is limited to a small task force which is usually given an 'even- more- important' priority. In general, U.S. mills have initiated more aggressive programs than those in Canada. As a rule, more staff are involved and the programs are supported by higher levels of management. In one major U.S. paper company, the program is supported by senior corporate management and has resulted in management training programs on process variability, instrumentation training programs on loop tuning, over a dozen engineers trained in control engineering, audit programs being carried out. The corporate objective is to have production management assume direct responsibility for product uniformity, and in so doing, to enshrine the process optimization activity as part of the corporation's on-going continuous improvement culture. This level of commitment has not been matched in any Canadian company.

Conclusion

Pulp and paper mill process variability is often much higher than commonly thought and impacts directly on product uniformity, manufacturing efficiency and competitive position. This is often the result of out of date process control practice at the control loop and valve level. Variability and control audits of North American mills show ample evidence of this. As a rule, mill staff need retraining in modern process control techniques before they are in a position to attempt to optimize process variability. On-going programs have been launched by a number of mills. These require changes to traditional mill staffing and organization in order to be successful on a sustained basis. Canadian mills are being less aggressive than their U.S. counterparts in addressing these issues. As a result of the current economic conditions, Canada's pulp and paper industry is in an excellent position to address the "culture", knowledge and organizational issues and to grow their organizations to take advantage of the gains that are proven to be available through minimizing variability.

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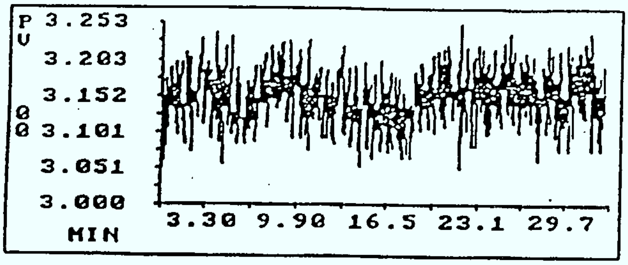

FIGURE 1

MACHINE CHEST CONSISTENCY vs TIME
Mean = 3.15   2-Sigma = 2.2%
Cycle Caused by Consistency Controller Tuning

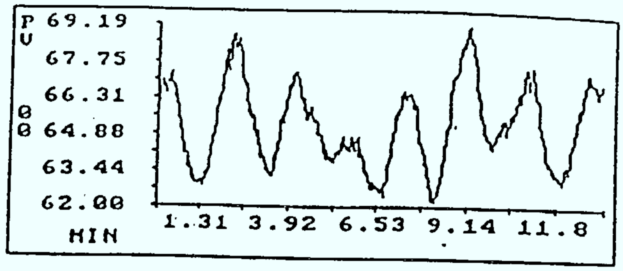

FIGURE 2

SAVEALL TANK LEVEL vs TIME
Mean = 65.27   2-Sigma = 4.9%
Cycle Caused by Level Controller Tuning

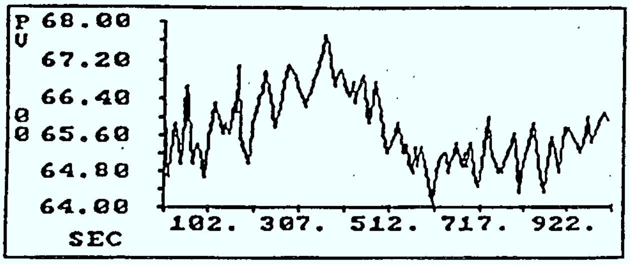

FIGURE 3a   TIME TRACE

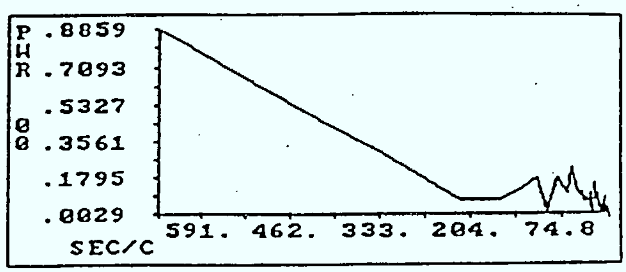

FIGURE 3B   POWER SPECTRUM

CHLORINATION STAGE BRIGHTNESS - ON MANUAL
5 SECOND READINGS
Mean = 65.72   2-Sigma = 1.5

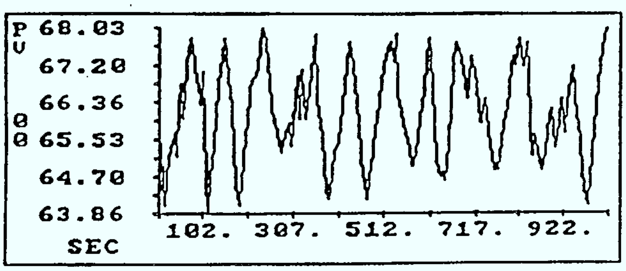

FIGURE 4a   TIME TRACE

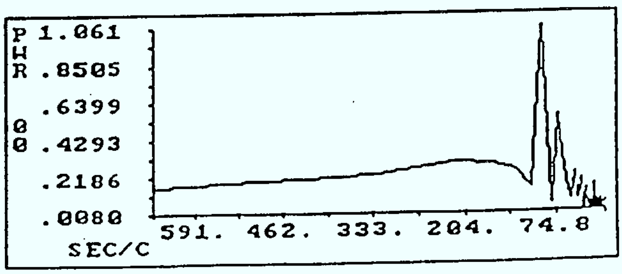

FIGURE 4B   POWER SPECTRUM

CHLORINATION STAGE BRIGHTNESS - ON AUTOMATIC
5 SECOND READINGS
Mean = 66.1   2-Sigma = 2.0
Cycling on Automatic is Caused by Brightness
& Chlorine Flow Controller Tuning

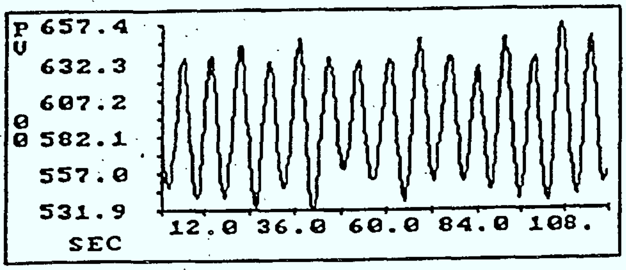

FIGURE 5

TMP STOCK FLOW TO BLEND CHEST vs TIME
Mean = 590   2-Sigma = +/- 11.6%
Cycle is Caused by Valve Positioner Gain Adjustment

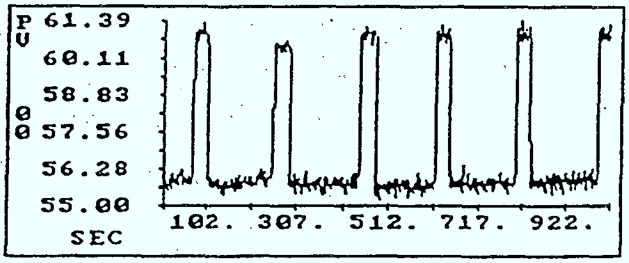

FIGURE 6

CHLORINE DIOXIDE SOLUTION FLOW - ON AUTOMATIC
1 SECOND READINGS
Mean = 56.8   2-Sigma = 4.01 (7.053%)
Cycle is Caused by 5% Stiction in the ClO_2 Valve

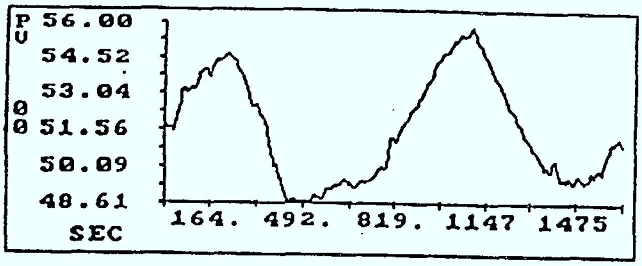

FIGURE 7a TIME TRACE

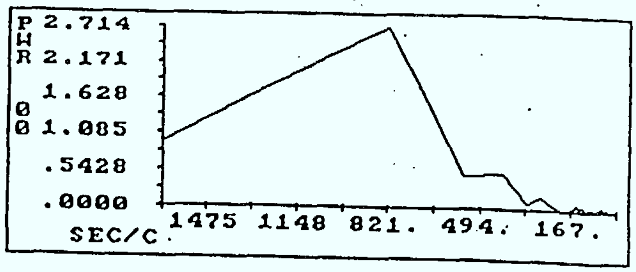

FIGURE 7b POWER SPECTRUM

WHITE WATER CHEST LEVEL VARIABILITY

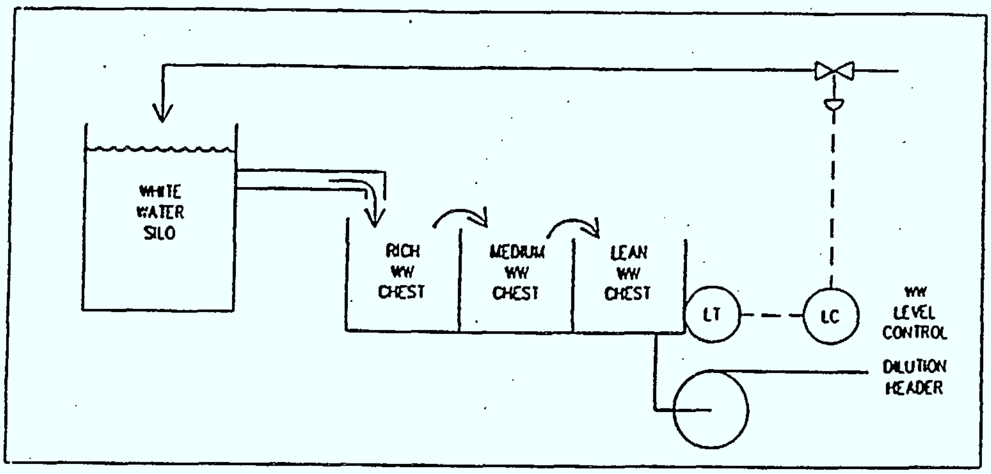

FIGURE 8

WHITE WATER CHEST LEVEL CONTROL

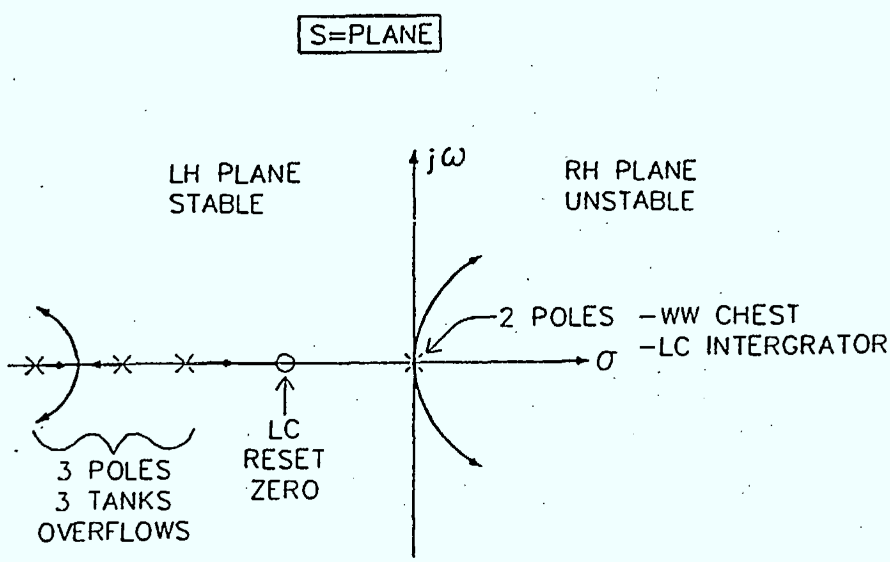

FIGURE 9

WHITE WATER CHEST LEVEL CONTROL ROOT LOCUS SHOWS LEVEL CONTROL TO BE INHERENTLY UNSTABLE FOR ALL PID TUNING SETTINGS

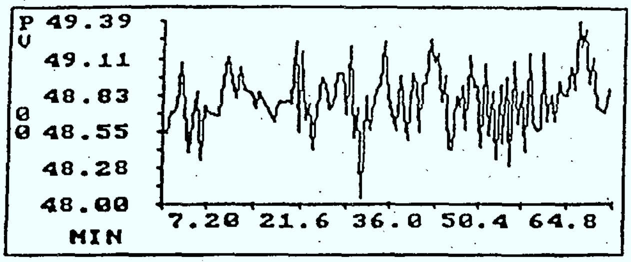

FIGURE 10a BASIS WEIGHT vs TIME

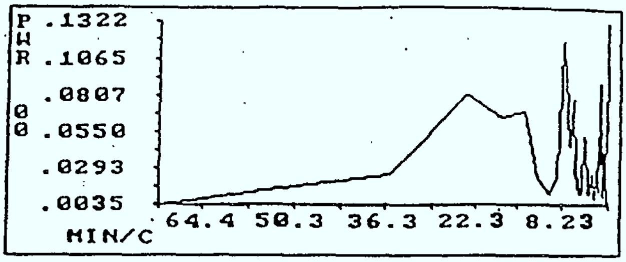

FIGURE 10b POWER SPECTRUM

SCAN AVERAGE BASIS WEIGHT - ON CONTROL
Mean = 48.800 2-Sigma = .475 (.974%)

FIGURE 11a BASIS WEIGHT vs TIME

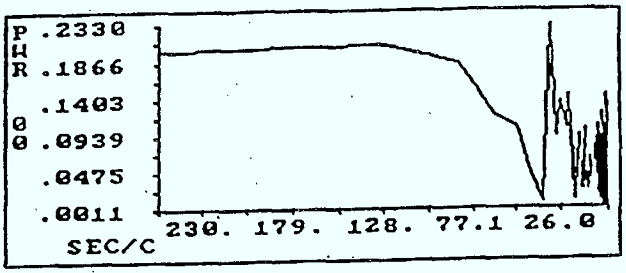

FIGURE 11b POWER SPECTRUM

BASIS WEIGHT VARIABILITY IN FIXED POINT
Mean = 48.900 2-Sigma = 1.907 (3.900%)

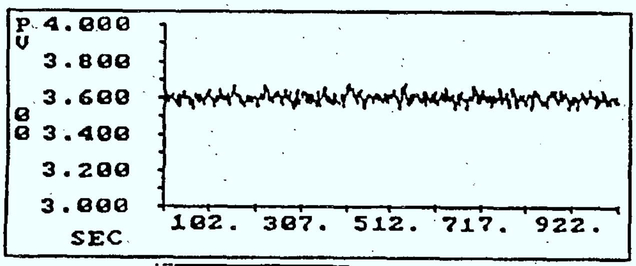

FIGURE 12a TIME TRACE

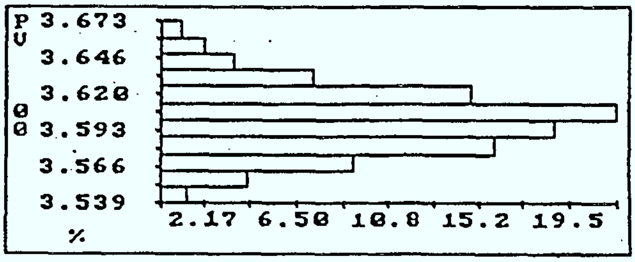

FIGURE 12b HISTOGRAM

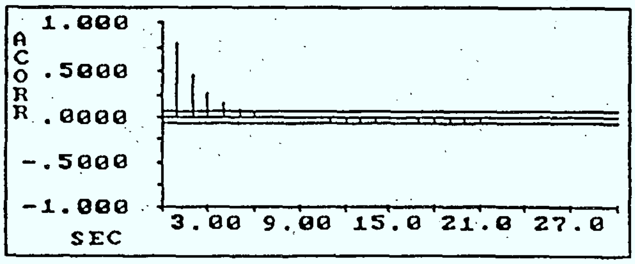

FIGURE 12c AUTOCORRELATION FUNCTION

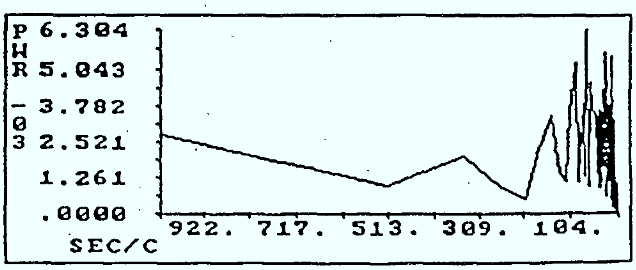

FIGURE 12d POWER SPECTRUM

LAMBDA TUNED TO NEAR MINIMUM VARIANCE CONTROL

* Figures 1 to 12 were originally presented at the 1991 TAPPI/ISA PUPID Process Control Conference, Lake Buena Vista, FL, March 3-7, Copyright TAPPI 1991.

ADVANCED PROCESS CONTROL IN PULP AND PAPER MILLS

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Abstract: This paper discusses three recent projects in advanced process control that led or are leading to commercial applications in the pulp and paper industry, a kamyr digester chip level adaptive controller, a paper machine profile estimation algorithm, and a general-purpose adaptive controller. The ingredients of success in each project are analyzed. These examples highlight the importance of close university-industry collaboration. However, successful applications of advanced control are few and far between. Some of the likely causes are discussed, hopefully leading to a discussion of possible remedies. In particular, I feel that industry should spend more on R&D, put more emphasis on advanced control, and control staffing in mills. A major Canadian weakness is the lack of a strong process control supplier industry. Industry should encourage start-up high-tech companies, as a healthy supplier industry will eventually benefit the pulp and paper industry. Finally, it is important for engineering research in universities to address problems relevant to industry. In this light, I believe that tripartite (University-Supplier-Industry) can play a crucial role.

INTRODUCTION

The pulp and paper industry was one of the pioneers of computer process control, [1,2]. Some of the major breakthroughs in modern control theory were first tested on paper machines, [3–5]. Today, the vast majority of paper machines in the world are computer controlled. Over the years, several surveys have been published on the status of process control in the pulp and paper industry. Some recent surveys have specifically focussed on the application of advanced control, and in particular of adaptive control, [6–8]. Whereas those reviews focus on the technical aspects of the problem, this particular presentation will not. Instead, it will try to analyse why relatively little advanced control is found in an industry that was a pioneer in the early days of computer process control.

Like chemical processing plants, pulp and paper mills are very interactive plants with extensive recycling. They consist of both batch and continuous processes. The nature of these processes is also very varied. The control problem in the pulp and paper industry shares many characteristics of the control problem in the process industries. Because this is an old industry, many pulp and paper mills are old and were designed without much concern about their controllability. Raw materials characteristics vary, especially in the pulping plant and chemical recovery area. A major problem is to produce consistent quality in the face of a highly variable species mix in the feed material. The processes in a pulping plant are poorly known. Despite intense activity in the field, quantitatively accurate kinetic models of delignification are not yet available. Little is known of the mixing and dilution of gas in a fibre suspension, yet it has a direct influence on the bleaching reaction rate. Flow patterns in process vessels are generally poorly modelled. Most processes are non-linear and multivariable. Often, sensors are not available to measure key process variables. Many sensors use inferential measurement, and are affected by factors other than the variable of interest, and so require frequent calibration. In general, more sensors have been developed for the paper mill than for the pulp mill. The applications of computer control systems have centered around the paper machine for which many turnkey control systems and sensors are available. In this paper, I want to briefly present three successful applications of advanced process control I have been involved with. Then, because such is the focus of the conference, I will try to discuss ways of improving the adoption of advanced control in industry.

KAMYR DIGESTER CHIP LEVEL CONTROL

A Kamyr digester is a vertical plug flow continuous reactor in which wood chips are cooked in the presence of a sodium hydroxide solution. Wood chips and cooking liquor are fed to the top, and the pulp is extracted from the bottom. The retention time is a function of the plug velocity and of the column height. The velocity is largely determined by the production rate, thus at constant production rate, a constant chip level is equivalent to a constant residence time. A constant residence time is, with a constant temperature important to maintain the desired degree of delignification. Thus, chip level control is important. Although, it would probably be better controlled from the top, chip level control is often achieved by manipulating the flow of pulp out of the bottom of the digester (known as blow flow). Unmeasured changes in chip size and density, wood species, cooking conditions affect the movement and elasticity of the chip column, and hence the process dynamics. This is the main justification for applying adaptive control to this loop. I have studied this problem on and off for the last 10 years. In 1986, through joint Paprican/McGill work, we successfully implemented a self-tuning controller on an industrial digester in Eastern Canada [9]. More recently, a joint effort between Paprican, UBC and McMillan Bloedel led to a more general and sophisticated scheme [10]. Different versions of this system, including a multivariable version where both the chip meter speed and the blow flow are manipulated, have been tested in several pulp mills in British Columbia, [11,12]. The single-input, single-output version is currently being commercialized by MoDo-Chemetics of Vancouver, in collaboration with Paprican. It is now being installed in several mills in North-America.

An additional benefit of using adaptive control on this loop is that it may provide advance warning of a serious operational problem, chip column hangup. Hangups occur when a portion of the chip column separates and plugs the digester. If not detected at an early stage, recovery measures are costly and very disruptive. However, from first principles we can predict that a hangup will result in a zero process gain. Because the adaptive controller estimates this gain, it has the potential of providing advance warning. Our experience has shown that it can forewarn hours before the problem becomes noticeable to the operator, by which time it is too late to take corrective measures other than shutdown.

PAPER MACHINE PROFILE ESTIMATION

The paper machine is by far the most automated of all pulp and paper processes. Although most functions on paper machines are still controlled using very simple control algorithms, many of those control problems are not trivial. Indeed, control of web processes is a class of process control problem on its own. A range of online sensors installed at the dry end of the paper machine is available to measure critical properties such as basis weight, moisture, thickness, *etc.* The paper machine is by far the best instrumented process in the industry. While the gauges traverse the web in the cross-direction (CD), the sheet moves in the machine direction (MD) at very high speed. For instance, on a 9m wide newsprint sheet moving at 1500 m/min, during a 40s scanning time, 1000 m of paper have passed under the gauge. Thus, the path of the gauge on the sheet is at a very shallow 0.5 degree angle relative to the machine direction. Therefore, the raw profile measurement contains a vary significant machine direction component. The problem is then: is it possible to retrieve the true profile from this raw signal?

In 1988, our laboratory proposed a novel scheme consisting of a least-squares parameter identifier for estimating CD profile deviations and a Kalman filter for estimating MD variations [13]. In 1989, this led to a three-year cooperative project between UBC, Measurex-Devron and Paprican. During the past three years, research has concentrated on the analysis of basis-weight and moisture data. The algorithm has benefitted from major input from the industrial partners in the project. Industrial data provided by Measurex-Devron has proven invaluable. Plant trials arranged by Measurex-Devron at one of their client's sites yielded very promising initial results [14]. A key to the success of this project was the close interaction between the partners, with frequent meetings, and an annual one-day workshop. This project will hopefully lead to a successful commercial application. Research in this area is of commercial importance to the Canadian pulp and paper industry. From our point of view, collaborative research is an important means for encouraging industrial research and development expertise in Canadian companies. Technical expertise in the area of paper machine control has been brought together at the UBC Pulp and Paper Centre, and we are planning to build on this achievement. In addition to personnel, an extensive data base of process measurements taken from a variety of paper machines has been assembled. This combination of research facilities, technical expertise, and industrial collaboration is unique. Moreover, we believe that this project, and the strong ties it has created will help Measurex-Devron to fully play its role as worldwide CD controls centre for Measurex.

A LITTLE LUST

Adaptive control is a complex and slowly maturing field, after more than thirty years of research. When a control engineer wants to develop a control scheme for a particular process, one of the first tasks to be accomplished is the identification of the process dynamics. The second major task is then to design the controller that will achieve the desired control objective. Adaptive control can be thought of as an automation of that design procedure, *i.e.* on-line identification and control design. A major difference is that the entire procedure is performed on-line, in real-time and without human supervision. Because of this, extra care has to be taken when implementing such a scheme. A current research trend is to develop an emulation of the human supervisor using an expert system overlooking both the implementation and the operation of the adaptive controller. Such a system would greatly improve the reliability of current adaptive control schemes. However, a major drawback with current adaptive control methods is that they require prior knowledge of the structure of the plant dynamics, *i.e.* of the order and dead time of the process transfer function. Wrong assumptions may lead to instability, obviously an undesirable feature. Over the last ten years, I have been in search of a better adaptive controller, *i.e.* an adaptive controller that: i) will give the desired performance with the least amount of prior knowledge; ii) will be simple to commission and to use; iii) will survive in an industrial environment, in the absence of a knowledgeable control engineer. The route we have taken is to abandon the usual transfer function model for what we believe is a more flexible structure, a network of Laguerre filters. This is what we call the Laguerre Unstructured Self Tuner (LUST) [15]. Using this approach, the choice of the model order, and of the deadtime become much less critical. We think this approach is particularly appropriate for applications in the process industries, and in particular the pulp and paper industry, as shown during successful mill trials [16].

The "Universal Adaptive Controller"

Recently, two young engineers from Universal Dynamics Ltd., an engineering firm in Vancouver, BC got word of our work on Laguerre-based adaptive control and read through the PhD thesis describing the methodology. Shortly after, the company embarked on the development of a commercial adaptive controller based on this technique. It took 9 man-years of development, and several plant trials to develop a reliable commercial adaptive controller, known as the "Universal Adaptive Controller" (UAC) [17]. The UAC is available as a stand-alone multi-input, single-output adaptive controller. Already several units have been sold and installed. The UAC has also been incorporated into a kiln automation system developed by Universal Dynamics, now running on several lime kilns.

Although it is too early to declare the UAC a commercial success, it can already be considered a technical one. Both the engineers in charge of the development and the management at Universal Dynamics have to be commended for seeing an opportunity, and embarking on a risky project. To put this development in perspective, let me say that to my knowledge, the UAC is only the fourth "general-purpose" stand-alone adaptive controller ever to be marketed, and the first one from North-America.

DISCUSSION

I have limited this paper to work I have been personally invoved with. From my own experience, I can say that it is possible to transfer rather advanced control technology to the mill level. This has to be a cooperative effort between a research group, a supplier and the pulp and paper industry. Despite the relative success I have had in this endeavour, there is in my mind much room for improvement.

Let us start with the receiving end, the industry. For many years, it has been acknowledged by many experts [18] that industrial R&D is paramount to the economic and social future of Canada. Yet, among industrialized countries, Canada has one of the lowest gross expenditures on R&D as a ratio of its GDP. The pulp and paper industry is not exempt from that problem, with R&D at only 0.3% of sales, compared to about 1% in the US and in Sweden [19]. If it were not for Paprican, very little, if any long term research would take place in the industry. As far as process control is concerned, only a couple of companies have a corporate systems and control group. Very few mills have a formally trained control engineer. In many companies, a control engineering position is a dead end as far as the corporate ladder is concerned. Some years ago, a survey revealed that a single Swedish company had as many control engineers as the whole Canadian pulp and paper industry. This may have marginally improved over the years. Today, no mill should be without at least one or two properly trained control engineers. Although advanced control is definitely not going to solve all the problems of the industry, it is an essential ingredient in the economic viability of any plant. It is not always easy to evaluate an investment in advanced control in standard terms, such as ROI. Often, it is has more to do with positioning the company than with a 6-month payback. This however does require a change in mentalities, not only in the pulp and paper industry, but in the process industry in general. Let me give you an example from my personal experience, although not from the pulp and paper industry. In the mid-seventies, I came from France to Canada to do my PhD on adaptive control of TiO_2 rotary kilns. I had contacts with a a producer with production plants both in France and Quebec. When time came to do plant trials, I was obviously expecting to go to the Canadian plant, just 50km from Montreal where I was doing my PhD. Rapidly, it became obvious that the plant management was not receptive to the idea. I ended up having to go to France for two one-month plant trial periods. After graduation, I was hired by the French plant to implement my adaptive controller. This controller resulted in improved quality, and increased production. More importantly, ten years later, it played an important role in allowing the French plant to nearly double its production. Meanwhile, the Quebec plant has drastically curtailed production, and is threatened with closure. I do not mean to say that my adaptive controller could have prevented that, but I think that what I saw in that plant is symptomatic of the management attitude in many Canadian plants.

The process control supplier industry is heavily dominated by a few, large companies based either in the US or in Scandinavia. No longer is there a large Canadian owned process control supplier. Neither is there any significant Canadian presence in the manufacturing of pulp and paper process equipment! Given the size of its pulp and paper industry, Canada should be supplying digesters, paper machines, and paper machine control systems to the world. Instead it ends up buying them from the US, Sweden and Finland. Not only does it represent a sourly missed opportunity, but it also hurts the Canadian pulp and paper industry which ends up being dependent on foreign technology. The Scandinavian pulp and paper industry has been quick to realize the opportunity in developing and supplying equipment to the industry worldwide. A recent article in IEEE Spectrum analyses the transformation of Nokia from a major paper and rubber producer to a key European high-tech player [20]. I do not know of any parallel in Canada. It is difficult and risky for a small firm to develop an innovative product, and try to penetrate a process control market dominated by large suppliers. Process industries tend to favor well established suppliers of control equipment, and generally value service more than technical innovation. SCAP Europa is a Spanish firm that markets an adaptive predictive control system (APCS). It was founded in 1985 by J. Martin-Sanchez, who from 1981 to 1985 was a University Research Fellow at the University of Alberta. During that period, he also held an NSERC stategic grant, that allowed him to further develop his APCS methodology. A native Spanish, he returned to Spain only after he failed to attract Canadian investors to establish his firm right here in Vancouver. Now SCAP employs about 50 people, and is expecting to show its first profit this year. The Canadian pulp and paper industry should encourage start-up companies that want to develop high-tech products such as sensors, control systems of use to the industry, either through the use of venture capital, or simply by making its plants more open to trial of new technology. The pulp and paper industry would benefit from a healthy supplier industry.

Finally, the research community is not exempt from reproach. Not enough research is relevant to the needs of the industry. Control researchers should not advocate advanced control methods just for the sake of technology. Good engineering should always prevail, *i.e.* the simplest technique that satisfies the requirements should be used. Benefits of advanced control should be clearly stated in terms the industry can grasp. This is where I believe tripartite collaborations (University-Supplier-Industry) and programs like the Networks of Centres of Excellence can play a big role. However, research is a long term process, for instance building a successful research group takes years. It is thus important to find mechanisms to ensure stable funding for periods longer than the current 4–5 years.

CONCLUSIONS

In this paper, I have presented three cases of successful transfer of advanced control technology in which I have been directly involved. Hopefully, the reader is now convinced that advanced control has a role to play in an industrial environment, and is more than a toy for academic researchers. In my discussion, I have tried to outline some reasons why those methods are not used more frequently. The industry must realize that more than ever its future depends on its technological wits.

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"TRUCKBASE" Log Transportation Management System Approach

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The computer chip has arrived in the logging industry, and is sure to transform it as so many other industries have been. High resolution colour computer screens will soon become standard equipment alongside the gearshift in the cabs of logging trucks. High tech has come to the woodlands, and it's here to stay... for good reason.

Log transportation costs forest product companies millions of dollars every year. Woodlands operations alone will cost Alberta-Pacific the equivalent of the total operational costs of the woodroom and pulp mill combined. Log transportation is the highest cost phase in woodlands. Clearly, a management system is a requirement for efficient log transportation.

In 1991, Alberta-Pacific Forest Industries Inc., was awarded a Forest Management Agreement to build a 1500 air-dried metric tonne per day pulp mill and the rights to manage a forest area of approximately 61,000 square kilometres in the north eastern corner of Alberta. Alberta-Pacific's Forest Management Agreement covers an area from the Saskatchewan/Alberta border in the east to approximately Slave Lake in the west. The north boundary is approximately 50 kilometres south of Wood Buffalo Park and extends south to the Athabasca/Lac La Biche area.

Harvesting will commence this winter to ensure a fibre supply at the mill site for start-up of the pulp mill in July, 1993. The level of harvest, which is 80% deciduous, will initially be 600,000 M^3. This will increase steadily over an 18 month period to the operating level of 2.5 million M^3 per year. During peak haul season more than 600 loads per day will be hauled to the mill by a truck fleet numbering more than 125 units.

Since 1991 Alberta-Pacific has been working with Silvacom Ltd., an Edmonton forest consulting company, and Vehicle Monitoring Corporation of Vancouver, B.C., to develop a revolutionary truck dispatch, geopositioning, monitoring, optimization and management system for the forest products industry. This system, registered as TRUCKBASE, features:

- Computer aided truck dispatching and traffic control
- Radio data links between trucks, loaders and the mill;
- Truck monitoring, which includes geographic positioning, truck health, payload weights, TM9 data, emergency and other data;
- Central tire inflation; and
- Management information systems for log haul coordination.

TRUCKBASE will monitor and control the entire log traffic of Alberta-Pacific. It includes four software modules: Geopositioning and Computer Aided Dispatch; a Haul Management Module; an Optimization Module and an On-Board Data Collector Module.

Geopositioning and Computer Aided Dispatch (GPS/CAD)

GPS/CAD will monitor and control trucks, loaders and road maintenance traffic at all times. Global positioning through satellite technology will allow the dispatcher to know where its trucks and loaders are at all times. An on-board GPS receiver tied into the on-board computer system will transmit by radio geographic coordinates periodically, at an interval yet to be determined, but probably 15 or 30 minutes.

This information will be displayed at the mill control centre on a computer map of the FMA using a large, high resolution monitor

Haul Management Module

The entire data collection system will be tied together with a sophisticated management information system called the Haul Management Module. This will interface with the mill's accounting and logyard inventory system. It will also be accessed by the individual log haul contractors, as well as by the Alberta Forest Service and Transportation

Optimization Module

Advanced operations research techniques will be used to optimize truck dispatching and traffic control, as well as to reduce any bottlenecks throughout the FMA. A computer model will provide the best routing solutions to the dispatcher. For instance, the optimization model will balance the arrival of trucks at any loader or weigh scale so that wait time is reduced to a minimum. Four trucks per hour scheduled to any loader, and no more than 25 loads per hour returning to the mill, will provide maximum efficiency for both Alberta-Pacific and its contractors. This means reduced dispatch staffing, reduced errors in payment (particularly for back hauling records), interest benefits in "just-in-time" delivery and increased loader efficiency. It will also calculate the best available options should a piece of equipment such as a loader break down.

On-Board Data Collector Module

Alberta-Pacific has received approval from Alberta Forest Service to use the on-board computer to replace the written TM9 form, or bill of lading. The TM9 information will be entered at the truck's computer terminal. Verification of the data would occur before the truck left the loading area, so that any errors can be corrected immediately. The computer, developed by Vehicle Monitor Corporation, will also collect the weight from the truck's on-board scales and the location of the truck from the satellite GPS and transmit the data via radio system to the central dispatch computer.

Conifer sawlogs will be shipped to other mills. In these cases the computer technology will allow contractors and truckers to be paid based on truck scale weights to avoid delays caused by inter-mill invoicing. Similar to most mills in Alberta, speed and vehicle weights will be monitored and recorded by the computer. Reports produced by the on-board computer software would only be generated where speed limits or gross vehicle weights were exceeded. This cuts paperwork and staff time dramatically.

Truck health

Alberta-Pacific will contract all harvesting, hauling and road maintenance. The company believes that the independent, entrepreneurial contractor is more innovative, more efficient, and more cost conscious. All logging will be contracted to either stump to roadside contractors or to phase contractors for feller-bunching, skidding, or delimbing. The log loading equipment is expected to be no more than ten loaders, which will also be owner/operator contracts with Alberta-Pacific. Similarly, the trucks will also be owner/operators contracted directly to Alberta-Pacific. Fleets may develop over time but initially the preference will be for a one truck per owner ratio. The first priority for hiring will be qualified people who live in Alberta-Pacific's woodlands operating area. The desire to hire local trucks identified a need to provide training and ensure a minimum skill level for truck drivers.

Training Programs

A new log haul training program offered by Keyano College at Ft. McMurray is providing training for new drivers. All log truck drivers will require log haul certification and Keyano College will probably provide this service for Alberta-Pacific. Experienced drivers will probably require no more than a couple hours to meet certification requirements. A business awareness course for new contractors, to help them through the bookkeeping and other needs of an efficient business, is part of the training program.

Hauling Configuration

Eighty-eight per cent of the timber hauled will be deciduous, with aspen the primary species. All logs will be hauled in long-log form, to cut down on crane and woodroom handling at the plant site. The Alberta-Pacific woodroom is designed to process logs either butt ahead or top first. This is a recent trend in Alberta which is likely to spread. The design allows the trucker to mix butts ahead and back to achieve maximum distribution of axle weights.

Alberta-Pacific will be contracting seven-axle truck units using tandem-axle jeeps with tandem-axle pole trailers. Truckers are expected to achieve pay loads of 36 to 38 tonnes for summer hauling and 44 to 46 tonnes winter pay loads on highway hauls. Although Alberta-Pacific will be building a significant number of private roads, all trucks must use public roads to get to the mill, therefore all trucks must be highway legal.

Consistent with Alberta-Pacific's pulp mill philosophy of efficient energy consumption and lowest exhaust emissions, all trucks will have computerized engines. This will provide precise metering of fuel and oxygen, to reduce fuel consumption and emissions.

On-board computer

Each truck will be equipped with an on-board computer, a "black box" arrangement mounted out of the way in a rugged case. A display terminal and keyboard will be mounted in the cab. The computer will collect data from the Central Tire Inflation system, on-board scales, the global positioning system, truck health system and radio. It will send and receive data by radio to "home base", either the mill or scale house. The dispatcher will be able, for instance, to warn of an accident ahead or bad road conditions. It will have the capacity to store data until it is either polled by home base, or until it transmits to home on a pre-programmed schedule. Some data such as truck health and incident or event data can be off-loaded with a high speed device such as spread spectrum radio. The technology also gives the driver continuous monitoring of internal engine components.

Truck Owner Reporting and Monitoring System

Alberta-Pacific recommends that each trucker install a home computer with a modem that can access the central dispatch computer and through a password, download all information pertaining to their truck. A revenue cost program similar to the REVHAUL program developed by Forest Engineering Research Institute of Canada would be installed on the operator's home computer. The data from the central dispatch computer would feed directly into this program. This information, as well as costs entered by the trucker, will be used to calculate driver's wages, income tax, W.C.B., G.S.T., actual hourly rate of the truck, truck costs, and profit.

Data from the truck's computerized engine will also be passed onto the owner's computer. Preventive maintenance or "exception" reports would be generated that would indicate problems developing in the truck. For instance, there may be one cylinder overheating -- the computer will give you that message. As well, driver performance can be monitored so the owner to take corrective action for poor driving habits -- such as, improper shifting -- or to identify efficient driving procedures and recommend them to other drivers.

Central Tire Inflation

Another innovation that we are requiring for installation on all trucks is a thirty-year old technology called Central Tire Inflation -- CTI -- developed by the U.S. military for use by rubber tired vehicles in off road or poor road conditions. By varying tire pressures, truck drivers can match vehicle performance to road and load conditions... without getting out of their vehicles and even while the truck is in motion. Some timber sales in the northwest United States have a restrictive clause that trucks must be equipped with central tire inflation to haul logs.

CTI systems use the air brake compressor and pressure tank. All tires -- steering, drive and trailer -- are equipped with rotary air valves and plumbing to deliver air to the tires. Some use external air hoses, while newer systems allow for air delivery through the inside of axle housings. The truck drive selects air pressures based on road, load and speed conditions. An on-board computer doesn't allow the driver to change tire pressures at unsafe or incorrect pressure-speed conditions. Lower pressure results in greater tire deflection and a much larger tire to ground footprint.

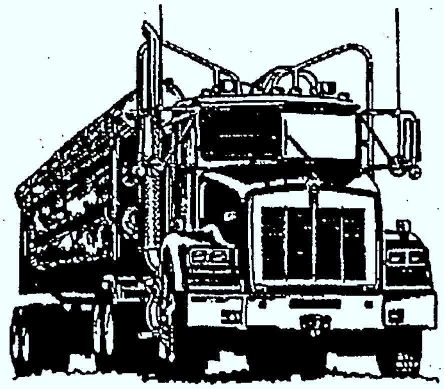
What this means is that trucks can travel through soft or rutted forest roads where they could otherwise not haul, because of the ability to lower tire pressure, thus extending the hauling season. It means that road maintenance can be greatly reduced, mainly through the elimination of "washboarding" and reduction of ravelling on gravel surfaces. Less costly subgrade and surface materials can be used for haul roads, a big benefit with respect to northern Alberta. It also dramatically increases tire life, another benefit for the owner-operator.

CTI also means that truck drivers have fewer back problems from jarring. Obviously when washboard isn't created and the ride is smoother, cycle times -- the time required for a truck to leave the mill and return with a load -- are dramatically reduced.

Summary

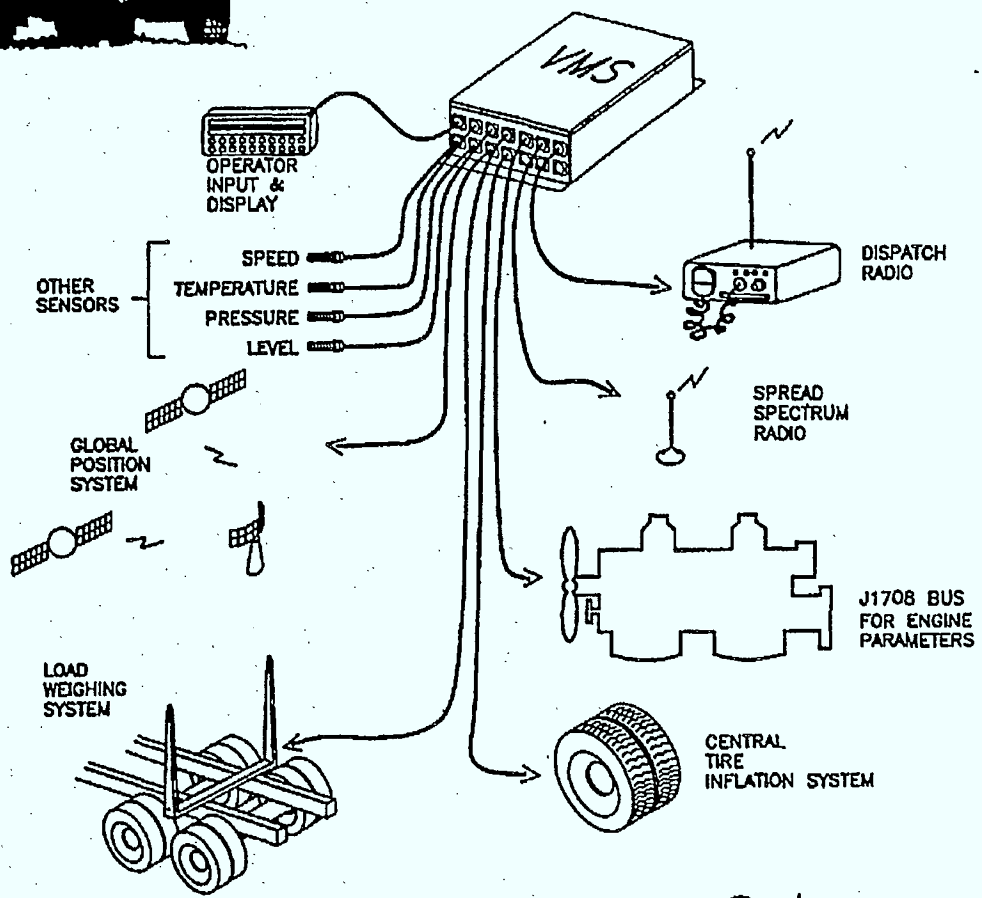
The benefits to a forest products mill of TRUCKBASE and the associated technologies are immense. Direct cost savings to the mill will include reduced road construction and maintenance, reduced direct wood deliver costs, reduced clerical and management costs. Indirect savings will include improved information for management decision making, lower costs for the truck owner-operators, which will translate into lower delivered wood costs.

Potential cost saving benefits to the Alberta government are also immense... in road and bridge maintenance because truck loads and tire pressures will be constantly monitored and adjusted to suit operating conditions. Furthermore, the costs of monitoring and regulating the log haul operations will be substantially reduced, as data will be made available to the Alberta Forest Service and Transportation electronically.

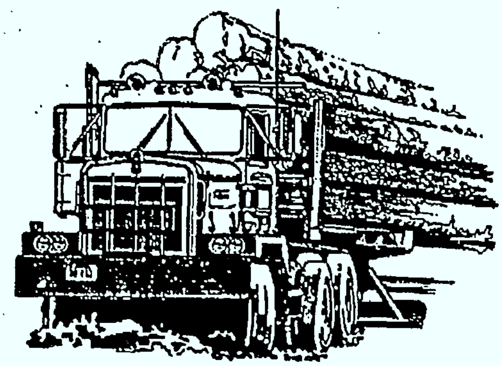


TRUCKBASE configuration

Figure 1: Vehicle Monitor System Components



AL-PAC



Arraytag Technology for Log Tracking

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Introduction

Arraytag technology has been under development at the University of Victoria and at ArrayTech Systems Inc. in Victoria, B.C. for the past three years. The technology consists of low-cost printed tags called arraytags and image processor based arraytag readers to read the tags. The key advantages of arraytag technology over other technologies such as bar-code technology are a large field-of-view and a large reading distance. Prototype systems for lumber and log tracking within MacMillan Bloedel Ltd. are in the final implementation stages. The technology is now being marketed for a wide range of industrial applications.

This paper describes the components and performance of arraytag technology and concludes with a discussion of a log tracking application.

Arraytags

A typical arraytag is shown in Fig. 1. The tag uses a number of black and white printed cells arranged in an octagonal pattern to encode a tag number. The arraytag shown uses 32 cells; 24 for encoding the tag number and 8 for error detection. Arraytags may be read in any orientation and multiple arraytags may be read within a single field-of-view. For log tagging, the arraytags are printed on wet-strength pulpable paper and staples are used to attach the tags to the ends of logs.

Arraytags may be printed in bulk and made available in booklet or roll form or they may be printed on-line with a conventional printer. Human readable numbers as shown in the figure and other information may also be printed on the tags.

Arraytag Readers

Arraytag readers consist of a lens system, a video camera system, a frame grabber interface and an image processing computer as shown in Fig. 2. A simple arraytag reader uses a single fixed focal length lens, a single black and white CCD video camera, a low-cost frame grabber and a microprocessor based image processor. High-resolution and high-speed arraytag readers may use multiple lenses and cameras, a full-featured frame grabber or multiple frame grabbers and a high-performance image processor.

Lenses

The flexibility of arraytag readers is made possible by the wide range of standard off-the-shelf lenses that are available for use with CCD cameras. The lens selection includes microscopic, wide angle, telephoto, manual zoom, computer-controlled zoom, auto iris, and auto focus. The focal length of the lens is the primary determinant of the reading distance and the depth-of-field. Reading distances up to a few hundred feet and depth-of-fields about half the reading distance are feasible. The iris of the lens is an important factor in determining tag lighting requirements. Simple fixed focal length, fixed iris lenses are inexpensive ($200) and well suited to applications with known geometrical and lighting conditions. Computer controlled zoom and focus lenses with auto iris ($1,500) may be used to read arraytags within large viewing volumes under varying lighting conditions.

Video Cameras

Black and white CCD video cameras range in price from $400 to $25,000 depending upon features such as resolution, dynamic range, electronic shutter capability, automatic gain capability and the methods used to acquire and transmit the fields that make up an image.

Arraytags for logging application require about 50 pixels across a tag so that a CCD camera with a resolution of 640 x 480 pixels has a far field-of-view of about 13 tags x 9 tags or about 52" x 36" for 4" arraytags.

Many cameras have electronic shutters with speeds to about 1/10000 sec. that can be used to "freeze" moving objects. Most of the electronic shutter cameras, however, capture only a field at a time so that the effective resolution is only 640 x 240 pixels. Therefore, for fast moving objects the far field-of-view is reduced to about 52" x 18". Interpolation across scan lines can, however, be used to increase the 18" dimension.

The dynamic range of a camera determines the maximum permissible ratio of the intensity of well lit tags to dimly lit tags that can be read within an image. This is important for log bundle arraytag readers that may have some tags in dark shadow and others in bright sunlight.

The auto gain feature of a camera is used to compensate for illumination variations that occur when natural lighting is used.

Frame Grabbers

Off-the-shelf frame grabbers for arraytag applications range from $500 to $4,000 depending upon their features. Inexpensive frame grabbers often grab only 512 x 512 images from a standard RS-170 video signal. More expensive frame grabbers often grab higher resolution images, and can grab images in a variety of formats and provide some image processing capability. More expensive frame grabbers also often use higher-speed memory so that the image processor has faster access to the individual pixels of an image.

Image Processors

Arraytag image processors can vary from a simple personal computer (PC) to a very high performance multi-processor using R1SC (reduced instruction set computer) or DSP (digital signal processor) processors depending upon speed requirements. Portable arraytag readers that read only one tag at a time use battery powered single-board computers with the power of a PC. Arraytag readers for high-speed conveyor systems or high-speed vehicle identification require high-performance image processing.

The approximate performance of several microprocessors used as arraytag readers is given in Fig. 3. The times given in the figure are the approximate times to find and decode a single tag in a typical image using the stated microprocessor in a typical system. The architecture of the system and the speed of the memories can influence the listed figures considerably. The performance of an arraytag image processor can usually be increased by a factor N over a single processor if N processors are used in a multiprocessor configuration. Hence a 3 processor i860 system, for example, can process about 21 typical frames/sec. Frames containing multiple tags and frames with a great deal of background clutter require more processing time.

Log Tracking System

An example log tracking system is shown in Fig. 4. In this example, logs are delivered by truck to a sort yard. The scalers and graders carry out the scaling and grading functions, staple arraytags to the logs and enter the data about individual logs into hand-held computers. At the end of a shift, data in the hand-held computers is downloaded to a database computer system. After the logs have been scaled, graded and tagged, they are sorted into piles for subsequent handling. Logs are taken from the sorted piles by a heel loader or front-end loader to form bundles. The bundles may be assembled within stationary bunks or within truck-mounted bunks. As the bundles are assembled, or possibly after they have been assembled, the arraytags are read so that new information about each log in the bundle can be obtained for downloading to the database system.

Bundles from the sort yard are discharged into the water for barging or sent by truck to a designated mill inventory area. Arraytags may be read from logs when a bundle arrives at the designated mill so that additional information as shown in Fig. 4. may be added to the log database record.

This example log track system uses arraytags to track logs from the sort yard to the sawmill. The database records acquired for each log contain a great deal of information and can be used for quality control, inventory control, billing data, loss control, sawyer data and management data. The details of these applications is beyond the scope of this paper.

For the example tracking system, arraytag numbers are used at four locations to access the database. At the scaling and grading site where tags are applied, a portable arraytag reader may be used, however, human readable numbers on the tags may alternatively be suitable. If sequentially numbers tags are taken sequentially from a booklet or roll of tags, only a small number of tag numbers need to be actually keyed into the hand-held computers to provide the tag numbers for the log records.

At the bundle forming site, tag numbers may be read manually with a portable arraytag reader or automatically with a heel-loader arraytag reader, a front-end loader arraytag reader, a bunk arraytag reader or a bundle arraytag reader.

A heal-loader arraytag reader is an arraytag reader mounted in the cab of the loader and focused on a viewing volume located so that the tagged end of logs can be passed through the viewing volume as the logs are loaded into the bunk. This reader can continually scan for log tags passing through the viewing volume or it can be triggered by the loader operator. A beep signals a successful read. This system is analogous to a grocery store bar-code reader system.

A front-end loader arraytag reader is a stationary mounted reader focused on a viewing volume through which tags pass as logs are loaded into the bunk. Front-end loader readers, like heel-loader readers, must freeze moving tag images and decode tags rapidly so that a feedback beep can be produced in a timely manner.

A bunk arrarytag reader uses an arraytag reader that continually scans a bunk while the bunk is being loaded. Reread tags are only recorded once. Since a bunk reader continually scans the bunk while a bundle is being formed, logs can be placed on top of previously read log tags and the obscured tags will not be missed. A pan-and-tilt mechanism that positions the camera to overlapping frames within the viewing volume is an effective means of covering the large viewing volume that this reader requires.

A bundle arraytag reader is the same as a bunk reader except that only one image of the end of the bundle is processed. Log tags embedded in the middle of a bundle are missed. A bundle arraytag reader, for example, can read all the tags visible from the rear of a bundle on a logging truck.

A portable hand-held arraytag reader, possibly mounted on an extension pole, can be used to manually read all the visible tags in a bundle. Manual operation is time consuming but it may be acceptable as a backup operation in case of failure of a primary automatic reader.

The fourth site shown in Fig. 4 where arraytag readers are used is at the sawmill entrance. Since logs may enter the mill on a conveyor, tag-end first or tag-end last, two cameras are used to automatically capture the images for the tag reader at this site. A photo-cell detector is used to trigger the reading operation.

Conclusions

Arraytag technology is a new automatic identification technology that is well suited to log tracking and many other tracking applications. The technology uses low-cost arraytags and carefully selected video cameras, lenses and microprocessors to provide cost effective log identification.

Two log tracking projects are currently in the prototype stage and several more projects are under discussion. Although the benefits of log tracking are difficult to quantify, the precise information that can now be made available on individual logs opens many exciting possibilities.

Acknowledgments

The author acknowledges the support of the British Columbia Advanced Systems Institute, the Science Council of B.C., the Natural Science and Engineering Research Council of Canada and MacMillan Bloedel Ltd. Peter Baker of ArrayTech Systems Inc. and Brent Sauder and Jan Aune of MacMillan Bloedel Research have been key contributors to this research and development.

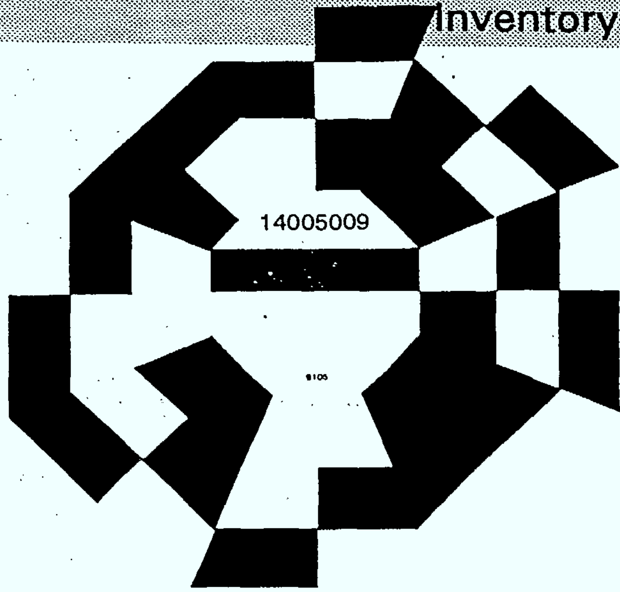

Fig. 1. Arraytag

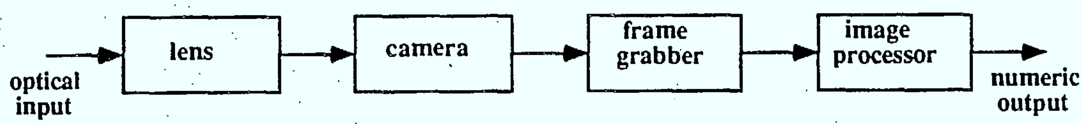

Fig. 2. Arraytag Reader Components

Microprocessor	Approximate Time to Find and Decode a Tag in a Typical Frame
Motorola 68030	4 sec.
Intel 386 DX 33 MHz	3.5 sec.
Intel 486 DX 33 MHz	1.5 sec.
Intel 486 DX 50 MHz	1 sec.
Texas Instrument TMS320C30	.6 sec.
Intel i860	.14 sec.

Fig. 3 Microprocessor Performance as Arraytag Readers

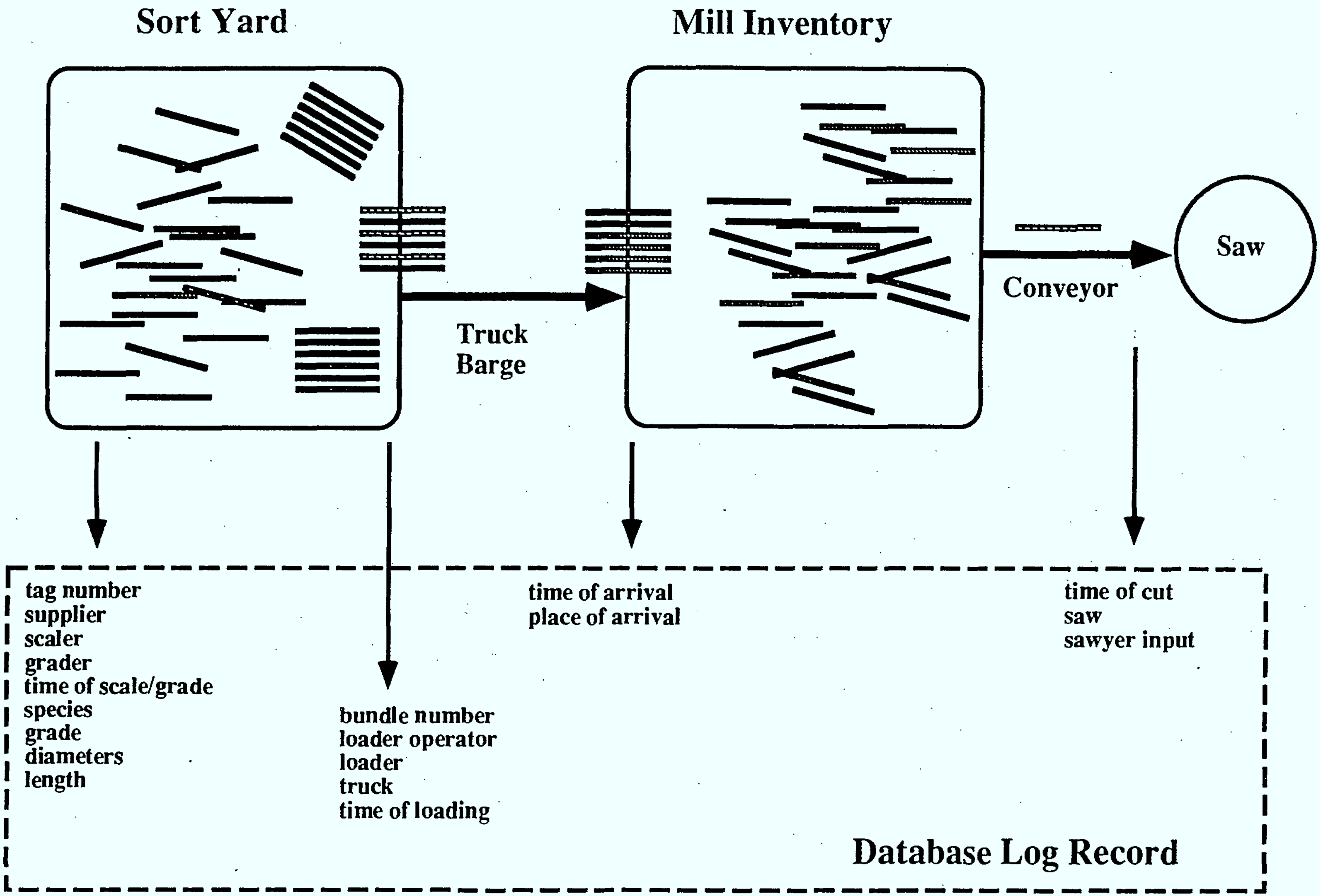

Fig. 4 Log Tracking System

Real time quality control system for automated lumber mills.

Thomas C. Maness
Scott E. Norton

Abstract

This paper describes a methodology for real-time sawmill production monitoring using existing process control equipment. The resulting system ties together various machine centers in a sawmill by using marking and reading techniques similar to bar-coding, and a PC based expert system which would collect information from the machine centers and provide real time advice to supervisors and maintenance personnel. The system would provide both a real time quality control function and monitoring to ensure that the correct production strategy is being followed to match marketing plans.

Background:

British Columbia is the world's leader in the export of softwood lumber, supplying some 40% of world exports. The value of this production can hardly be overemphasized, as nearly 45,000 British Columbians were directly employed in the solid wood manufacturing industry in 1988 (2). Of this production, an increasing amount is made up of high value specialty products which capture specific market niches, the so called value-added approach to manufacturing.

A recent study (1) found that BC manufacturers could capture $1.2 - $1.7 billion dollars in additional revenue by adopting a value-added strategy, with a total possible addition in direct employment of nearly 4,000. Two of the implications of value-added manufacturing reported in this study are that "effective materials management is essential to profitability", and "specialty product manufacture demands much more rigid quality control in production".

Putting these two implications to work in the sawmilling industry is a difficult undertaking. The production of lumber at a sawmill involves a complex sequence of decisions at the various manufacturing stations as a log is processed into component products. These manufacturing stations include log bucking which reduces log stems into shorter logs, primary sawing at the headrig which cuts the bucked logs into rough lumber, and secondary processing which edges, resaws and trims the rough lumber into its final green dimensions. In a modern sawmill, many of these decisions are automated by using computer controlled optimization algorithms working from a set of known or "guessed" final product values. The objective of the mill is to produce a mix of products which maximizes net revenue. Such automated processes definitely aid in the production of custom products to meet specific customer needs.

However, two problems are inherent in this approach. First, the set of product values used in the algorithms are not necessarily the correct set to maximize net revenue. Determining this set of product values is a complex and time consuming problem in itself. Secondly, each manufacturing station typically operates in isolation of those preceding and following it. Optimizing a set of individual manufacturing stations is not the same problem as optimizing the production of the mill as a whole. While various techniques have been employed to address the problem of determining the correct sawing strategy at individual machine centers (4, 5, 6, 8), there have been few attempts at coordinating the various machine centers in a sawmill to work together to achieve a common goal.

Optical scanning techniques and computer aided manufacturing at separate machine centers has helped a great deal in this regard, but there remains much to be achieved by coordinating the separate machine centers into balanced process. A recent study by Maness and Adams (7) found that a 26-36% gain in revenue can be

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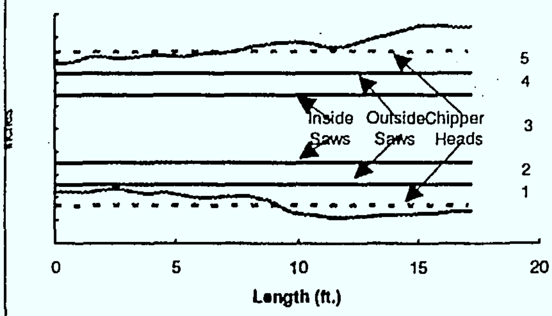

Figure 1. Plan view of log going into QUAD bandmill.

obtained by coordinating the various machine centers in a sawmill which produces only dimension lumber. The opportunity is quite likely to be much higher for a mill engaged in speciality manufacture.

The primary problem in sawmill manufacture is one of quality control. Since each piece entering a given manufacturing station is essentially unique, it is difficult to predict with a degree of certainty the type of products which can be sawn from it. Typically a log is optically scanned at the headrig machine center, and an algorithm is used to determine what final products would be obtained from the log if it were sawn in various configurations. The log is then sawn with the optimal configuration, and the various flitches proceed down the manufacturing line to the edger. The flitches are then scanned, with a similar process occurring to determine the optimal edging process. The problem occurs when the two optimization systems do not agree.

A Practical Example:

Figure 1 shows the plan view of a log going into a QUAD bandmill. In this example, a log is sawn with a 2-2-6-2-2 pattern because the headrig logic believes that four valuable boards could be obtained from the

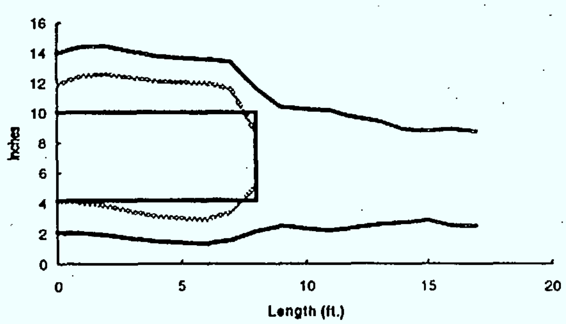

Figure 2. Right Outside Side Board

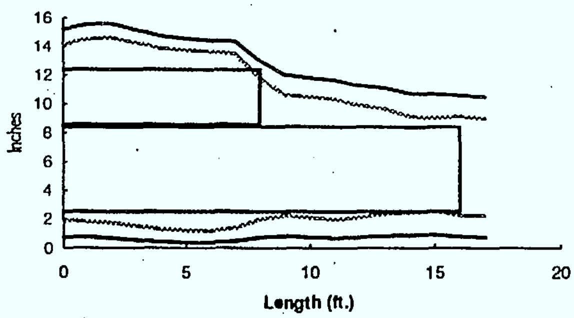

Figure 3. Right Inside Sideboard

removed at the headrig. However, when the side flitches arrive at the edger, the edger is unable to obtain these boards predicted by the headrig system. This situation is shown in the Log Detail Report (table 1) and in the figures showing the actual geometry of the side flitches as seen by the edger (figures 2-5).

The Log Detail Report shows that the headrig logic thought it could obtain one 8' 2x4 from each of the two outside flitches (flitches 1 and 5). However, figures 2 and 3 show that the edger is unable to obtain any board from flitch 5, and the 8' board obtained from flitch 1 has wane present. The headrig should have cut a 2-2-6-2 pattern and changed the offset slightly. The probable result would have been a longer board from flitch 1 with all other boards in the pattern unchanged. The result of this change is potentially more than just an increase in recovery as 16' material is often valued much higher than 8'.

The headrig logic was in error, but because the flitches are lost in the manufacturing process they could never be traced back to the original log. The result is that the mill personnel do not realize that the headrig logic is in error until either their gross recovery falls dramatically or they are unable to meet their customer's orders. By this time it is too late to correct

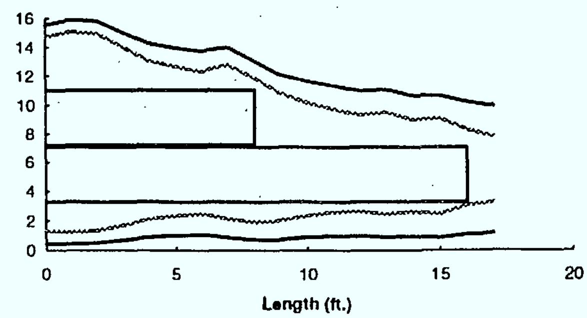

Figure 4. Left Inside Side Board

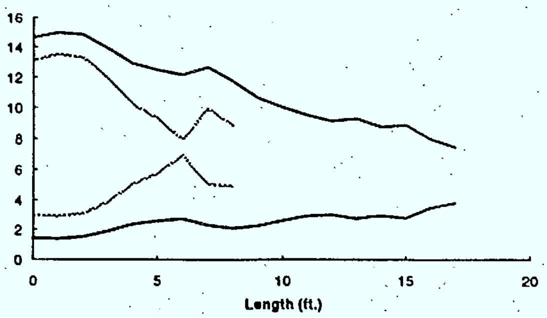

Figure 5. Left Outside Side Board

the original problem, the source of which is still largely unidentified.

A second type of commonly occurring problem is to maintain accurate size control. At present this is done by hand measuring a sample of boards from each machine center at various times during the day. This method is effective, however, most automated mills already have the type of sophisticated scanning equipment present to automate this task. Again, the problem is material flow tracking.

Figures 6 and 7 show quality control charts that can be obtained from an automated system. In this case the example is X-Bar and S charts for flitch 1 coming from the QUAD. The X-Bar chart shown in figure 6 is slightly more complex than a usual chart as it also shows the standard deviation and range for each sample. This embodies much (if not all) of the information in the S chart.

These figures show a commonly occurring situation where the average board thickness is in control meaning that the machine is properly set. However, at various times during the day the thickness variations become extreme, meaning that the lumber generated during these time will exhibit excessive planer skip.

If information is kept on file regarding the operation of the machine center during the time the problem occurred, an expert system can aid in the diagnosis of the problem in several ways. First a database of rules can be maintained which show problems which have been diagnosed in the past and exhibit similar patterns. This is particularly helpful for a maintenance person with limited experience.

Secondly, the system can check the database of machine conditions to determine if conditions which have caused problems in the past were occurring during the time the problem was occurring. If so, the system can recommend where the maintenance personnel should look to resolve the problem.

Once the problem is found the system could call out a step by step procedure to resolve the problem. This would lead the maintenance person to an effective problem resolution as well as provide on the job training.

In the example shown above, the problem was caused by excessive feed speed of the sharp chain. The average feed rate of each log can be kept in the database which would allow a simple diagnosis of this problem by following a rule based system.

Methodology:

In the past, these types of problems have been diagnosed using detailed production studies, where each log that goes through the sawmill is visually

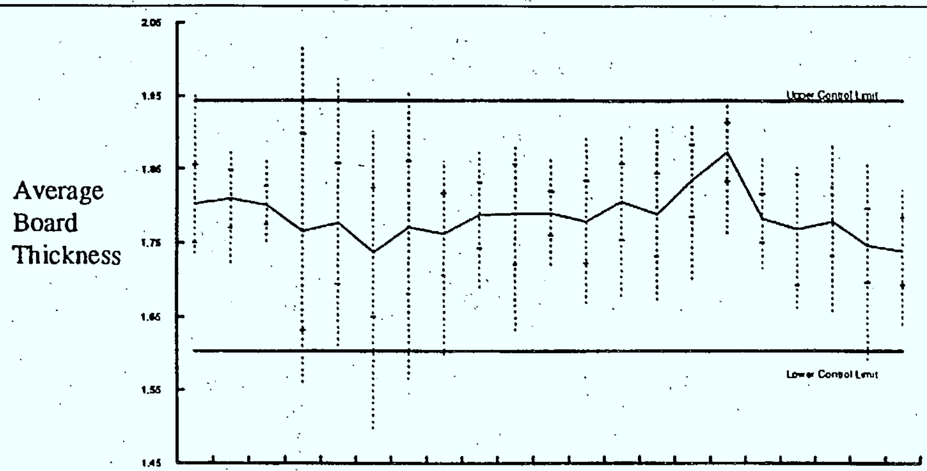

Figure 6. Control Chart for Average Board Thickness and Range.

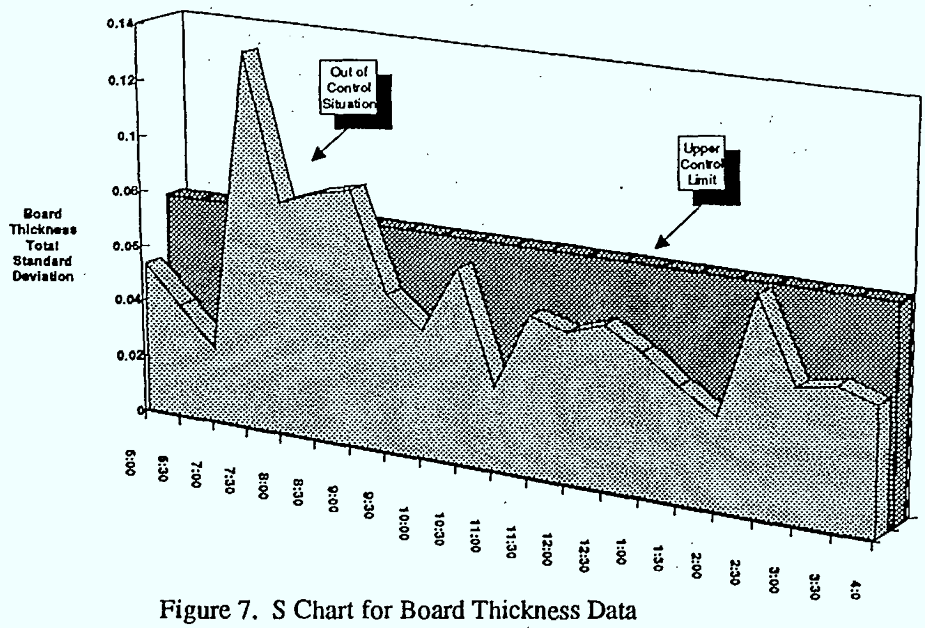

Figure 7. S Chart for Board Thickness Data

traced and the various products are hand tallied at each machine center. These studies are quite expensive to perform, and production at the mill must be slowed down to a crawl to allow tracing the various intermediate products as they pass through a complex series of connecting conveyors. Consequently, studies of this kind are almost never done, and the mill operates with very little information of how the machine centers are working together. Additionally, when these studies are done the desire for minimum disruption in production often leads to inaccuracies and poor experimental design.

A rapidly advancing group of techniques for analyzing the design and management of manufacturing systems have evolved from research in artificial intelligence and expert systems. Expert systems can play a valuable role in a manufacturing environment by providing advice in real time which help diagnose potential problems before a process gets out of control. In a production environment these systems would combine the use of statistical quality control, operations research and artificial intelligence into a cohesive package. Systems have been developed which aid in manufacturing planning and control systems (11) and dynamic scheduling in a manufacturing environment (3). The success of these techniques have not been overlooked by the forest products industry. Recently, Massey et. al. (10) have described the development of an expert system to diagnose problems with a softwood veneer lathe. Mendoza and Gertner (9) describe other potential uses for expert systems to be used in conjunction with operations research models to optimize the overall production environment.

This project is developing a methodology to incorporate these techniques into a sawmill environment. Specifically, we are developing a system which uses the computer aided manufacturing equipment presently installed in modern sawmills to trace the flow of products through the mill and report back when potential problems exist. The types of problems which can be determined using this methodology would include both the diagnosis of a problem from an individual machine center, such as the saws are dull or out of alignment, as well as the much more difficult to obtain diagnosis that separate machine centers are working out of concert as shown in the previous example. The system will be completely automated, that is, all information will be obtained from currently existing computer scanning equipment, with a master controller aggregating this information and providing production reports and real time advice to production supervisors.

This project is for a study period of three years to develop a closed loop monitoring system for a sawmill. Currently, a system is being developed to monitor intermediate products produced from the headrig to the edger. Subsequent years will extend the system to tracing all products produced from the bucking station to the trimmer. The initial prototype system consists of a board marker and reader to be used at the headrig and edger respectively, a PC based computer system to maintain the database and run the expert system, and the software necessary for data collection, reporting, and real time feedback. A cooperating organization will be found to provide a test site to install the equipment with an automated headrig and edging system capable of communicating the necessary information.

Summary:

Effective materials management and quality control are two of the most important concepts in sawmill profitability. At present many sawmills are turning to advanced technology to manage machine processes which used to be handled manually. Witness the expansion into computer scanning and automated setworks in both large and small sawmills. The challenge of the future is to effectively manage this vast array of technology to produce high quality lumber products at the right time, satisfying customers and reducing wastage and inventory carrying costs.

This project will develop real time quality control methods operating in the sawmill environment to determine if automated machine centers are working in concert to produce a desired product output distribution. This combines fields of statistical quality control and artificial intelligence to develop techniques which monitor overall sawmill performance in real time, giving advice to production operators to change operating parameters in such a way that will help meet customer orders, maximize profits and enhance quality in production. Research will fall into the following categories:

- Development of marking and reading techniques to keep track of piece flows through the mill.
- Data collection and processing from different machine centers in the mill.
- Statistical quality control techniques to develop rules for determining what production parameters may be changed to solve various production problems.
- Development of an expert system shell to provide real time advice and quality control charting.

While many research dollars have been spent developing individual sawmill machine centers which work in an optimal fashion, no one has made a concentrated effort to balance these diverse machine centers to work as a system. By developing these types of techniques now, the North American sawmill equipment manufacturing industry gains a head start on the rest of the world in offering this technology.

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Date: 21-Jun-91
Time: 6:31 PM

Log Detail Report

Shift: 1
Species: FIR

Log Nbr: 501
Set: 2-2-6-2-2
Offset: 0.40
Time: 9:27

Length: 17.5
SED: 11.6
LED: 16.0
Volume: 17.65

Flitch	Predicted Recovery				Actual Recovery				Machine Center	Time
	Nbr	Dim	Length	Volume	Nbr	Dim	Length	Volume		
1	1	2X6	8'	8.00	1	2X6	8'	8.00	SAAB	11:01
2	1	2X6	16'	16.00	1	2X6	16'	16.00	SAAB	11:02
	1	2X4	8'	5.33	1	2X4	8'	5.33		
3	5	2X6	16'	80.00	5	2X6	16'	80.00	GANG	9:42
	1	2X6	8'	8.00	1	2X6	8'	8.00	GANG	9:42
	1	2X4	8'	5.33	1	2X4	8'	5.33	SAAB	11:36
4	1	2X6	16'	16.00	1	2X4	16'	10.66	SAAB	10:59
	1	2X4	8'	5.33	1	2X4	8'	5.33		
5	1	2X4	8'	5.33					SAAB	10:59
	MBF/CCF	0.846	Value	$33.79	MBF/CCF	0.786	Value	$30.85		

Table 1. Log Detail Report

Date: 20-Jun-91
Time: 3:28 PM

Shift Summary Report

Quad Performance

Shift: 1
Species: FIR

Nbr Logs	765	**Avg Length:**	16.7 feet
Elasped Time:	4.15 Hours	**Average SED:**	13.1 in.
Nbr Logs/Hour:	184	**Average LED:**	15.2 in.
Cut/Hour:	26.56 MBF	**Average Volume:**	18.27 CF
Downtime:	0.62 Hours	**Total Volume:**	139.77 CCF

Flitch	Size	Count	Predicted		Actual		Sawing Accuracy				Wedge Defects
			Volume	Value	Volume	Value	Average	St	Sw	Sb	
1	2"	425	4.39	$856	3.78	$737	1.778	0.055	0.042	0.036	26
	4"										
2	2"	732	15.49	$2,788	14.5	$2,610	1.751	0.029	0.016	0.024	2
	4"										
3	4"	285	14.72	$2,723	14.5	$2,683	3.801	0.035	0.014	0.032	0
	6"	126	10.08	$1,814	9.9	$1,782	5.812	0.039	0.016	0.036	1
	8"	219	23.36	$4,322	22.78	$4,214	7.779	0.037	0.016	0.033	1
	10"	135	28.8	$7,200	26.19	$6,548	9.670	0.039	0.015	0.036	4
4	2"	760	16.21	$2,918	15.01	$2,702	1.752	0.028	0.016	0.023	1
	4"										
5	2"	399	4.12	$742	3.55	$639	1.781	0.055	0.040	0.038	22
	4"										
			117.17	$23,363	110.21	$21,914					57

Table 2. Summary Report

Operational Decision Support for a Pulp Mill

Ted Stedman
Sierra Systems Consultants Inc.
Vancouver, B.C.

Introduction

This paper is based on work done over the last nine months on automated operational decision support systems for kraft pulp mills. The project participants were Sierra Systems Consultants Inc., Pulp and Paper Research Institute of Canada (PAPRICA-N), and two kraft pulp mills in the interior of B.C.

This project addressed mill operational information from an Information Engineering perspective rather than the traditional approach from the process side. In the first phase of the project, the team interviewed a large cross section of people from both participating mills to identify information needs, the types of decisions that were made, and priorities. Models were then developed representing information flows, data, the process, and the relationships between them. Next, a technical design was done which defined the target system. The prototype, scheduled for completion in June 1992, is being developed based on the target system. The prototype will demonstrate the concepts contained in the requirements document and the technical design. The final phase of the project will be the development of a business case for implementing a system of this type. The business case will provide a framework for estimating costs, benefits, necessary prerequisites, and the expected impact on the mill and the employees.

What is operational decision support?

Decision support provides tools and techniques to help managers and supervisors make better decisions. Operational decision support applies these tools and techniques to mill managers, supervisors and operators who make day to day decisions (e.g., production rate, chemical usage, and alternate operating strategies) regarding the running of the mill. Operational decision support has a short term perspective but provides data that can be used over the long term to make decisions that will improve the operation. Statistical Process Control (SPC) is an example of an operational decision support tool.

In the past, it has proven difficult to implement millwide information systems due to confusion over what constitutes a millwide system and difficulty justifying the expense of a full millwide system. A millwide system ties together all of the information and computerized systems, including business, process, and operational, within a mill to provide an overall integrated system. Operational decision support differs from a millwide system as it does not require all of the information and computerized systems to be tied together for implementation. However, a decision support system can provide a further step towards millwide. Operational decision support addresses this by providing an intermediate stage that can be reached at a lower cost and in less time, thus allowing mills to examine the costs, implications, and benefits of millwide without committing to a full system. Ultimately the integration and data sharing provided by the decision support system will form part of the millwide system. Millwide can be implemented through an evolutionary approach.

Current situation

Currently two types of information and systems are used in the mills. Process data is generally real-time and is used to control items such as flow-rates and levels. Business data, such as costs, orders, and production, are used to manage the operation. Business systems provide information, typically one week to two months old by the time it is received, that is usually available too late for operational decisions. As a result, it is used either as a score card (how did we do) or for making strategic or medium term decisions. It is not generally used for short term decisions as the need has passed by the time the information is available.

Finally, because of the different frequency of collection, timing of presentation, and sources of data, it is difficult to combine the business and process data in a way that provides useful decision support information.

Where will the data come from?

Data for operational decision support systems will come from the Distributed Control Systems (DCS), the business information systems, and manual procedures. DCS will provide flow rates, levels, production, and quality information. Business systems will provide unit costs, orders, personnel and equipment information. Both of these sources will be supplemented by manual data (test results for example) and external data (remote air quality stations for example).

Diagram 1 shows how an operational decision support system fits into the data gathering systems already in place in a mill. Selected DCS data is transferred to the operational decision support system at regular intervals, although not necessarily at the same rate as the DCS acquires the data from the process. The decision support system will maintain the data for longer periods than is usual with a DCS, and as a result, will require its own database. The decision support system will automatically summarize or archive the data allowing summarized data to be stored for long time periods.

Business systems data is either accessed on request or transferred on a regular basis. The decision on whether to transfer or access the data is based on required data, access frequency, and retention. Some data, such as unit costs, must be transferred to the decision support system since it becomes an integral part of the operational decision support database. Other data, such as detailed customer information, may only be required periodically and could be maintained in the business system.

Mills may have access to external data, for example remote water or air quality stations. These external sources can frequently be accessed through a modem and the data can be transferred to the decision support system and become part of the decision support database.

The final source of data is manual entry of data from the mill where no automated links are currently available. For example, test results may be entered manually so that they can be used in quality and trend analysis or operators may enter causes of incidents that occur allowing the system to correlate these to other information.

The decision support system would then provide managers, supervisors, operators, and engineering access to all of this data through a single view for analysis and reporting.

What areas would use an Operational Decision Support system?

As Diagram 1 illustrates, a decision support system would be used in most areas of the mill. Mill management would use the system to quickly determine the current status (operating rates, costs, quality, environmental issues) and use this information in setting priorities.

Supervisors would use the system to review the current situation, watch for and respond to trends, and to plan operating strategies. "What if" capabilities allow supervisors to review scenarios and the likely impact before selecting a course of action.

Operators use the system to evaluate the effectiveness of their decisions. Information on quality, cost, and environment allows the operators to focus on the key areas of concern for the mill.

Finally, technical areas use the database for a variety of analyses to identify problem areas, track the impact of changes, determine the root causes for problems, and project the impact of proposed changes.

What would Operational Decision Support be used for?

The main areas of concern in a pulp mill are production, cost, quality, and the environment. Operational decision support will address all of these areas by providing information on the process, relative costs, trends, and impacts.

As shown in Diagram 2, decision support performs three main types of analysis to aid in the decision making process. Historical analysis is used to help the mill understand what has happened, and to meet quality and environmental reporting standards. This portion of the system will primarily consist of graphs and diagrams showing trends, and specific information in response to specific queries. For example, the historical component would be used to answer customer queries on the quality of a shipment. This would include not only the grade and quality test results, but also information on the process while the pulp was being produced and environmental information. Historical analysis would also allow ad hoc queries on the database.

The current information component would contain tailorable displays of key indicators for individual managers and operators to determine how the mill was operating. Each user or area would be able to identify their own key indicators allowing the system to be customized not only for the mill, but also for the users. This information would identify operating rates, costs by area, performance to environmental standards, and quality. The combination of the current information and historical trends allows the mill to identify and respond to potential problems quickly. Current information analysis can also include SPC and Statistical Quality Control (SQC) functions, many of which can be automated based on the data already entered into the system.

The predictive portion of the system will forecast future outcomes based on the current situation and any planned changes to the operation. This will allow mills to perform "what if" analysis on costs, quality, environment, and production before deciding what actions to take. This form of analysis can be used both for short term decisions on operating strategies, and for longer term decisions on process and equipment changes. The predictions can be based on either an explicit model of the process, or an implicit model created from historical data. Operational decision support will provide the ability to predict the impact of changes in the process on cost, quality, environmental emissions, and production. This will allow operators to explore several scenarios and select the one with the greatest likelihood of success.

One of the key aspects of a decision support system is the ability to process large amounts of related information. For example, cost will not be treated in isolation. The system will also show the impact on quality of any proposed changes being used to reduce costs.

Potential components

Over the next few years, many technologies and concepts will be combined to form decision support systems. Some of the key areas to watch are described in the following sections.

1. Expert Systems

When combined with the large amount of data available in a decision support system, expert systems will be able to assist mill managers and operators by making quick recommendations based on large amounts of information.

2. SPC and SQC

Statistical techniques are a natural component of a decision support system. Most of the information required for these techniques will reside on the decision support system allowing automatic updates and detection of problems.

3. Improved Communications

Improved communications between DCS, business systems, and other standalone devices will simplify decision support system implementation.

4. Standard User Interfaces

Improvements in standard interfaces will allow decision support, DCS, and business systems to operate on the same workstation and have a consistent look and feel. This advance will improve the acceptance of new systems and reduce training and implementation difficulties. Ultimately, the user will not be concerned with which one of the several systems is providing the required information, but will instead focus on using the information to do the job at hand.

5. Open Systems

Computer vendors are moving towards systems that provide open architectures for software development and communications. This makes it much easier to tie applications running on different computers together into a consistent system for the users. UNIX is the best known example of an open system.

Proof of concept prototype

A prototype system is being developed as part of the project mentioned earlier to prove the concepts developed in the study. The prototype currently includes the following components:

- standard user interfaces;
- real-time reporting of process and business information;
- trends;
- tracking product through the process and reporting on conditions at each point in the production process;
- current unit costs by area of the mill;
- lost time reporting.

The technical architecture of the prototype is based on the information flow model, the data model, and the process model. Using an object oriented approach based on the concept of process areas and process elements, an integrated decision support database has been developed.

The prototype takes advantage of state of the art tools using a relational database, fourth generation development language, windows, and statistics package all running on workstations under UNIX.

Benefits of decision support

The benefits from an operational decision support system as envisioned in the project will be examined and clarified in the last phase of the project. Generally decision support systems, through better information and analysis, provide the following benefits.

- Reduce costs through faster response to problems.
- Reduce costs by providing current cost information.
- Improve environmental compliance by tracking conformance to regulations and predicting problems before they occur.
- Use "what if" to evaluate a number of options before making actual changes.
- Meet more stringent quality reporting requirements with automated access to the quality information.
- Reduce the paperwork required to comply with ISO 9000 standards.
- Provide faster response to customer questions.
- Provide customers with more detailed product information.
- Improve quality by detecting problems early and adjusting the process to correct the problem.

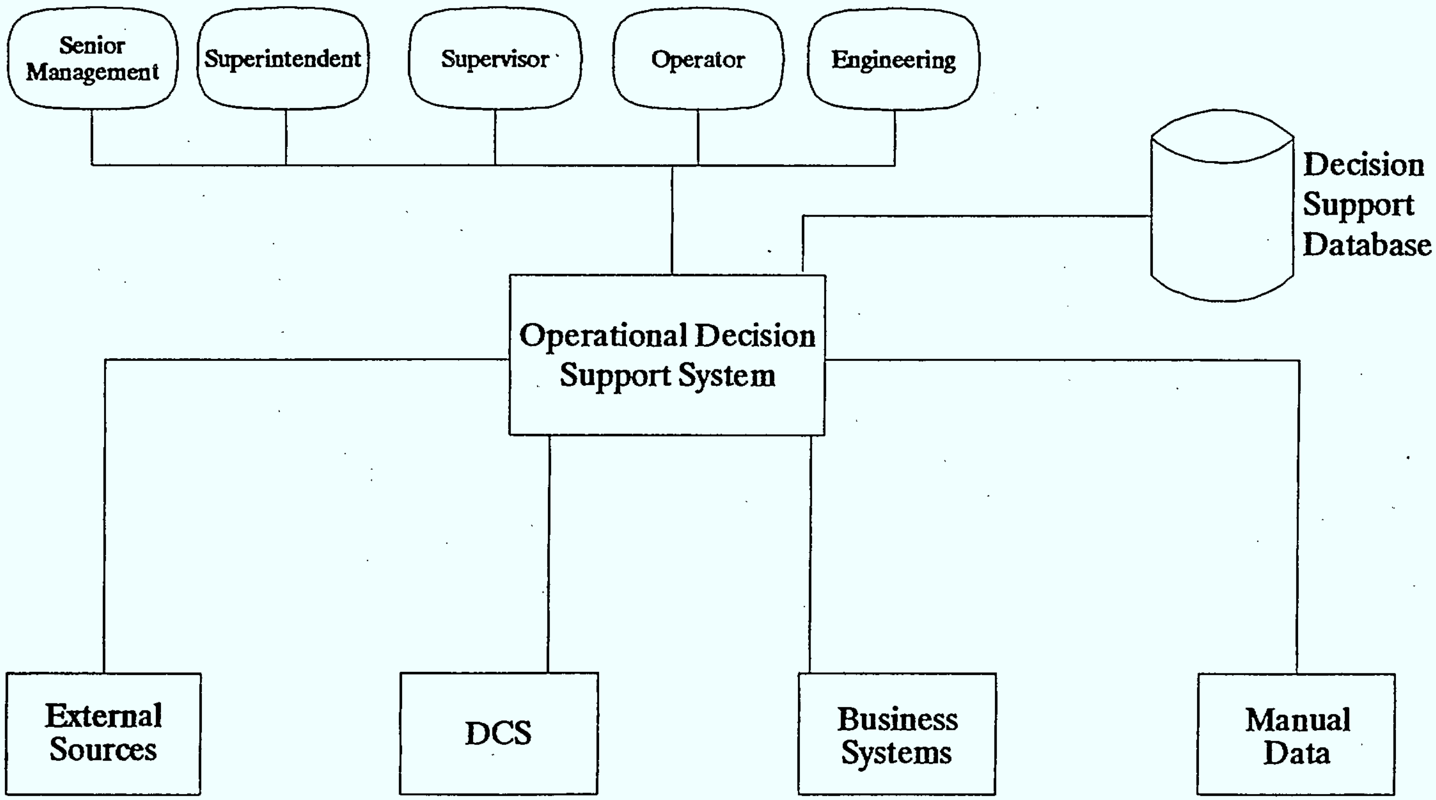
Major lessons from the project

Both the requirements portion of the project and the development of the prototype taught several lessons. The main point was the importance of the human interfaces. Everyone wants an easy to use interface. When asked to explain what was meant by easy to use, we found that people wanted to access their application in as few steps as possible and to have consistent applications with standard usage and operations. Finally, ease of use means seeing only the information important to them. The prototype we developed uses windows and a consistent visual interface that focuses on the operation to address these concerns.

The second lesson was that although a great deal of information is already collected in the mill, much of it is not easily available throughout the mill. Frequently trips around the mill are required to collect the needed information. The sources of much of this data changes over time, for example, as new process sensors are added to the mill. As a result, our prototype is designed to provide access to DCS data, business data, and manually entered data and to easily add new data sources.

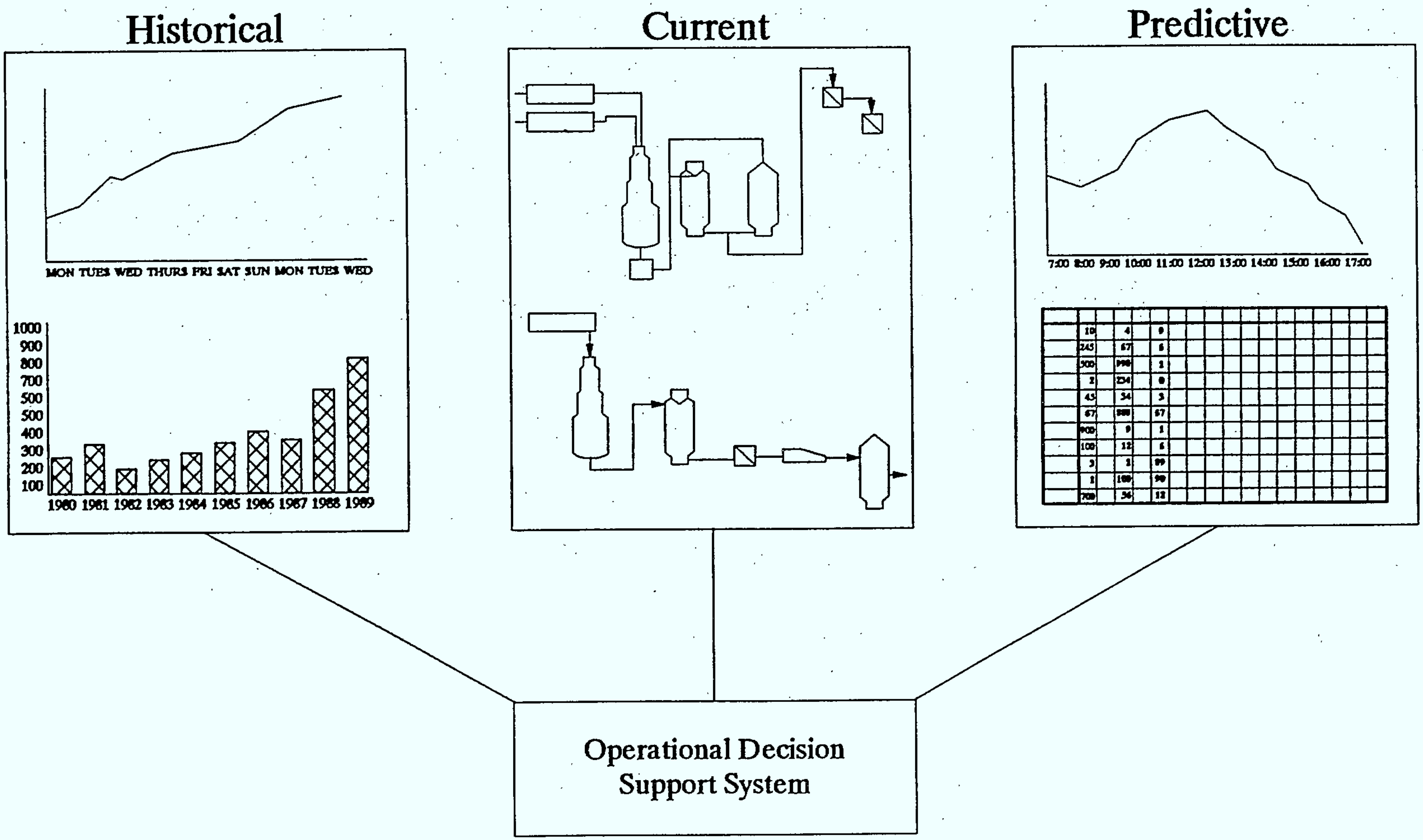
Finally, the mills need a variety of functions, some of which are provided by existing applications and packages, some that are not currently available, and others that build on the existing applications and data. A decision support system should be able to integrate with these other functions to share data and provide access to functions.

DIAGRAM 1
OPERATIONAL DECISON SUPPORT SYSTEM



ODSS

DIAGRAM 2
DECISION SUPPORT - USERS



DECSUPP

Inventory Control and Management in a Boxboard Plant

Kevin R Lyon
Technical Manager
Australian Paper Manufacturers
Petrie Mill, Queensland
Australia

Introduction

The Petrie Mill of Australian Paper Manufacturer's Cartonboard Group is located 26 kilometres north of Brisbane, the capital city of the state of Queensland in Australia. The one machine on that site is 3.5 metres wide and produces 120,000 saleable tonnes per year of multi-ply coated and uncoated cartonboard essentially from secondary fibre in the grammage range from 230 to 480 grams per square metre.

In 1984 a strategic review of Cartonboard Group business opportunities identified improved customer service as one of several initiatives which would improve our competitive position. At that time the marketplace was supplied direct from the making machine in cycles of 4-8 weeks duration. An objective was set to dispatch product ex the mill to customers within 14 days of receipt of the order. To meet this objective it would be necessary to separate the marketplace from the making machine. This was to be achieved by building a warehouse capable of storing up to 10,000 tonnes of product in its lowest value added state, that is in parent or 'jumbo' roll form. Critical to the success of the concept was the development of a system which enabled parent rolls weighing up to 15 tonnes each to be stored without spindles.

The implementation phase began late in 1987 but it took several years to become effective because during that time we were selling everything we could make and it was impossible to build the parent roll store stock up to the point (about 7,000 tonnes) at which the system operated efficiently. The concept is now fully operational. The marketplace is now supplied from the parent roll store and the making machine programmed for maximum efficiency to keep the correct mix of product in the parent roll store. In 1991 the average conformance to the 14 day customer service objective over the 26 cycles was 95%. On the other hand some customers may choose to place orders for product to be despatched on an agreed date up to three months away with 95% confidence that the product will be delivered on time.

Management and Control Systems

Obviously, effective control over the inventory in the parent roll store is critical to meeting our 14 day customer service objective and forms the major part of this presentation. It is supported by several other initiatives which have been implemented over the same time frame. The essential elements are shown in Figure 1 and will be discussed in turn.

Scheduling Computer

The concept of using a specially modified personal computer for inventory control in the parent roll store was sold to the top management of the Cartonboard Group in 1986 by a group of international consultants to the pulp and paper industry, and is shown diagrammatically in Figure 2.

In theory the scheduling program would use information from the shell program to control any number of cycles based on an analysis of product mix in the parent roll store, forecast demand and demand dates by product grade and thickness, and planned events such as making machine maintenance shuts. The consultant group developed the shell program which creates the 14 day cycles and handles the communications between the scheduling program and the mainframe computer located at APM's Head Office in Melbourne; transmitting the necessary cycle information to the mainframe for use by the on-line customer order entry system, and receiving customer order details and market forecast information necessary to program the making machine.

In practice the system proved to be unworkable with one run taking 2½ days to complete. The problem appeared to be that although the shell program handled the communications well, the consulting group had a very poor understanding of how the scheduling program worked. Much effort by the Petrie Mill Scheduling and Systems Controller has reduced the run time to 10 minutes, and this is expected to fall to 2 minutes when the scheduling computer is upgraded to a 486 model. Even so the scheduling program does not appear to have the flexibility to cope with changing product mixes which are part of the real life situation in our mill.

To overcome the deficiencies of the scheduling program a series of spreadsheets have been developed by the Scheduling and Systems Controller at Petrie Mill which work remarkably well in controlling the inventory in the parent roll store and programming the making machine. A limitation with this system is that information from the Finishing Management System (refer to Figure 3) e.g. the daily parent roll stock report, and the order progress report, together with market forecast and future (unprogrammed) customer orders from the mainframe have to be manually entered each working day into the spreadsheets. This effectively limits the span to three cycles - current, next, and future although this can be extended if needed.

A vital part of the inventory control system is to be able to estimate with reasonable accuracy the number of 'good' tonnes, as distinct from gross tonnes of product by grade and thickness in the parent roll store. This is where the other management and control systems shown on Figure 1 come into play.

Distributed and Machine Process Control Computer Systems

The first distributed control system was installed in 1987 when the industrial wastepaper slushing plant was upgraded and a new slushing rejects handling plant installed. The system has been progressively extended to include the refiner room, wet end chemical addition and ancillary equipment, and a new office waste paper slushing plant. All the configuration was done in-house.

The first machine process control computer was installed in 1973 and has been upgraded several times since. The current system includes grammage and moisture measurement and control, and measurement of thickness, brightness and colour, and smoothness.

The original intention was to connect the machine process control computer with the distributed control system in global mode to provide a single window on the process but the distributed control system has grown to such an extent that global integration of the two systems is no longer possible with the existing architecture. The two systems are connected but for the exchange of data only.

Total Quality Management

Total Quality Management (TQM) which embraces the philosophy of Total Quality Control and Statistical Process Control or 'getting it right the first time' was introduced in 1986 and still provides the impetus for continual improvement to the process. Participation in TQM team activities has actually been written into the industrial agreements with the major trade unions on site.

Quality Assurance System to ISO 9002

The decision to seek third party certification for a Quality Assurance (QA) system to ISO 9002 was taken in 1989 but progress was slow until two years ago when a member of staff was appointed full time to drive the project. The Petrie Mill Quality Assurance System was recommended for certification to ISO 9002 by Lloyds of London Quality Assurance Group on 27 April, 1992.

The scope of the Petrie Mill QA system is quite extensive. The Quality Manual is 41 pages, and the Procedures Manual 120 pages. There are 62 Work Procedures ranging in length from 5 to 100 pages, and 123 Work Instructions ranging in length from 5 to 25 pages. There are 1615 Controlled Documents.

We perceive a degree of synergy between the QA and TQM systems with the discipline required by the QA system providing the mechanism for locking in the continuous improvements identified by the TQM process.

Expert System Computer

Development of a personal computer based mill specific troubleshooting 'expert' system began in April 1992 and will enable us not only to capture the accumulated experience of our senior operators (many of whom will retire within the next 2 years), but to add new knowledge as required. The interface is user friendly and the system will be available for use by the operators 24 hours a day 7 days a week.

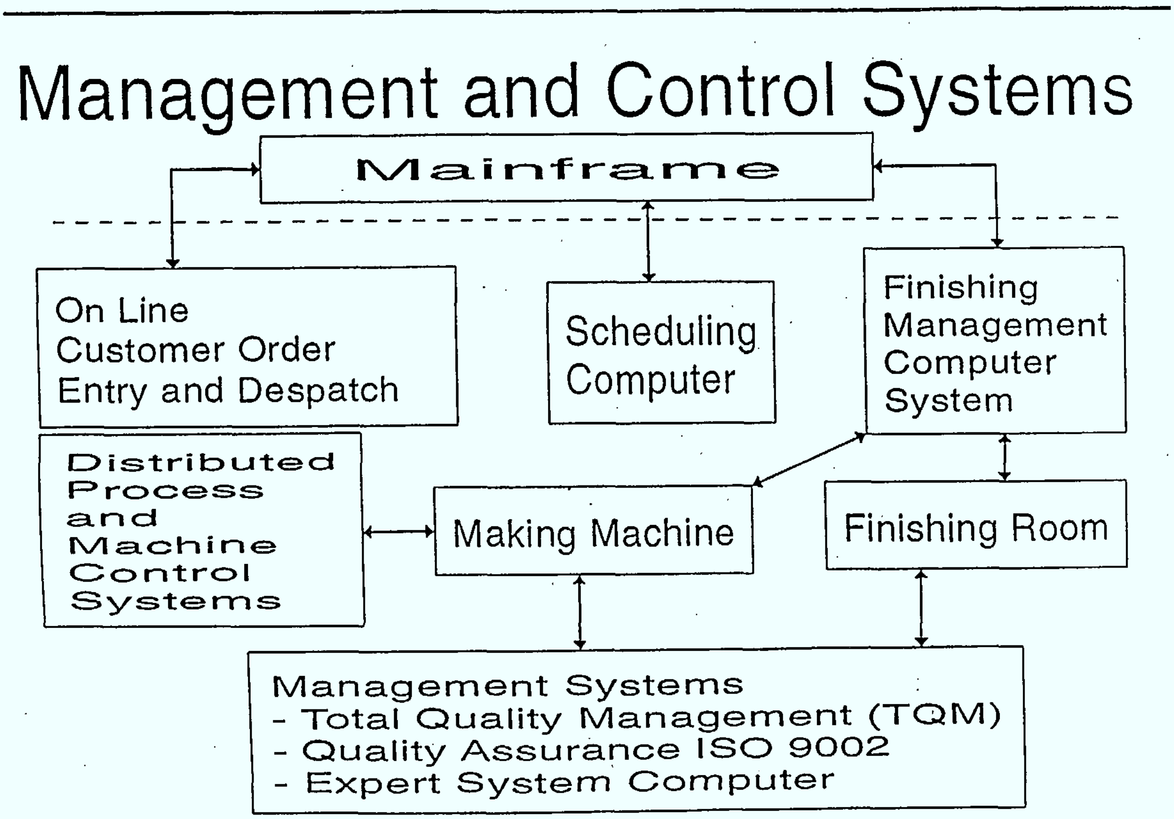

Management and Control Systems
Mainframe
On Line
Customer Order
Entry and Despatch
Scheduling
Computer
Finishing
Management
Computer
System
Distributed
Process
and
Machine
Control
Systems
Making Machine
Finishing Room
Management Systems
- Total Quality Management (TQM)
- Quality Assurance ISO 9002
- Expert System Computer

Figure I

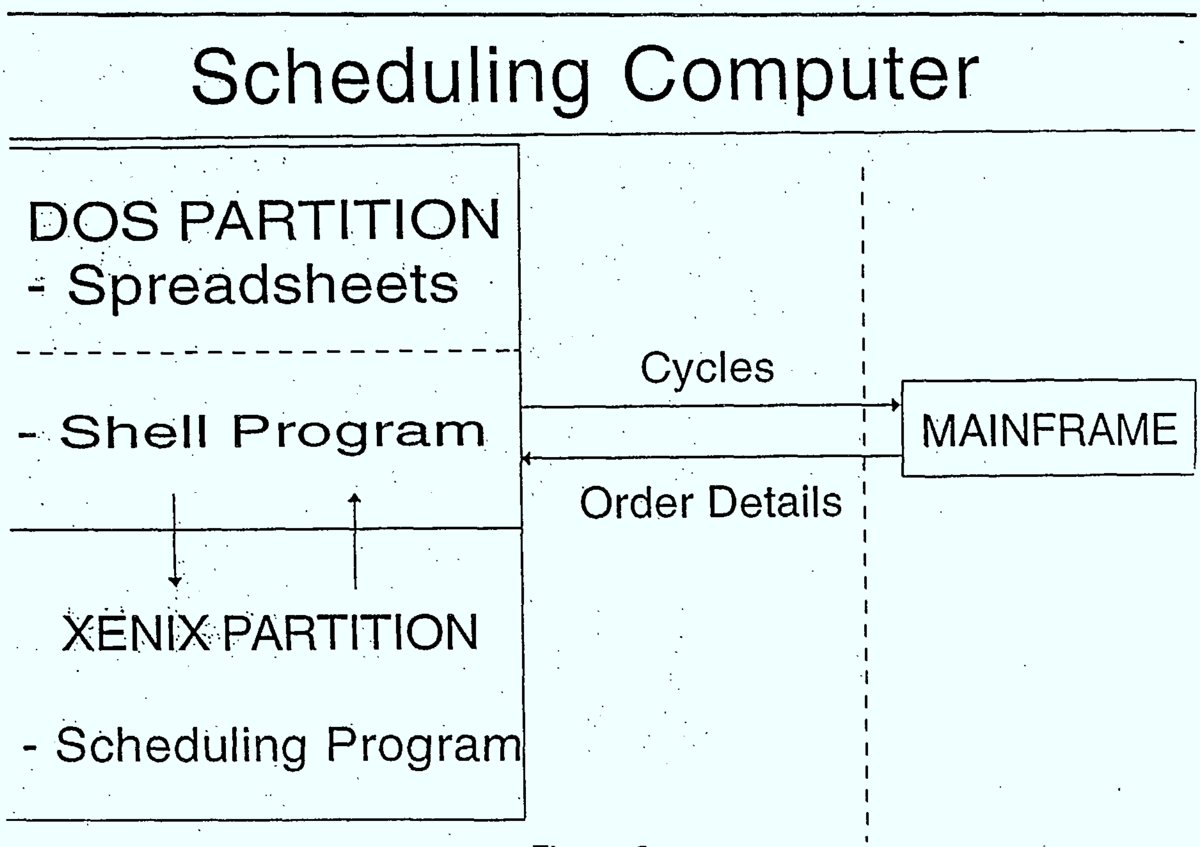

Scheduling Computer
DOS PARTITION
- Spreadsheets
- Shell Program
XENIX PARTITION
- Scheduling Program
Cycles
Order Details
MAINFRAME

Figure 2

Finishing Management System

Relational Database

- INPUTS:
  - Parent Roll Details
  - Product Test Data
- STOCK TRACKING SYSTEM
  - Winders (2)
  - Sheeters (3)
  - Guillotines (2)
  - Weigh Station
  - Packing Station
- OUTPUTS
  - Parent Roll Stock Report
  - Order Progress Report
  - Broke Reports
  - Other Stock Reports
  - Deckle Filling Reports

Figure 3

An Expert System to Support Site Preparation Decisions

M.P. Curran[1], M.M. Johnston[2], Y. Wand[3]

Introduction

Proper reforestation of a harvested site often requires a site preparation treatment (mechanical, burning, or chemical) which may critically affect long-term site productivity if improperly planned or executed. Many economic, operational, and other resource value considerations go into a site preparation prescription; from a long-term productivity perspective, the most crucial consideration is the "biological appropriateness" of a given treatment. The objective of the SYTEPREP (SYstem To Evaluate PRescription Effects on potential Productivity) project, which is based on expert system technology, is to develop a prescription tool to predict the ecological effects of various site preparation treatments and thereby assist users in selecting a "biologically appropriate" treatment. Presently, the system has been developed as a prototype for use in the Nelson Forest Region of the Province of British Columbia and has been distributed to over 100 users. Included in this document are brief summaries of the development and implementation process as well as future plans for the SYTEPREP project.

Background

The project commenced as a Masters thesis project (Johnston 1989) under the direction of Dr. Yair Wand, Associate Professor, UBC Faculty of Commerce, in cooperation with the Protection Branch of the B.C. Forest Service. The objective was to examine the applicability of expert systems technology to site preparation decisions by developing a prescribed burning effects system. Five experts were consulted and several conceptual models developed and evaluated. The *limiting factor* concept was eventually adopted to model the effects of prescribed fire on the direct and indirect growth factors; this concept is summarized for fire in Curran (1988). A prototype of the Fire Effects system was built using the VP-EXPERT software package. Parts of the system were also implemented in TURBO-PROLOG (which later became PDC-PROLOG).

The project was continued in October 1989 as several contracts between Michael Johnston and the BC Forest Service, under the coordination of Mike Curran, Research Pedologist, Nelson. A B.C. Science Council grant, applied for in November 1989 by Dr. Wand, was approved with Science Council funding beginning in April of 1990. In June 1990, prototype versions of the FIREFFEC system were released for field testing, with version 1.2 being widely released in May 1991. As of March 1992, systems for fire (FIREFFEC), mechanical (MSPEFFEC) and chemical (CHEMEFFEC) treatments have been developed. The SYTEPREP shell system which integrates all three systems (the chemical system will be added to the SYTEPREP system shortly) was released as

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[3] *Associate Professor, Faculty of Commerce and Business Administration, University of British Columbia, 2053 Main Mall, Vancouver, B.C., V6T 1Z2 (604)822-8395*

a prototype in December 1991 and a total of about 20 field office workshops have been held over the last three years.

System Development Methodology

The development of the systems in the SYTEPREP project involves a process known as knowledge engineering (KE). This involves developing a conceptual model of the problem and acquiring the knowledge from experts. A prototyping (iterative) approach is then used to develop the systems. This method allows experts and prospective users to periodically evaluate the design of the system. It is also much easier to make major modifications to the system at an early point in the development process when a working version can be tested by the experts. Extensive rewrites of the system code may be partially avoided if major problems are detected early. The KE process is aided by knowledge base documentation which formalizes the knowledge in the knowledge base.

Many experts have been involved in the development of the systems, and have included the fields of ecology, vegetation management, fire behaviour, silviculture, and pedology. Some of this knowledge was from partially overlapping disciplines and this required a central expert (Curran) to resolve conflicts and formulate the conceptual framework for the system. Some expertise has also been obtained at group workshops where the system has served as a focal point for group discussions.

The Limiting Factor Concept

The limiting factor concept is a useful tool for ecological modelling. This concept states that the growth rate of a plant will be determined by the level of the factor that is the most limiting (least optimum). This is a very easy concept to understand and implement in any sort of manual or computerized system. It also allows the overall problem to be subdivided, which facilitates the modelling of each factor separately, and allows the users to focus on the more limiting factors. It is acknowledged that the limiting factor concept is a simplification of ecosystem processes (i.e., some factors compensate for others), and attempts have been made to reduce oversimplification by applying the main effects (e.g., moisture limited nutrient uptake) to the factor which is most responsible (e.g., moisture).

SYTEPREP uses the limiting factor concept to compare effects of a proposed treatment on various direct and indirect growth factors. Each growth factor is rated on a relative 1 - 8 scale for both the No-Treatment and Post-Treatment cases. This relative scale is the underlying outcome of the system and both experts and users relate to this descriptive scale quite well. Similar factor rankings indicate comparable limitations. The SYTEPREP system also explains the reasoning why a growth factor is rated at a particular level. Figure 2 illustrates the limiting factor concept with the growing site represented as a barrel full of water. The volume of water in the barrel is conceptually equivalent to the potential productivity of the crop tree. The productivity is limited by the most limiting factor just as the level of water is determined by the height of the lowest stave in the barrel. The underlying objective is to determine whether the proposed treatment is expected to have a net negative or net positive overall effect when compared to the No-Treatment option. Figure 3 illustrates a screen from the system which compares the No-Treatment and Post-Treatment limiting levels.

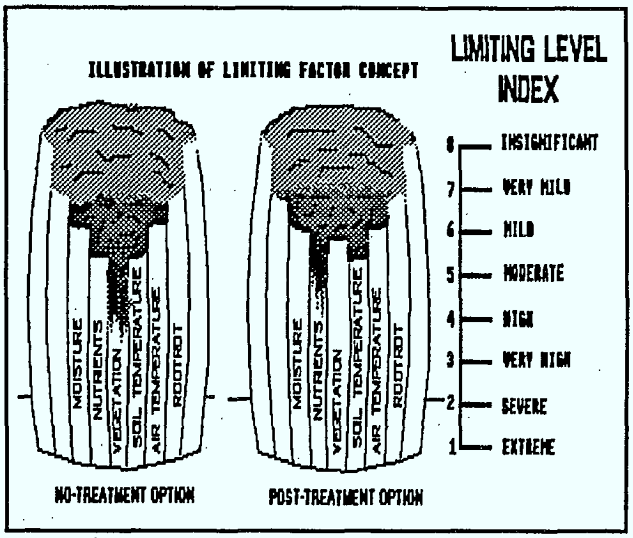

Figure 2 Illustration of Limiting Factor Concept, demonstrating a "net positive" effect when a proposed treatment has improved tree growth conditions

The time frame that the system currently models is the "seedling establishment" phase; although some factors clearly vary in the length of time that they will affect the performance. There are currently seven growth factors coded into the system list. In the example (Figure 3), a net-negative effect is predicted because rooting substrate is expected to become most limiting. The user must then decide, based on all other considerations, which

Future Plans

The SYTEPREP decision aid is not intended as an end in itself; it is being developed to accommodate operational needs. Immediate plans are to complete validation and ensure a robust system is available for operational use. Based on feedback and funding interest, future plans are to finalize the knowledge base in the overall SYTEPREP system, extend it to include an equipment complement selection based on trade-offs between desired disturbance type and inherent site sensitivity to compaction, displacement, etc., short-term economics trial, and a planting stock type selection tool. Future system platforms include a Windows version and a DOS-Extended version. Expansion into other forest regions in B.C. will occur at appropriate times and based on available funding interest.

System Products

- Fire Effects, MSP Effects, and SYTEPREP systems
- User's manual
- Computer-Based Tutorial
- Workbook (draft form)
- Research Report describing knowledge base (draft form)
- Journal Paper
- Knowledge Base documentation

Literature Cited

Curran, M.P. 1988. Slashburning Effects on Tree Growth and Nutrient Levels at Mission Tree Farm: Project status. In: Degradation of forested land: "Forest Soils at Risk", eds. J.D. Lousier and G.W. Still, Proceedings of the 10th B.C. Soil Science Workshop, Feb. 1986. Research Branch, Ministry of Forests, Victoria. pp. 294-313.

Johnston, M. 1989. An Expert System to Predict the Ecological Effects of Prescribed Fire unpublished M.Sc. Thesis. The University of British Columbia, Vancouver, B.C.

BC Ministry of Forests - Nelson

of these two options is appropriate (scalping vs. no treatment) or try another comparison; in the example, the user should probably consider a more "biologically appropriate" treatment. The user is also cautioned that each factor has different ramifications from a long-term productivity perspective. For example, while a similar ranking may be indicated for both Rhizina, the "tea break" fungus that attacks seedlings for two years after a fire treatment, and site nutrient depletion, Rhizina is much less of a long-term problem than site nutrient depletion.

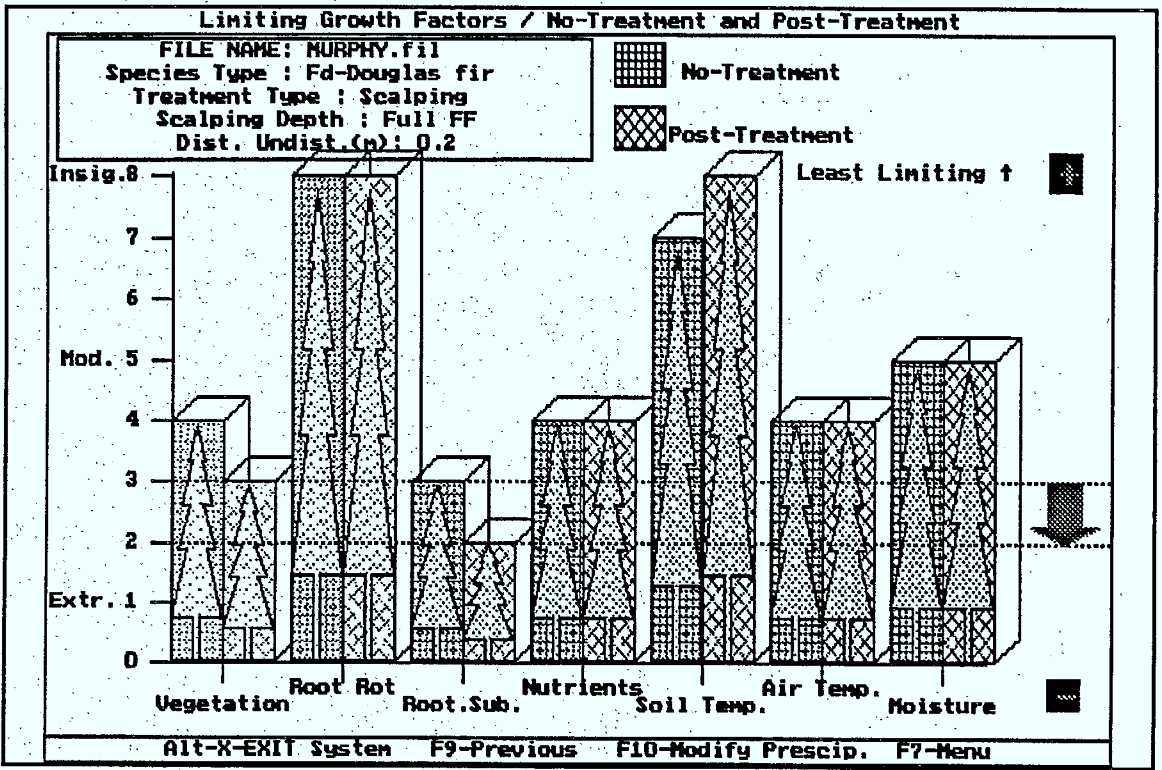

Figure 3 Comparison of No-Treatment and Post-Treatment Limiting Levels

The SYTEPREP Program

There are four basic components to the systems in the SYTEPREP project: the knowledge bases, the inference engine, the user interface, and the site-specific information databases (see Figure 4). The knowledge bases contains knowledge in the form of rules. The inference engine is the mechanism that controls how the knowledge in the knowledge base is used. The user interface controls the communication between the system and the user. The site specific information database contains information pertaining to the biogeoclimatic site classification system and the brush hazard (level of vegetation competition) on the site.

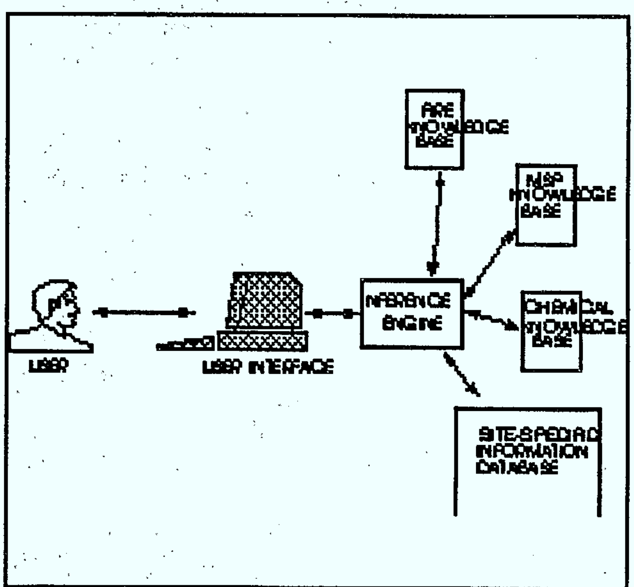

Figure 4 Structure of the SYTEPREP System

Most of the system has been written in PDC-PROLOG. Turbo-C has been used to link the system to a third-party image display library. An overlay linker (a program which swaps program code in and out of memory) was used to enable the system to run in a 640K DOS environment. The products used in the development of the system do not require the payment of any run-time royalties and the system is distributed freely by the B.C. Forest Service in Nelson.

Use of the System

Users are cautioned that the SYTEPREP decision aid is not designed to replace common sense, thought and local experience, but rather to help encourage "management gaming", thought, and discussion during development or reviews of a proposed prescription. The comparison of trade offs between possible treatments helps encourage discussion and enables extension of research results and local experience to staff who develop site prescriptions (these are often the more junior staff). As a tool to assist in the selection of the "more appropriate" treatments, this decision aid will provide a crude ranking of possible treatments; the user, however, is cautioned that the ranking is simply a numerical exercise based solely on limiting level index numbers. The user is expected to compare at least the top ten options and make his/her own judgements in selecting a treatment or no treatment.

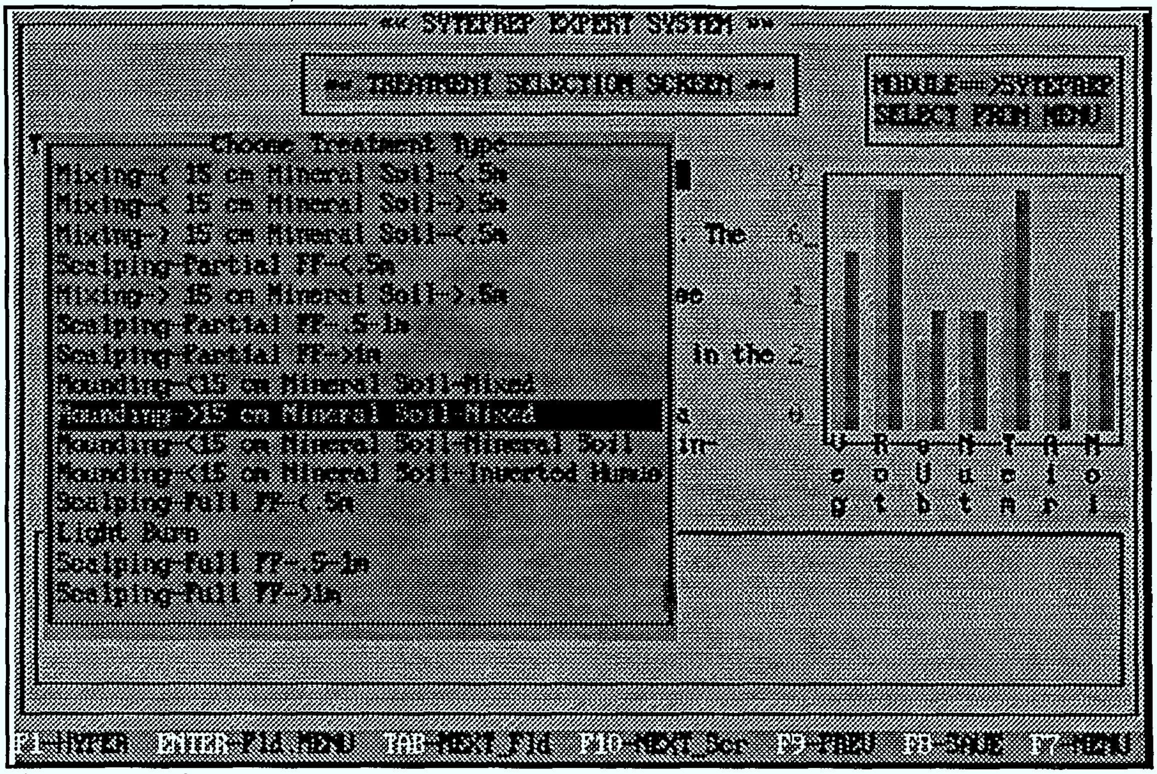

Figure 5 Choosing Treatments from a Rank-Ordered List

Figure 5 illustrates a system screen where the user can choose a treatment from a rank-ordered list. As the cursor is moved, the limiting levels for each treatment are displayed and compared to the no-treatment option in the box on the right hand side of the screen.

Validation and Implementation of the System

Validation refers to the steps taken to test whether the system outputs conform to both the expert's reasoning and local field experience. Both the conceptual model, and the specific rules are validated by consulting with experts. As well, test cases (both research sites with hard data and operational field experience) were used to compare the system outputs with solutions proposed by experts. Experts consulted were both source experts (originally involved in knowledge acquisition) and non-source experts.

The systems have been implemented in a step-wise manner. The prototype Fire Effects system was initially demonstrated at workshops in the summer of 1990. The prototype Mechanical Site Preparation system was demonstrated in summer 1991 and the prototype SYTEPREP system, which integrates the above systems, was demonstrated and released in December 1991. Feedback from these workshops has been extensively used to improve the reasoning and enhance the user interface of the systems.

Future Plans

The SYTEPREP decision aid is not intended as an end in itself; it is being developed to accommodate operational needs. Immediate plans are to complete validation and ensure a robust system is available for operational use. Based on feedback and funding interest, future plans are to finalize the knowledge base in the overall SYTEPREP system, extend it to include an equipment complement selection based on trade-offs between desired disturbance type and inherent site sensitivity to compaction, displacement, etc., short-term economics trial, and a planting stock type selection tool. Future system platforms include a Windows version and a DOS-Extended version. Expansion into other forest regions in B.C. will occur at appropriate times and based on available funding interest.

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Johnston, M. 1989. An Expert System to Predict the Ecological Effects of Prescribed Fire unpublished M.Sc. Thesis. The University of British Columbia, Vancouver, B.C.

BC Ministry of Forests - Nelson

Economic Benefits from the Automated Planting of Seedings

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Introduction to Silva Nova

Looking back at history, one will find that people have tried to mechanize tree planting for centuries with a varying degree of success.

The techniques used in the efforts to reach the goal have become more and more sophisticated. Experience has shown that it is a difficult task to build a planting machine that can meet all requirements regarding: costs, efficiency, availability, etc...

This presentation is a short summary of a project carried out by at first MoDo Mekan and thereafter Storebro Bruks AB, Sweden, in cooperation with the biggest Swedish forest companies and the Swedish Forest Service and experiences from the 1991 season in Canada.

What's the Need for Mechanical Planting?

In 1977 Prof. Bäckström of the Swedish University of Agriculture Sciences showed that there are several reasons for mechanizing the planting operation:

- The cost for manual labour tends to increase faster than cost for machinery.
- Shortage of manual labour.
- Unbalanced need for manual labour Summer/Winter.
- Manual planting can be very heavy and tedious and make it hard to motivate for a biologically acceptable planting.
- A short planting season requires high productivity.
- The annual reforestation area tends to increase.

These reasons are still in high degree valid for many countries where forestry plays an important role.

Demands

The basic difficulties are to be found in the fact that a planting machine has to combine two fundamentally different operations. First, the ground has to be scarified with a device that has to do a rather brutal work. On the other hand, the planting device shall handle a small and vulnerable seedling. This can lead to conflicts between hi-tech and biology.

The machine must also be capable of making an acceptable planting in different terrain classes and on varying soil types. The possibilities for a successful planting also vary within the planting site.

The Silva Nova Development

The first efforts in the **Silva Nova** project were carried out in the 1970's at MoDo Mekan, owned by the Swedish forest company MoDo. The machine was designed for normal bare-root seedlings, that were used at that time, and working with a patch scarifier and an intermittant-plowing planting device. The biological results were, however, not good enough.

After a long series of testing, the first prototype was built in the end of the 70's, looking in principal like the machine of today. The major problem still remaining was the use of a patch-scarifier. The planting capacity was notably improved but the field tests, however, also revealed many weakness in the design.

The scarifier was changed from patch scarifying to a type of continuous working.

In the beginning of the 1980's, the field testing was intensified. Studies showed promising results but still many stops were registered due to technical breakdowns.

Commercializing of the Project at Storebro Bruks AB

In 1982, Storebro took over the project and started a rigorous testing program. The year after the **Silva Nova** reached an acceptable level regarding planting ability and availability.

These results ended with orders from the tree biggest Swedish forest companies: SCA, STORA and Domänverket.

In the season of 1985, a new company, Korsnäs Marma, joined the group of customers and since then, there have been five prototypes in operation in Sweden for testing out the system.

Results so Far

The machines already show a remarkably high technical availability, 70-80%, and produce between 950-2,000 planted seedling per G15 hour.

Calculations show that Silva Nova is competitive, with efficiently runned manual planting, with a productivity of 1,300 seedlings/hour and a mechanical availability of 70%. SCA's machine reached already in 1985 a productivity of about 1,500 seedlings per hour and availability of 85%.

The results varies considerably between the machines, depending on sites, the experience of the operator, seedling quality, etc...

Calculations

Total production for a season, a technical utilization of 70% will be appropriatively 1.000.000 plants per machine. The forest companies will operate about 80-100 days per season with an average 1.5, 8-hour shifts per day.

The prototypes have been using containerized seedlings. The main plant system being used is the HIKO (multipot), with seedling size variations (in green parts) from 10-40cm. Other plant systems have also been used.

Another development is new numerical control system with a hydraulic sensorial system for the planting depth. This gives a simple, exact and fast control of the planting and scarification work from the operator's cabin.

Functions

The operator sets and controls the planting depth, the rotation speed of the cones, pressure downwards/upwards and the cone angle (track profile) depending on site conditions.

During certain conditions, it is recommended to change the continuous scarification into patch scarifying.

The push button control panel is designed in order to be able to easily change the program and modify the scarification work according to the requirements of the site.

The Role of the Seedling Producer

An important factor in order to get the utmost out of an investment in a tree planting machine, is the planning of seedling production and distribution.

The planting machine has to be efficiently used during the short season to reduce the total cost per planted hectare or seedling.

Seedlings in good condition should be produced according to strict specifications, with new growing schedules for delivery from early spring to late fall. This differs drastically from the routine used today in the nurseries programmed for manual planting requirements.

Intense communication and cooperation between the seedling producer and the planting operations is essential for a good result. The seedling producer has to accept the new role of a manufacturer/supplier with:

- regular scheduled deliveries of his products, to given specification.
- sorting in the nursery.

- cold storage of the seedling. (Ready for delivery)

Canadian Experience

During the 1991 season, Silvana Import Trading Inc. operated two **Silva Nova** planting machines in Quebec. One million trees were planted. F.E.R.I.C. did a long term study on the machines which will be presented in a separate report.

Costs per Planted Tree

The results indicate that a planting machine today is competitive with manual planting.

COSTS PER PLANTED TREE CAD $

PRODUCTIVITY ASSUMPTION	FORWARDER USED ONLY FOR PLANTING	FORWARDER ALSO USED IN LOGGING
	CAD$/TREE	CAD$/TREE
LOW 1300 TREES/PMH	0,247	0,239
AVERAGE 1500 TREES/PMH	0,214	0,207
HIGH 1600 TREES/PMH	0,201	0,193

MANUAL PLANTATION

GOVERNMENT CREDIT	
MANUAL PLANTING	0,165 CAD$/TREE
SCARIFICATION	0,084 CAD$/TREE
TOTAL	0,249 CAD$/TREE

Other Economical Benefits

Many factors of economical influence make it harder to calculate precisely the benefits of mechanical planting.

In Scandinavia, one of the most important factors behind the development of a planting machine has been to balance the work force needed throughout the year. Harvesting operations have been heavily recognized. Seasonal workers are hard to come by due to strict hiring rules.

In Canada, it is almost the opposite situation. In many cases, seasonal planting is combined with unemployment insurance to make up a yearly income.

I have tried to pinpoint some functions that are affected by manual/mechanized planting.

+ = LOWER COSTS

- = HIGHER COSTS

OPERATIONS	MANUAL	MECHANIZED
PLANNING	-	+
SUPERVISING	-	+
ADMINISTRATION: (HIRING, SALARIES)	-	+
QUALITY CONTROL	-	+
CAMP ARRANGEMENTS (HOUSING, KITCHEN, TRANSPORT)	-	+
SEEDLING HANDLING	-	+
PLANTING QUALITY	DEPENDING ON INDIVIDUAL PLANTERS	-
CAPITAL COST	+	-
TRANSPORT OF MACHINERY	-	+

Required Changes in the Forest Sector

We have proved that mechanical planting may be done at a lower cost than manually. The techniques is here but some important factors have to change.

Industry and government have to show long term commitment, especially

in an introduction/development stage. The relatively high capital investment portion requires backing with long term contracts. Today's "quality" specification norms for manual planting contracts may also require adaptation to reality.

A machine and a person may not necessarily require the same control function.

With today's routine, it is not unusual to find a two men machine crew supervised by a two men provincial government crew and a two men crew from the forest company.

It is important that routines are adapted to the machines in order to utilize possible cost advantages.

Most crucial factors for using a capital intensive machine like a planting machine is:

* Planting season length
* Accepted planting depth
* Seedling quality and distribution system
* Adapted rules and regulations for mechanized planting contracts.
* Long term commitments from potential users and governments.

Silva Nova®

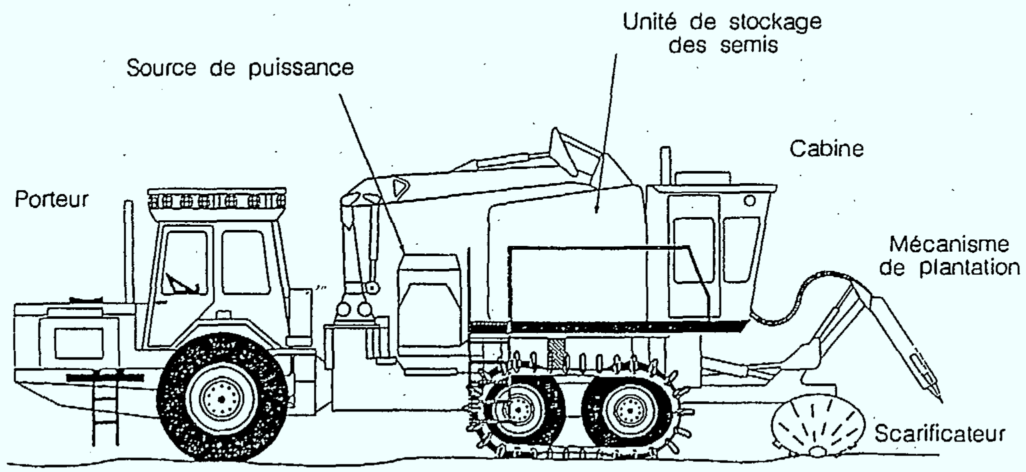

Figure 2. Schéma de la planteuse forestière Silva Nova.

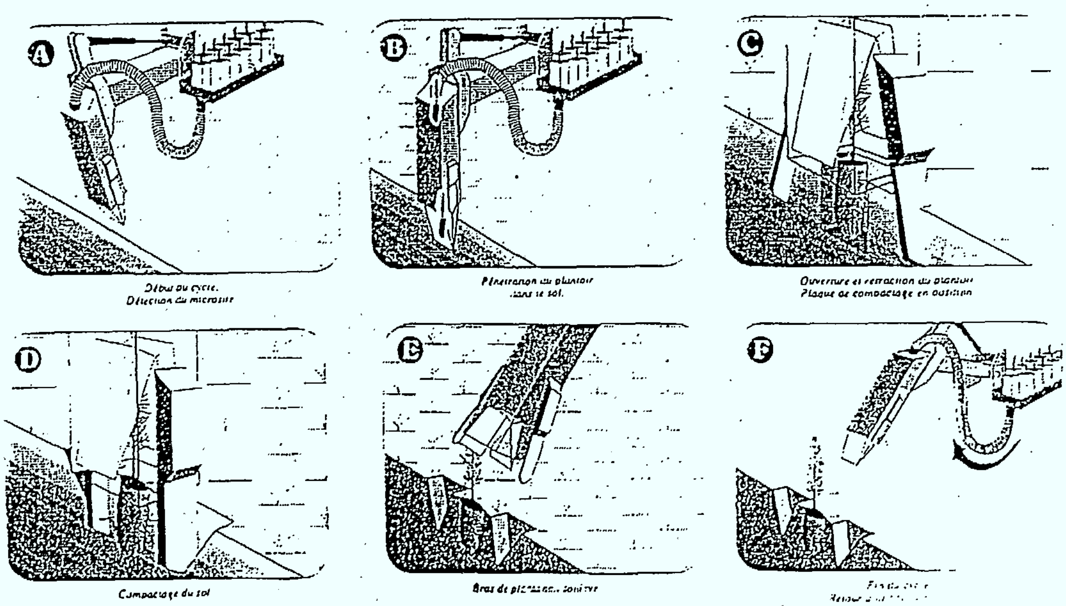

Figure 3. Cycle de plantation de la planteuse Silva Nova

Robotics for Silivculture Operations

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Forestry Canada
Petawa National Forestry Institute
Ontario

INTRODUCTION

Forestry has always been a key component of Canada's identity. We have 10% of the world's forests and this forest contains 14% of the world's conifer timber resources. We are by far the world's largest exporter of forest products; exporting 70% of our lumber production and 90% of our newsprint. The value of our forest products exports exceeds 21 billion dollars and represents 17% of our total exports. These forest products exports are twice that of USA and 5 times that of the Russia. Nearly 900,000 Canadians are employed in forestry related jobs (Forestry Canada, 1990).

One quarter of Canada'a land area of nearly a billion hectares is productive forest land and this supports a standing timber volume of 23 billion cubic meters of mainly softwood timber. This forest is 90% owned by the public from which we annually harvest 200 million cubic meters from about 1 million ha.

Our relationship to our forests has changed dramatically since the first European settlers arrived in Canada in the mid–1500s. Initially, the forest was viewed as a source for fur, later as an impediment to transportation and settlement, and over the past 150 years as an important source of wood products. Until fairly recently, mankind has behaved as if all the world's natural resources were unlimited. Canadians tended to view their forest resources as limitless.

Within the past few decades, Canadians have begun to realize that, as vast as our forests may be, they do not represent unlimited resources. With this realization, the Canadian government, through the passage of Bill C–29, the Department of Forestry Act (1989), has made a firm commitment "to promote sustainable development and competitiveness of the Canadian forest sector for the well–being of present and future generations of Canadians." This means that we are determined to ensure that our forests will meet current needs without prejudice to their future productivity, ecological diversity and capacity for regeneration.

THE SILVICULTURE PROBLEM

Sound forestry practice requires that, at the very least, there is adequate regeneration following harvesting. To achieve this we spend $700 million annually on silviculture; mostly on planting about a billion seedlings on about 450,000 ha. (slightly less than half the harvested area). Of course, on many areas, planting is not required since natural regeneration is adequate. To ensure the survival of quality forest stands, whether they are newly planted or natural, it is essential to carry out certain stand tending operations such as weeding and brushing, usually within about 5 years of the initial establishment of the stand. Later, as the young stand develops, several density reduction cuts or thinnings are necessary to maintain quality fiber production on a relatively few crop trees. Such stand tending operations are presently carried out only on 300,000 ha annually. This represents less than a third of the harvested area or little more than half the planted area.

In the northern softwood forests of Scandinavia and Europe, stand tending operations are carried out from 3 to 5 times during the rotation period of a stand. This "agro–forestry" approach achieves about a 5 fold increase in per unit area productivity under similar soil and climate conditions as found in Canada. Finland is such an example.

To accomplish such intensive silviculture in Canada, we would have to increase our level of stand tending activities by a factor of 100. Clearly this is not economically possible because of our high labor costs. It costs approximately $200 per day to keep a person working in the forest. This person is capable of brushing or thinning about one fifth to half a hectare per day in typical Canadian conditions for a single–visit cost of about $500–$1,000 per ha. Figure 1 illustrates the motor–manual method of cleaning or pre–commercial thinning.

Figure 1. Manual Thinning in Cape Breton, Nova Scotia

The productivity of a person can be improved by a factor of about five using existing machines which use technology developed in Sweden and currently being investigated by FERIC. These cleaning machines consist of a large circular blade (the teeth are independently removable) which is swept over the area containing brush or trees to be removed by an operator in the cab of a large tractor like vehicle. The blade motion is controlled by two joy–sticks similar to those used in computer or video games. Two such machines are shown in Figure 2.

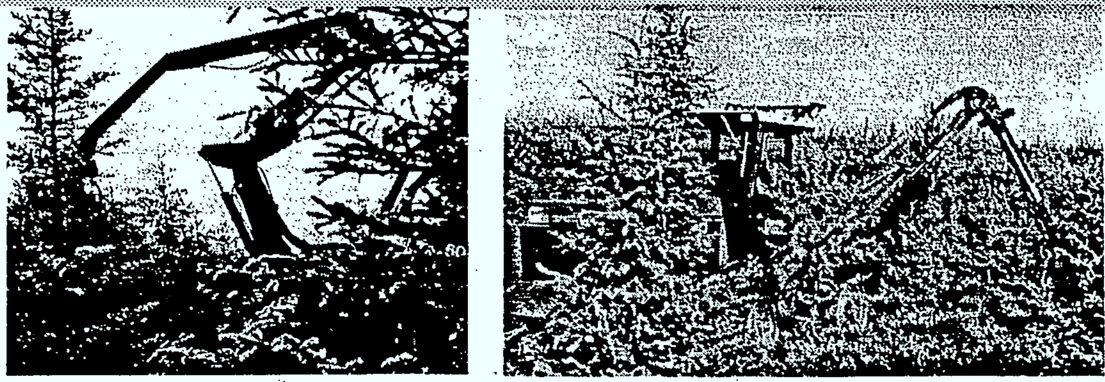

Figure 2. Cleaning, Thinning Machines Based Upon Swedish Technology Operating in Eastern Canada

ROBOTIC SYSTEMS

In Canada, as elsewhere, robotics in forestry has generally focused upon milling and processing, with some movement into the woods operations for logging and harvesting. Most developments have been aimed at tele–operated equipment, or equipment with computer assisted controls to improve the efficiency of manual controls. Thus, the major efforts have been to add high technology assistance to proven machines (Courteau, 1990). At Forestry Canada, in collaboration with the Forest Engineering Institute of Canada (FERIC), we are just beginning to investigate the potential role of autonomous robots coupled with image analysis, machine vision, neural networks and expert systems in some labour intensive silvicultural operations.

In the forest, the ground conditions are very rough. Many past attempts at mechanizing the cleaning operations in forests have foundered because of failure of the vehicle to operate in even relatively simple forest environments. There are really three choices of vehicle for silviculture operations: tracked, wheeled or "walking". The vehicle must not be impeded by steep slopes, very soft ground or large fallen trees. Moreover, it must be able to avoid damaging the trees which are to be protected. Generally, cleaning and brushing will be performed before the trees exceed two meters in height. A tracked vehicle must be able to travel between the trees to be protected, which means that it must be considerably narrower than 2.5 meters. A wheeled vehicle could also be designed to move between the protected trees, as is the case in the left photograph in Figure 2, or to pass over them as in the right photograph. These two wheeled vehicles are now operating successfully in fairly typical terrain found in Eastern Canada. In the long term, a walking vehicle such as that developed through DARPA funding may provide the ultimate solution. Such a vehicle should be able to go to any part of the forest which can be reached by a person on foot and without damaging any of the trees to be protected.

As we see in factories, space and other areas of application of robotics, the ability to control tools either automatically or by tele–operation is quite advanced. Although the traditional approaches used by robotics systems engineers involving sophisticated machine vision, world models and complex trajectory planning may be feasible, a major breakthrough in control of autonomous robots (Brooks and Connell 1986; Brooks, 1986) offers hope of being able to build robots with sophisticated behaviour using the most simple control structures. For example, the six–legged robot in Figure 3 has only one very simple control CPU and another even simpler control and sensor input CPU. It has only rudimentary touch and proximity sensors, yet in can navigate through a very cluttered terrain without difficulty, climbing over or going around obstacles and following people.

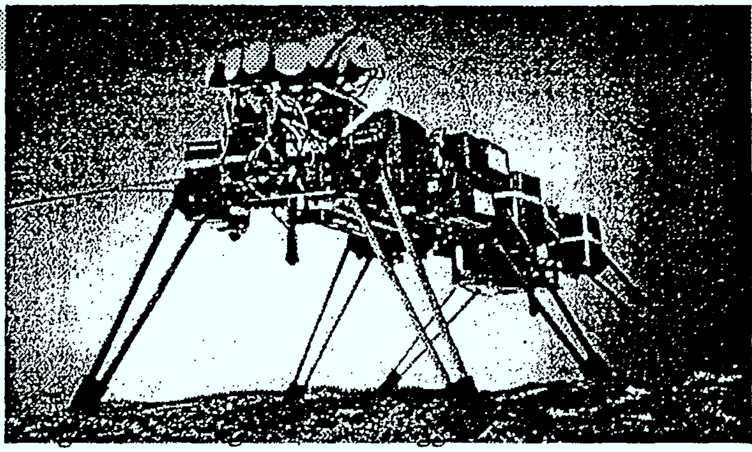

Figure 3. Ghengis II, a Walking Robot Developed at MIT

It will be necessary for robots working in the field to know where they are with respect to the individual trees they are to preserve, to the perimeter of the stand in which they are to operate and to each other. The Global Positioning System (GPS) is becoming an economical means of determining position. However, for round the clock operations, it is not yet practical as there are lengthy periods of the day when the system is not usable because of inadequate satellite coverage. It is also inoperable under the forest canopy.

Fixed radio beacons operating in a manner similar to LORAN can be used for local navigation. For field operation of robotic systems in the future, we will make extensive use of some of the new forest management technologies, such as Geographic Information Systems, containing information on the stands, topography, soils and species identification. Using the Canadian developed Multispectral Electro-optical Imaging Seensor (MEIS), we can obtain very detailed information of the forest, and even individual trees, which can be coupled intosuch systems (Till, et al., 1997). Laser and radio ranging within a stand is also practical.

The problem which is most challenging and interesting to us in all the potential robotic applications is the one of vision. How can we recognize one species from another? In Figure 3, we see an example of three different species of young conifers. A professional forester can distinguish among these very easily. It is more difficult to develop computer algorithms to do so.

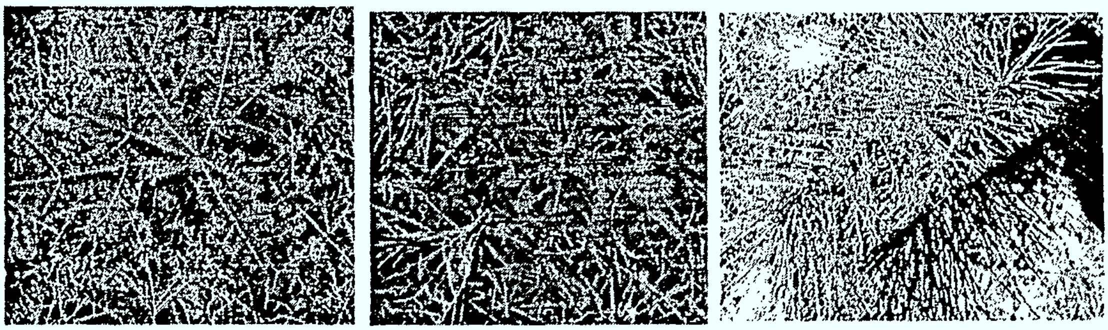

Figure 4. Young Fir (left), Spruce (centre) and Pine (right)

In Figure 4, we see the problem facing the operator of a cleaning machine in a real forest. In this case, he wants to preserve spruce at a specified spacing, eliminating the fir and other trees, most of which are about twice the height of the trees to be protected. This is a relatively easy problem. In most similar cases, the task would be to protect the "best" tree at a given spacing. To do so, one must recognize the various features, such as species, height, stem diameter, "straightness", health and vigour, etc. One advantage we may have over the human eye is that we need not restrict our vision system to the visible part of the spectrum.

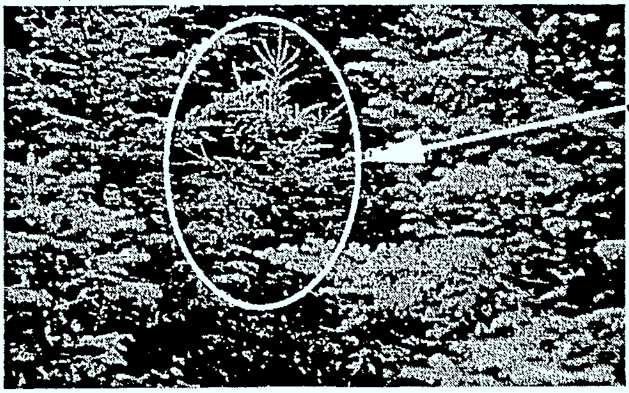

Figure 5. Cleaning/Thinning Operation in Cape Breton, Nova Scotia

CONCLUSIONS

Scientists at PNFI have considerable experience in the development of Expert Systems to provide assistance in making management decisions in many areas of forest management (Kourtz, 1990). Coupled with the expertise in forestry which is available at or to the Institute, we are confident that once the vision, control, navigation and mechanical problems are solved for any given task, the decision rules for autonomous or near autonomous operations can be developed. PNFI has considerable digital image analysis expertise which can be applied toward solving the machine vision problems. The use of digital image analysis for satellite and airborne remote sensing systems is well established in forestry. Machine vision has evolved considerably in many areas of factory situations and for the recognition of specific shapes for character recognition and for military applications. To our knowledge, very little has been done to apply image analysis and pattern recognition to the forestry vision problems which have been introduced here. Some of the tools which we expect to be applicable and with which we hope to be able to perform some experiments include but are not limited to: mathematical morphology; fractal analysis; neural network analysis; and multichannel classification. With the adition of experience in subsumptive control, we expect to be able to have simple demonstration systems available within two years.

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Development of a Robotic Vision-Based Tree Embryo Handling System

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INTRODUCTION

I would like to begin by giving you some of the background of this project. This system was originally begun as a student final project for the Robotics and Automation program at the British Columbia Institute of Technology. BCIT has a mandate to provide technical education which is relevant to industry, and encourages student projects which address specific needs in industry to help provide that education.

This project was undertaken to meet a need of the Forest Biotechnology Centre of BC Research in their embryogenesis research. At a certain point in their process, the tree embryos must be moved from a batch environment into discrete test vials. This thankless task is currently being done by tweezer-wielding lab workers who often suffer eyestrain and fatigue due to the small size of the embryos at this stage (<2mm.). BC Research then was interested in an automated method of transporting the tree embryos from a petri dish into a rack of test vials. To this end, my partner and I discussed several bulk handling methods with Dr. Dane Roberts at BC Research, none of which were viable for various reasons. The approach we finally settled on was to employ a small revolute robot which would use a light vacuum to pick up the embryos and move them into the test tubes one at a time. To detect and locate the embryos we chose to use machine vision techniques employing an arm-mounted camera and an inexpensive video digitizer. The computer used for processing the video information and calculating the embryo locations was an IBM clone 286 with math coprocessor.

What I would like to do today is trace the development of this system as a typical example of a machine-vision application for any of you who may be contemplating a vision-based robotic solution to a manufacturing problem. I will also try to give an overview of the current state of computer vision in general and point out some of the pitfalls which may trap the unwary.

Description of Robot System

The robot we used in this system is a small 5 degree-of-freedom revolute design manufactured by CRSPlus of Burlington Ont. The size of the robot allowed it to fit inside the sterile hood needed to work on the embryos. It had the payload capacity to allow mounting of the video camera to the arm without drastically affecting the robot's motion. It used DC servo motors rather than stepper motors for smoothness and noise control, and it had provision for run-time interfacing to the PC. A thoughtful design of the end-of-arm tooling made up for the apparent deficiencies of a limited work envelope and having only 5 DOF's to work with. Finally, the cost of the base robot was only $20,000, a bargain in the robotic field.

Machine Vision Considerations

When we were deciding on our machine vision platform for this project, we had two choices. We could have used a rudimentary, inexpensive ($200) video frame-grabber and written our own image acquisition and manipulation routines, or we could have used a commercially available image acquisition board ($3,000) and the sophisticated software library ($7,000) which accompanied it. Although we chose to go with the first option primarily because of the educational benefit of writing our own software, other factors in this choice were the prospect of churning through reams of poor documentation learning another programmer's way of thinking, and the fact that the more sophisticated card also required a more sophisticated computer than we had available at the time. Commercial applications generally run on the fastest '386 or '486 available, since the size of the image generated by the high-end frame digitizer cards can easily exceed 1Mb and processing time increases accordingly. Our frame-grabber, on the other hand, creates images only 64kb in size, which are easily processed by a 12MHz '286.

Lighting

In any machine vision application the lighting in the environment must be taken into account and often must be tightly controlled. Fluorescent lighting is usually not acceptable, and shadows often need to be eliminated by judicious placement of indirect lighting. Sometimes the colour of the lighting needs to be controlled as well in order to bring out some feature of the image being processed. In the case of this project, we were able to reduce this dependence on strict lighting control by choosing a black background for the light coloured embryos. This gave the embryos a high contrast against their background for a wide range of lighting intensities and colours, allowing us to isolate the embryos in the digitized image with a simple adaptive thresholding algorithm.

Camera and Lens

Along with lighting, a proper choice of camera and lens needs to be made for each application, taking into account the desired resolution of the image, size of the image field, and the environment in which the camera will be operating. Some applications require the use of a colour camera, which can create far more problems than you can imagine, since the apparent colour of an object is even more dependent on variations in lighting than the apparent brightness of the object.

If measurements are to be taken with the vision system, either the camera must be fixed at a given distance from the target or some reference of scale must be included in the target field. Fixing the camera's position is the more common method, since using an optical reference entails writing code to find and measure the reference before processing the rest of the image. In this project, the camera mounting was somewhat problematic, since the small size of the embryos dictated that the camera be close enough to give the embryos some form in the video image. This placed the camera inside the working envelope of the robot, so a static fixed mount was unworkable. Instead, we mounted the camera to the side of the robot arm and relied on the repeatability of the robot to position the camera reliably.

Computer Vision in General

At this point I would like to digress briefly from the technical jargon and attempt to illustrate an important point about computer vision. Imagine that a person having been blind from birth were to miraculously acquire sight, how would you explain to him what he was seeing? What frame of reference could you use? To a lesser degree, this is the problem facing a computer programmer who is attempting to write a machine vision application. The computer "knows" nothing at all about the image it is "seeing". All it has to deal with is an array of numbers. It is up to the programmer to determine what information is to be extracted from the image and how to do so. Images which we can readily interpret as familiar objects are horrendously difficult to describe to a computer. Even the task of optical character recognition, with its two-dimensional simplicity, takes a considerable amount of programming sophistication.

In general, the process most machine vision applications follow to fulfill their purpose adhere to a common path. First, the raw image is acquired from the camera and stored in the computer as a memory image. The size of the memory image is largely determined by the video digitizer used, with higher resolution (and thus greater storage requirements) being associated with more expensive ($3,000 and up) digitizers. The digitizer we chose to use creates an image 256 pixels wide by 242 lines high in 256 shades of grey. This translates to a memory image of less than 61 kb, a size easily handled by a '286 based computer. The cost of this digitizer was about $200.

The second step in processing the image is usually some form of thresholding used to blank out unwanted portions of the image, normally the background. One or more levels of light intensity may be used to establish a threshold which is used to mask out pixels with grey levels above or below the threshold value. Determining an appropriate threshold level can be a problem if lighting is not strictly controlled to provide a consistent range of light intensities. In the embryo handler we developed a thresholding algorithm which would compensate for variations in light intensity over a limited range.

Normally, a simple thresholding of an image is not sufficient to eliminate all noise in the image, noise being loosely defined as anything that you are not interested in. Some form of filtering is usually performed on the image to eliminate noise and often more sophisticated filters are used to enhance certain portions of the image. In the embryo handler we used a low pass filter to eliminate specular noise and we also developed a method of erasing any object which was touching an edge of the image, since processing only part of an object would result in erroneous data.

With the pre-processing out of the way, processing of the resulting clean binary image could proceed. To generate a set of distinctive data for each embryo in a given image, we used a technique known as chain encoding. This is just one of several methods of discriminating between "blobs" in an image, but it seemed the best suited to the application we were developing for. Chain encoding involves describing the perimeter of each "blob" as a series of vectors, with each vector "pointing" to the next point on the perimeter. With this method we were able to determine the area, perimeter length, and centroid of each object in the image, as well as the location of each object in the image. To determine the position of the root of each embryo, we took advantage of their characteristic shape to define the root as the farthest point on the object's perimeter from the centroid of the object.

Finally, when image processing is complete and desired information extracted, something needs to be done with the information. In this case, the locations and orientations of all the embryos in an image are transmitted to the robot then the robot is commanded to run a program loop which cycles between the test tube rack and the petri dish, transporting each embryo in turn.

Overview of Industry

Although the digitizer we used for this project required us to do a lot of low-level programming, a company developing a commercial application would typically use a much more sophisticated digitizer/software package. Because this is a relatively new industry, each application developed is normally a turnkey solution to a specific problem, so the cost of development is usually reflected in the cost of a system. A minimal system consisting of a fast '386 or '486, video camera, video digitizer and software will cost around $10,000. Prices go up from there as features are added or requested.

Some of the things I would like to caution you about, if you were considering a machine vision system, are the issues of compatibility and capability. Most systems being sold today are developed for a MS-DOS based platform. The near-infinite variety of such machines and their peculiarities make perfect compatibility between computer and digitizer a distant dream, particularly with the higher-end digitizer cards. It seems that problems increase manifold with cards over 1k by 1k resolution. The situation with such equipment is not unlike high-end audio equipment, where you really have to love tweaking the hardware in order to get the greatest benefit from it. The computer itself, if not properly put together, could prevent a system from working reliably. Power supplies must be both powerful and clean to ensure trouble free operation, and the motherboard itself should be of high quality. Tower cases are often an unsuspected culprit in problem systems because the horizontal position of the expansion cards prevents effective cooling of the cards by convection.

Another source of trouble in commercial systems is in the software. Many users request that a system run under Windows 3.x, not realizing that the additional overhead of Windows can slow an already computationally expensive application down to a crawl. Furthermore, programming tools and techniques for Windows are only now beginning to be widely understood and used by computer vision programmers.

Conclusion

Although what I've said here doesn't sound encouraging, things are improving. Vendors of machine vision systems are becoming more proficient at writing for Windows, and as their client lists grow, more programs are developed with a wider variety of applications. The advent of a 32 bit operating system along with a 32 bit bus architecture should enable computers to process images significantly faster than they are able to now. As image processing becomes more mainstream, the price of a versatile system should drop into the realm of personal affordability. What's more, I feel that our development of this robotic application will help show that a useful application of machine vision need not be excessively expensive. Total cost of the prototype system is estimated at $30,000, including robot.

The Potential Use of the Sentinel UAV System in Forest Management

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SUMMARY

A civil variant of the CL-227 Sentinel Unmanned Air Vehicle System can conduct certain tasks, for forestry management and other industries, more effectively and safely than ground vehicles, helicopters and airplanes.

A key emergency role is in support to forest fire fighting. Fire mapping can be accomplished rapidly and accurately to provide for quick optimal planning of safe use of resources. Search and rescue and communications relay (UHF/VHF) can be supported.

Routine aerial photography/remote sensing can be provided for fire detection, cutting boundaries, inventory management and insect damage assessment. Road, track and power and telephone line conditions can be established. Precision spraying of small areas can be supported.

The CL-227 Sentinel System is at present in development for military roles. The system comprises: a helicopter like air vehicle, various mission payloads, an air/ ground data link, ground control station and launch and recovery equipment. For routine operations a minimum 2 man crew is sufficient.

Viability of a civil variant depends on cost competitiveness, degree of safety enhancement and the character of civil certification requirements.

1. INTRODUCTION

Development is preceding in many countries for military applications of unmanned air vehicle systems. Para-military applications include coast guard functions, and anti-drug program enforcements. A particularly efficient concept is that of a vertical take-off and landing air vehicle which minimizes the size and number of ground equipment, and personnel.

With the experience gained in military applications, extension of the use of unmanned air vehicle systems for commercial roles is logical. This paper describes the Canadair CL-227 Sentinel System as it might be applied to forestry management support and other commercial applications.

The experience gained at Canadair with the CL-215 and CL-415 water bombers and consequent relationship with the forestry industry and supporting government agencies provides a valuable synergy.

2. BACKGROUND

Canadair is a world leader in unmanned airborne surveillance systems. The CL-89 System is in service with the United Kingdom, French, Germany and Italian armies. The CL-289 System is in service with the German army and will be shortly in service with the French army.

The CL-227 Sentinel System is in the development process. It has Land and Maritime versions. In 1981-92, the air vehicle was developed and proven. In 1989 a joint US/Canadian evaluation was conducted. In 1989 and 1991 demonstrations of the Maritime version were carried out for NATO.

Work is proceeding to improve the CL-227 systems' capabilities including:-

- a higher gross take-off mass capability
- a higher power engine
- a larger composite fuel tank
- GPS for autonomous navigation
- additional payload capacity and variants
- improved mission planning control station performance including man machine interface

3. SYSTEM OVERVIEW

3.1 General

The figure provides a view of the prime mission equipment of the land configuration system. Key elements are:

- modular mission payloads (FLIR, daylight TV)
- data link
- ground control station
- air vehicle(s) (number is workload dependent)
- launch and recovery equipment

3.2 Modular Mission Payloads

All payloads are plug in and out of the air vehicle. The air vehicle can be re-configured to carry a different modular mission payload within 15 min. Imaging sensors are mounted on a two degree of freedom stabilized gimbal.

The forward looking infrared sensor provides day and night imaging capability with excellent heat source sensing. It is a passive 8-12 micron infrared image with 2 fields-of-view (search and close-up).

The television camera is a medium resolution black and white charge-coupled device fitted with a zoom lens. Television provides a superior capability during daylight, particularly when the humidity is high.

3.3 Data Link

The data link provides a narrow bandwidth uplink to transfer commands and data to the air vehicle, a video bandwidth downlink to transfer imagery from the payload to the ground control station, and a narrow bandwidth downlink to transfer status data from the air vehicle to the Ground Control Station (GCS).

It comprises the surface data terminal and the airborne data terminal which communicate by means of frequency modulated radio frequency signals, with a multichannel capability. The surface antenna can be mounted on a 3/4-ton trailer. The terminal can be easily and rapidly moved to a new location. The data link provides a radius of action of typically 100 km.

3.4 Ground Control Station

The ground control station comprises one to two computer work stations in a shelter mounted on a truck or van.

The computer hardware utilizes a Motorola based multi-processor architecture and VME bus. Two video cassette recorders allow simultaneous record and playback of imagery and a hard copy screen printer can be provided.

The GCS provides real-time commands to the air vehicle and to the payload. It is also used to plan the mission. The operator commands are given through keyboard, track ball and joystick. The operator sits in front of large, easy to read colour displays. All displays and controls are human engineered and graphic oriented. The GCS design provides for a rapid accurate correlation between the imagery with its annotated position coordinates and the digital map.

The air vehicle is controlled by changing the flight plan navigation way points, rather than piloting the air vehicle. Training requirements for the operators are low, typically around 2-4 weeks.

3.5 Air Vehicle

The air vehicle is a small unmanned helicopter comprised of: power module, propeller module, with six rotor blades and four legs, and payload module. The modular concept ensures ease of transportability and maintainability.

The air vehicle provides typically 3 hours of flight time and reserve with about 30 kg of sensor payload.

The power module consist of a gas turbine surrounded by the fuel tank. The engine generates electrical power. Standard truck diesel fuel is used. The air vehicle has two coaxial rotors turning in opposite directions. The cyclic and collective pitch of the blades is controlled by actuators equally disposed around a double swashplate similar to a helicopter. Yaw control is maintained by two magnetic particle clutches which transfer torque between the hubs. The autopilot prevents ground commands from placing the air vehicle at risk; this minimizes the training required of the air vehicle operator. The air vehicle carries an IFF transponder and strobe light for air traffic control and safety.

3.6 Launch and Recovery

Launch and recovery is highly automated and conducted by the GCS computers. A four wheel drive pick-up truck can be equipped with a hoist to handle the air vehicle, a fuelling/de-fuelling rig with integral fuel tank and place for the transport of the air vehicle and engine start equipment. Access to and operation in the 50m square take-off and landing areas is easily accomplished.

4. FORESTRY MANAGEMENT ROLES

These roles can be conveniently divided into two categories: emergency and routine. By their nature emergency roles are time critical and dictate a system design toward capabilities directed to rapid launch response, rapid imagery analysis and map correlation, timely communication interfaces and maximum daily flight frequency.

Support to fighting forest fires is a key emergency function. Fire mapping can be accomplished rapidly, based on a correlation between the imagery display annotated by GPS coordinates and the map graphical display. The imagery provides guidance for lines of ground access toward the fire lines, for preferred location of back fires and cutting clear lanes. The best areas of attack for water bombers can also be identified. The UAV system has advantage over manned aircraft approaches in the speed of response, rapidity of processing data, accuracy of data and less safety restrictions on operating in smoke. Twenty-four hour operations over a number of days are easily sustained.

Use of a dual payload of an imagery sensor and a communications relay permits the UAV to greatly expand the range of transmission and improve the coordination between various facilities. The communication relay application can be used on all flights, emergency and routine.

A third urgent role is search and rescue. Large area surveillance during each flight permits rapid infra-red detection of lost or injured persons. Real-time assistance can be provided to expedite routing of rescuers.

Use of remotely located video monitors closer to the emergency areas further hastens activities.

A less urgent application is precision spraying of single or several trees, or small areas, possibly in poorly accessible areas, to supplement helicopter or airplane spraying, or to minimize the sprayed area, for optimal environmental impact.

Routine fire detection area surveillance can be carried out. Typically line-of-sight to the UAV can be achieved to permit a coverage of 10,000 sq.km about the surface data terminal. Options to increase the speed of coverage include movement of the surface data terminal a number of times during a flight, and use of airborne tape recorders for playback during flight at higher flight altitudes.

Routine aerial photography/remote sensing provides for a number of diverse applications.

Cutting boundaries can be quickly established, correlating the imagery and map displays. Small cutting areas can be defined easily, with a facile extension in the future, if desired, to tree by tree cutting planning. The mapping also provides for preparation of an inventory catalog. A related activity during the mapping flights, or if required, special flights is the detection and inspection of insect damage.

Planning for roads can be readily carried out. Particularly near the end of winter and at other times. Conditions of roads can be identified to preplan the scale and priority of road repairs and to confirm accessibility. Washouts of roads and train tracks due to spring run-off and heavy rainfalls can be quickly established. The same and other flights can monitor the condition of power telephone.

The above applications are particularly useful in mountainous terrain operations, where road access is limited, and where safety constrains manned flights.

5. SYSTEM OPERATION

5.1 General

For routine operations a staff of two persons is adequate. Emergency operations might require the support of about 2-4 more people. The degree of training is low and the required skills easily picked up.

The system crew receives mission tasks from an operations centre and processes these tasks into flight plans with the aid of the sophisticated data processing facilities in the ground control station. The crew transmits either preprogrammed or manually generated air vehicle and payload commands and receives payload video imagery and air vehicle and payload telemetry data.

Image interpretation is facilitated by supplementing the video display with terrain, cultural and situation data displayed on the digital map monitor. A soft copy is available of the imagery from the complete flight and freeze frame hard copies of selected single frames of video images transmitted by the airborne payload.

5.2 Missions

A typical flight may include one or more of three types of tasks: search or surveillance (area, route or line, point), spraying, and communications relay. Flight plans are prepared and sent via the data link to the air vehicle.

Concurrently with the mission planning the air vehicle is prepared. Electrical power is applied and built-in test checks performed and the inertial navigation system automatically aligned. The engine is started, and the air vehicle commanded to take-off.

The air vehicle automatically flies from navigational way-point to way-point, commencing the search pattern on arrival at the search area. The operator searches by steering the payload sight line or by analyzing the image as the air vehicle translates across the ground. The operator adjusts the controls (for example, field-of-view and focus) to optimize the image. The imagery is displayed along with the continuously updated annotation giving the location of the air vehicle and the location of the centre of the image. When the location of a point on the image is desired, the operator moves the cursor on the display and the point's coordinates are automatically displayed.

The operator monitors progress and status. At any point, the operator can assume manual control and depart from the preplanned mission, in response to findings of the mission or to new task demands from the operations centre. A return to base warning is issued at the fuel state for safe mission termination. The air vehicle flies automatically to the recovery way-point, at which descent is initiated and landing completed.

5.3 Preparation for Next Flight and Turnaround

After landing the air vehicle is refuelled and a visual post-flight check performed. The serviceability is checked using automatic test equipment. The air vehicle is turned around in less than 30 minutes.

6. CONSIDERATIONS

The viability of a commercial UAV system is dictated by three considerations.

The first aspect is the cost competitiveness with the complement of alternatives: airplanes, helicopters and ground vehicles. With the system as a derivative of a military system in widespread use, the requirement would be to achieve a commercial development cost that can be amortized over the expected commercial market. In addition operating costs must be realized at acceptable levels. An input to the cost analysis is any gain in forestry sales as a consequence of the use of a more effective system for forestry management.

The second aspect is safety of ground and flight personnel. Use of a UAV system may reduce the number and hazards of high risk flights. Safer employment of ground personnel fighting forest fires can be considered. The import of finding lost or injured persons can be taken into account.

The third aspect is the character of civil certification achievable for operations over semi-populated or populated areas. Constraints may impose a costly system design penalty or impede efficient, effective operations. At present there are no civil certification standards for a UAV systems. Standards do exist in several countries for extension of UAV flights outside military ranges but still within protected airspace. Development of civil certification standards may take time. The acquisition of a certificate may be costly and lengthy.

An aspect with interplay between system operating costs and civil certification is the process of obtaining insurance and the cost of insurance.

7. ACKNOWLEDGMENTS

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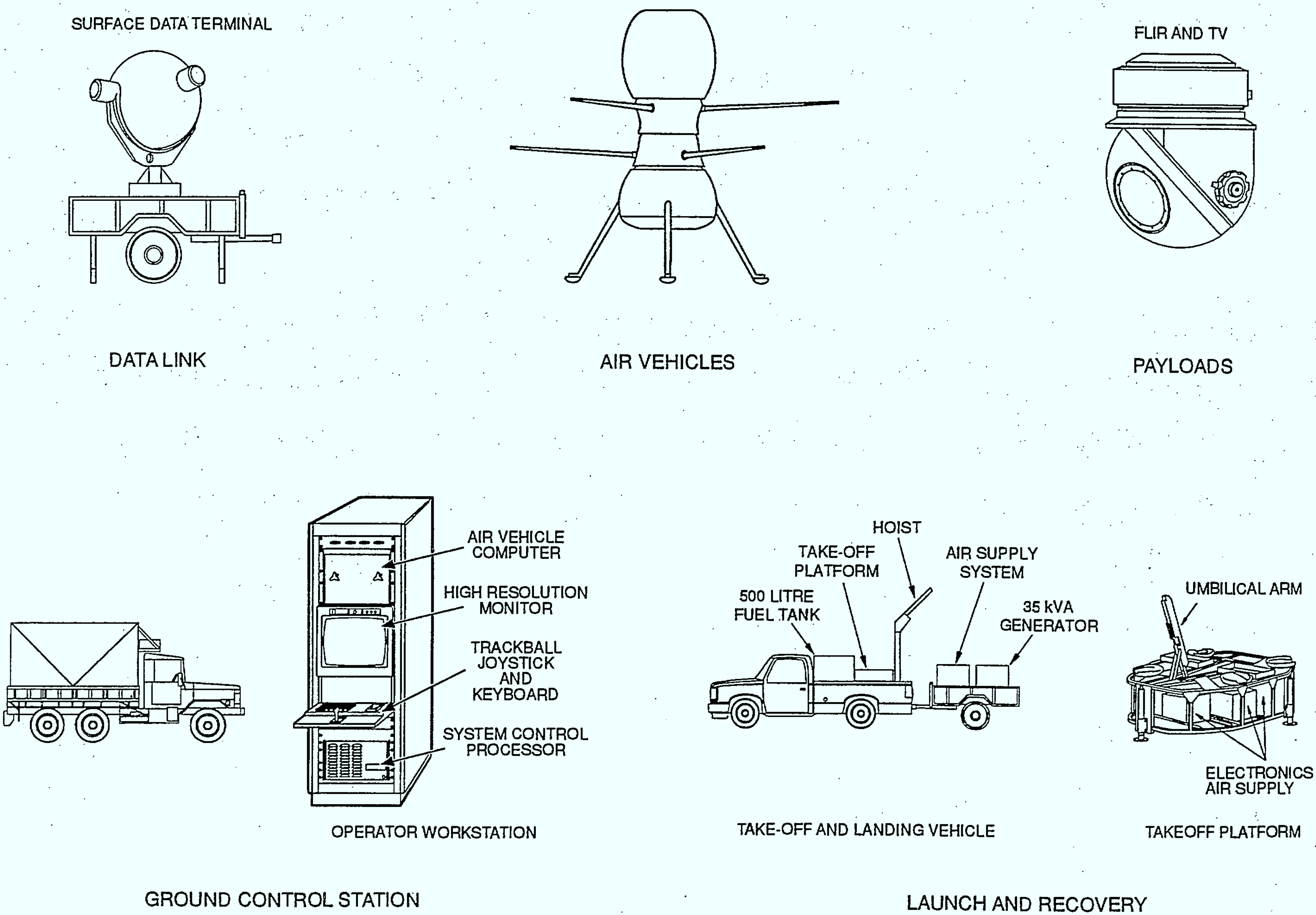
SURFACE DATA TERMINAL
DATA LINK
AIR VEHICLES
FLIR AND TV
PAYLOADS
AIR VEHICLE COMPUTER
HIGH RESOLUTION MONITOR
TRACKBALL JOYSTICK AND KEYBOARD
SYSTEM CONTROL PROCESSOR
OPERATOR WORKSTATION
GROUND CONTROL STATION
HOIST
TAKE-OFF PLATFORM
AIR SUPPLY SYSTEM
500 LITRE FUEL TANK
35 kVA GENERATOR
TAKE-OFF AND LANDING VEHICLE
UMBILICAL ARM
ELECTRONICS AIR SUPPLY
TAKEOFF PLATFORM
LAUNCH AND RECOVERY

Digital Orthoimagery and its Application in the Forestry Industry

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INTRODUCTION

The management of geographical information has undergone tremendous change over the last few years. The traditional map has been substituted by the digital map file. Computers must have digital data and traditional maps are not such a medium.

The shift towards computerized geographic databases has not always been easy. There are conflicting requirements of user groups, non-standard specifications and hardware and software considerations. Various estimates put the cost of data capture, preparation and structuring in the 65% to 85% range of the overall GIS implementation. It is also the most time consuming and, arguably, the most difficult to manage.

The map making process is expensive and slow because it is labour intensive and requires highly specialized equipment, such as, aircraft, cameras and stereoplotters. It is slow because it is subject to the vagaries of the weather and seasons for the photo and surveys. It is complicated because it combines specifications for land surveys, aerial photography, mapping, database structures, data formats and the GIS package.

It is contentious because all the participants must have input to the project specifications. Invariably there will be parties who feel that the dataset is too detailed or not relevant to their particular needs.

Participants must wait for the full duration of the the mapping phase before they have full geographic coverage. All maps have redundancy; not everyone wants all the information on a map.

Because the process is labour intensive and relies heavily on human interpretation, it is prone to errors of omission and interpretation. Quality assurance is a major factor in any mapping project.

And lastly, there are problems with the age and availability of data. Most maps are about four years old and the rate of updating is slow.

All of these have conspired to create difficulties. However, the present consensus is that the benefits of implementing a GIS far outweigh the costs of setting up the system.

Basic map data is collected photogrammetrically from aerial photographs. Photogrammetry is still the most cost-effective approach to mapping, and the methods are tried, tested....and,most importantly, accepted.

PHOTOGRAMMETRIC DATA

The creation of a basic map for inclusion to a GIS is very time consuming. Often the data collected has to satisfy many end-users who have to pay for data that is redundant to their needs.

Once the map compilation data has been acquired it is often out of date. There are many GIS/mapping programmes underway where the aerial photography is three to four years old. The delays can be attributed to two factors;

i) maps are compiled to satisfy many users when most people only require a subset of the data

& ii) the process of stereo and vector data compilation requires sophisticated optical equipment and trained personnel

An ambitious mapping programme will eventually encounter a limitation with the number of machines and trained personnel available.

One of the primary layers on any map is contours. The collection of this data is used to create a Digital Elevation Model (DEM). The elevations are collected on a stereo plotter from the stereo pairs of photographs.

DEM data can come from one of four main sources:

i) stereoplotter data from the same photos being rectified

ii) existing DEM data from similar or larger scale photos of the area

iii) from existing maps

& iv) by cross-correlation of stereo pairs of the photos being rectified

Of these sources, DEM's generated from existing contour maps are the least desirable and should be viewed as a last resort. They can be used when high accuracy is not required. The first two sources are the most common.

These processes are slow and costly and are superseded by digital orthoimagery. It is faster and cheaper to create maps, easier to update them and more information is available.

DIGITAL ORTHOIMAGERY

The orthorectification process entails the removal of all the distortions in the aerial photography. These come from:

i) the lens: the only point on a photo with the true scale is the principle point.

ii) the flight attitude of the platform; this is the pitch, roll and yaw

& iii) relief distortions

The photos are converted from a perspective geometry to an orthographic geometry suitable for mapping.

The images are geometrically correct and can now be imported to the data management system/GIS. The user can now compile his own vectors on an as-required basis through on-screen digitizing; so-called "heads-up". All major CAD and GIS can accept the imagery.

The photos must be controlled with ground control points. These surveyed points have an x, y and z co-ordinate. This process is called aerotriangulation or bridging. Once this has been done the photo block is controlled.

The photos are scanned to produce a digital raster image of pixels whose brightness corresponds to the original photo. The brightness values are from 0-255 and are byte-coded. The pixel size is determined by the scanning resolution and the higher the resolution the smaller the pixel.

The resolution depends on some variables. These are:

i) the scale of the required maps and their positional accuracy

ii) the initial photo scale

iii) the quality of the original photo emulsion

A poor quality photo will never yield a good quality digital counterpart; the photos must be of the same quality as ones used for stereo compilation...a poor quality photo can not easily be improved. Diapositives are best for good results, and the most desired. (The software has some image processing capabilities. However, it must be remembered that radiometric fall-off in a photo is not uniform across the image, and often many man hours of work will be needed to rectify the data. This cost is often disproportionate to the cost of getting good photography at the outset).

Intera's investigations have shown that scanning at 25 microns (+ or - 1000 dpi) is sufficient to permit orthorectification that meets the accuracy requirements for mapping scales that are four times the original photo scale: that is to say that 1:40,000 scale photography can be used for 1:10,000 scale mapping. By having smaller scale photography, there are cost savings in the number of photographs necessary to cover the target, the numbers that have to be scanned and bridged and, subsequently, the file sizes. Higher resolution means more data to process.

A scanned air photo will yield pixels whose nominal size is given by the following formula:

$$\text{Size (m)} \quad \frac{\text{scale fraction x scanning resolution (microns)}}{1{,}000{,}000}$$

A 9 x 9 photo scanned at 25 microns creates a raster of around 9200 x 9200 pixels. Because each pixel is byte-coded, the file is in the order of 85 Mb. Colour photos give file sizes three times larger than black and white, because each pixel requires three bytes...one for each colour.

The scanned air photo still contains all the systematic and random distortions present in the original photograph. The camera calibration is essential to remove the lens distortion. Orthorectification will remove these distortions on a pixel-by-pixel basis. The process georeferences the pixels to whatever co-ordinate system desired.

<u>The Digital Elevation Model</u>

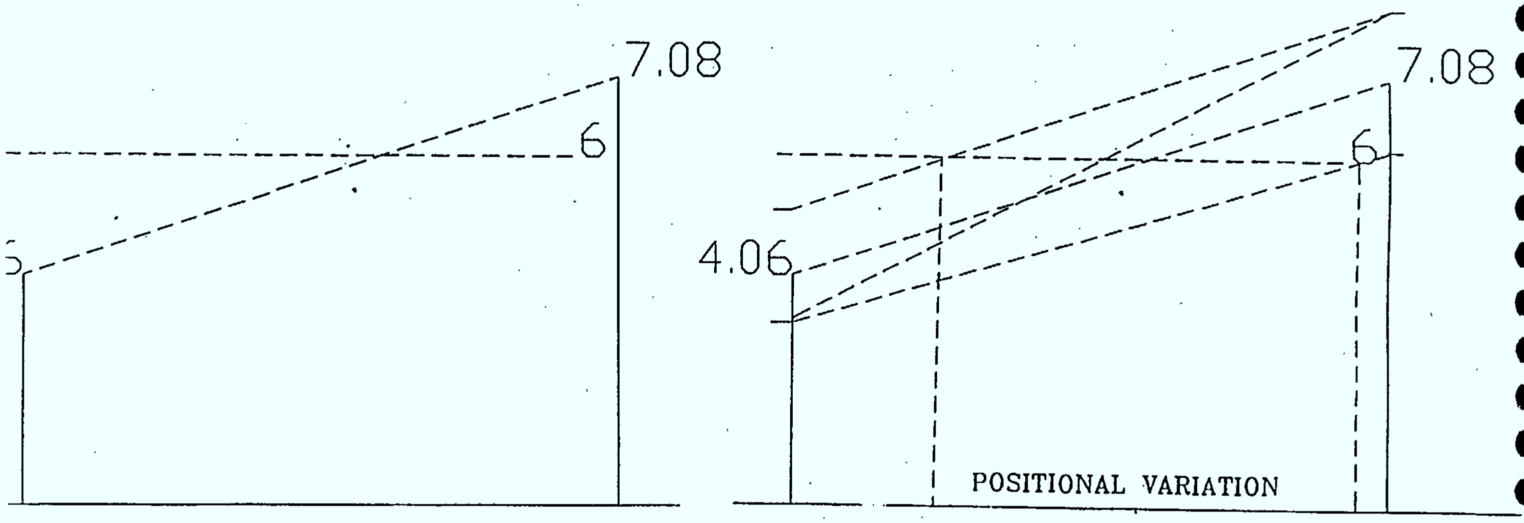
A DEM is a collection of x, y, and z points of known accuracy and so distributed that they are sufficient to permit terrain modelling.

Terrain modelling includes

i) contour production
ii) production of profiles and cross-sections
iii) estimates of volumes
& iv) estimates of slopes and aspects

Both the accuracy of the points and their distribution must be considered when a DEM is used for terrain modelling

A DEM consisting of highly accurate points is useless if the number is insufficient to represent the area properly. Alternatively, a large number of inaccurate points are also of little use. It is important that the positional accuracy of the points be known. The following diagram illustrates the point:



On large areas where the topography is uniform a small number of points is sufficient. In areas where there are large and abrupt changes in the topography more points are necessary.

Image matching, or cross-correlation, can be used to create a DEM. The software examines pixels in each photo of the stereo pair. When it finds a match it calculates the elevation value for that pixel based on known parameters. Cross-correlation does not work well in areas where there are tall vertical objects, such as buildings, or over featureless terrain, such as sand dunes and bodies of water. The scale of the photography very much determines what is and what is not a tall object: trees would be considered such an object on 1:4,000 scale photography but not on 1:20,000. A 2mm mapping grid might take 4-8 hours with traditional photogrammetric methods. Using the cross-correlation this falls to two minutes.

CONCERNS

There are a number of concerns in implementing a digital orthoimage landbase. Most of the following have been raised by prospective users of the data.

The two most frequently asked questions are related to file size and the cost of the product. File sizes are large. However, with the advent of new storage technologies, refinement of compression software and improved processing speed, digital orthoimagery has become a viable option. The following table outlines the file sizes.

DIGITAL ORTHOPHOTO

Scanning Res	100	75	50	25	18.75	12.5	um Res
File Size	3.1	5.4	12.2	49.0	87.1	196.0	Mb/Model (60%)
Photo Scale	*Pixel Size*						
3000	0.30	0.23	0.15	0.08	0.06	0.04	Metres
4000	0.40	0.30	0.20	0.10	0.08	0.05	
5000	0.50	0.38	0.25	0.13	0.09	0.06	
6000	0.60	0.45	0.30	0.15	0.11	0.08	
7000	0.70	0.53	0.35	0.18	0.13	0.09	
8000	0.80	0.60	0.40	0.20	0.15	0.10	
9000	0.90	0.68	0.45	0.23	0.17	0.11	
10000	1.00	0.75	0.50	0.25	0.19	0.13	
11000	1.10	0.83	0.55	0.28	0.21	0.14	
12000	1.20	0.90	0.60	0.30	0.23	0.15	
13000	1.30	0.98	0.65	0.33	0.24	0.16	
14000	1.40	1.05	0.70	0.35	0.26	0.18	
15000	1.50	1.13	0.75	0.38	0.28	0.19	
20000	2.00	1.50	1.00	0.50	0.38	0.25	
25000	2.50	1.88	1.25	0.63	0.47	0.31	
30000	3.00	2.25	1.50	0.75	0.56	0.38	
35000	3.50	2.63	1.75	0.88	0.66	0.44	
40000	4.00	3.00	2.00	1.00	0.75	0.50	
50000	5.00	3.75	2.50	1.25	0.94	0.63	
60000	6.00	4.50	3.00	1.50	1.13	0.75	

The advent of mass storage media such as CD-ROM's, DAT's and Exabyte tapes have certainly diminished this problem. An exabyte tape can hold 2.5 or 5 gigabytes of information, with jukeboxes of up to a hundred available.

INTERA has found that there are substantial savings in costs when implementing a DOI programme. These are between 30% and 70% depending on the number of map sheets. Most vector work can be done in a "heads-up" mode which needs less expertise.

Outlined below are some other concerns:

i) Loss of stereo capabilities: aerial photography is still the input medium, and it is in stereo
ii) Can existing vectors be overlaid?; yes
iii) Is new hardware and software necessary?; most organizations have adequate capacity. Your GIS must work in raster and have good storage.
iv) Is additional training needed?; competent computer literate people can use DOI
v) Is special photography needed?; No. However, it is better to have the flight lines orientated to the map sheets
vi) Can we use either colour or black & white photography?; Either can be used. File sizes for colour are three times larger.
vii) What and how much ground control is needed?; The same level of control is needed as for a traditional mapping programme
viii) Accuracy; it is 2 pixels rms.

<u>BENEFITS</u>

The following is a list of the benefits of utilizing digital orthoimagery in a mapping programme;

i) Visual representation and full information
ii) Ease of use, with no need for special training beyond normal GIS courses
iii) Incremental conversion on an as-required basis
iv) Updating can be done more rapidly and cost-effectively by the user
v) Less data to vectorize
vi) D.E.M. creation: slope and aspect information
vii) Existing vectors can be overlain
viii) on-screen digitizing can take place
ix) No need for sophisticated hardware and software. Most GIS will accept the data
x) Air photo is the input medium. It is cheap, understood, has a high level of information, and has stereo capabilities
xi) Any <u>good</u> air photo can be used, be it new or existing
xii) The data is of a high resolution
xiii) Soft copy parallax measurements should be possible

CONCLUSION

Digital Orthoimagery is now a viable product because of the advances in computer technology. GIS are increasingly being able to store and work both raster and vector data. More and more users want, and need, up-to-date information which can be rapidly and inexpensively updated by themselves. They wish to have more control over their databases. Their investment in these can be enhanced by having an image as an underlay. The data has better visual interpretation and provides a record of change. It is also a lot cheaper to produce maps this way than by conventional methods. This is truly the map of the future.

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Symbiotic Systems for Forest Production and Inventory Management

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1.0 Introduction

Planning of forestry activities takes place in a complex and highly uncertain environment, and is often influenced by conflicting demands. Decisions are subject to many conflicting factors, including the need for large capital investments, a long-term planning horizon, high susceptibility to risks, growing demands on the forest land base, more stringent forest renewal policies, public concern for environmental quality and sustainable development, and increasing international competition.

The use of computer technology and particularly GIS (Geographic Information Systems) systems, to address such issues is steadily increasing, but much of it has been focused on forest inventory data collection, data management, and mapping functions. Relatively little emphasis has been placed on operations planning, management, and control.

Traditional computer technologies have typically been too complex to use and hence have seldom been placed directly in the hands of the decision makers. This has tended to isolate the decision makers from crucial and timely information and make them overly dependent upon trained computer specialists as intermediaries.

The Vancouver based Symbiotic Systems Group of National Research Council, for several years, has been investigating and creating[1] ways in which to improve the application and integration of both existing and new computer technologies in the operational aspects of forest management. NRC's approach has involved three significant technologies:

- Symbiotic Systems technology,
- object-oriented programming,
- a layered software architecture

This paper describes their features and benefits, and illustrates how together they offer important advantages in placing computer technology directly in the hands of decision makers.

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[1] The Council of Canadian Forest Ministers' 1988 report, in recognition of such problems, made a number of specific recommendations on innovations and technology. One of these sought a greater commitment to R & D by " .... such organizations as the National Research Council (NRC)." Another recommendation (#7) suggested a focus on "... decision support systems for forest management." among other things.

2.0 Symbiotic Systems

A Symbiotic system is defined (Scriabin 1986) as a system which includes a human expert and a computer, and which creates symbiosis between the two. Webster defines "symbiosis" as "...the intimate living together of two dissimilar organisms in a mutually beneficial relationship".

In a symbiotic system, the "dissimilar organisms" are the human and the computer. Each, by working in its own way, helps the other component to further improve the current solution of a problem. In particular, the computer must cater to the human visualization[2] and creative ability, for it is here that the human still far outperforms the computer.

In a well designed symbiotic system the action of one partner (human or computer) leads to a constructive response by the other. The resulting synergism has been demonstrated to lead to better solutions than can be achieved by either partner alone, or by other non-symbiotic interactive systems (Scriabin et al, 1988).

This synergism can be achieved if the computer system appears to think in the same way as the human, drawing and manipulating the same kinds of graphics the human would like to use as visualization aids. It is important to note here that the human experts do not simply "see" the computer graphics, but they "visualize" some aspect of the problem in the context of their own prior knowledge and experience. The actual graphics on the screen, in a symbiotic system, provide the stimulus or "trigger" for this visualization process in the mind of the human expert.

A variety of symbiotic systems have been developed by the Symbiotic Systems Group at NRC in areas as diverse as airport planning, transmission line design, personnel scheduling, and forestry planning. Each of these applications was implemented using an object-oriented software development environment which has proven to be a very effective means to create symbiotic systems.

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[2] Here "visualization" is used in the dictionary sense:- "to make visible, especially to one's mind". The emphasis is placed on seeing in the mind what is not actually visible, rather than in the popular computer graphics sense, where the emphasis is placed on achieving maximum visual realism.

3.0 Object-oriented Programming

Traditionally, computer-based decision support systems have used procedural languages such as FORTRAN, PASCAL, and C. Fourth generation languages, which often accompany database management systems, have also become popular. Lately, use is also being made of expert systems. Typically in these systems, programs and data (knowledge bases and databases), are stored in separate files, and the program files operate upon the data files to generate the information for the decision-maker.

Recently a number of object-oriented programming systems (OOPS) such as SMALLTALK, AUDITION, ACTOR, and C++ have become commercially available. These languages feature a significantly different software development approach. In OOPS, programming is achieved by creating objects which are shadows of real-life objects. For example, cut-blocks, fallers, yarders, loaders, and contractors in the logging industry. These shadow objects encapsulate the properties of real-life objects (e.g., daily production rate, crew size). More than that though, these objects can also understand life-like messages, such as "load logs" for a loader and "fall trees" for a faller. In response to such messages, they mimic the behaviour of their real-life counterparts, in loading logs and falling trees. Finally, the shadow objects often have graphical icons which visually represent the real objects.

An object-oriented programming approach offers significant advantages over traditional programming:

- Objects encapsulate properties and behaviours of real life objects and thus subdivide the complex world into smaller, simpler pieces.

- An object can be developed and refined incrementally. At each stage of development something concrete and self-contained is available.

- Multiple copies of objects can be made, each one inheriting the characteristics of the original prototype. Furthermore, these copies can be specialized as required.

- An object can be re-used wherever required.

- Decision-makers are able to relate to object-oriented solutions readily because of the one-to-one relationship between real-life objects and the shadow objects.

FS2000 - NRC - Symbiotic Systems **Kotak - Whale**

Some OOPS also offer a capability to graphically represent objects, thus affording a visually rich interactive decision-making environment. Such systems allow the decision-makers to quickly assess situations by "look and feel" but without sacrificing quantitative data when it is required, and thus they provide an excellent basis for the symbiotic systems approach.

AUDITION, is one such object-oriented programming environment. However, AUDITION goes one step further than most OOPS, and includes a theatrical paradigm based on the use of objects called 'Performers' and 'Stages'[3]. Performers can be copied, or 'cloned' and the clones can quickly be given customized properties and behaviours, allowing for very fast incremental development. Stages are specialized performers that can hold other performers thus providing a scoping mechanism, which is not available in other object oriented programming systems.

The power of this theatrical paradigm is twofold. First, the paradigm is easy to understand and, second, the ability to layer substages over a stage and superstages below it parallels the typical multi-layered environment found in real life (e.g., cut-blocks which are part of a division, which is part of a region, which is part of a company). These features of the paradigm allow methodical and logical decomposition of complex multi-layered problems.

These features of OOPS environments and the theatrical paradigm combine to improve the software developer's speed and flexibility and ability to manage the programming complexity. These features encourage rapid prototyping thus reducing the cost, compared to traditional or other object oriented technologies, of trying out many alternatives. Together these lead to the development of user-friendly and intuitive decision support environments, and assist in achieving a symbiotic relationship between the decision-maker and the computer.

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[3] AUDITION's theatrical paradigm, is implemented through "prototype" based object structures (Performers) using delegation, which are layered on top of a class based object system with inheritance, similar to Smalltalk. Lieberman (OOPSLA '86 Proceedings, September 1986) points out some of the added benefits to the programmer, in both flexibility and power, of prototypes and delegation over classes and inheritance, for object-oriented programming languages. AUDITION combines both paradigms.

4.0 Layered Architecture

The Symbiotic Systems Group has developed, over several years, a layered architecture approach for the integration of existing and future computer technology for forest management decision makers.

The objective of NRC's layered architecture is to develop an object-oriented, integration framework which builds upon existing forest-land domain knowledge (e.g., growth/yield models, silviculture regime models, protection models), and forestry databases (e.g., GIS, forest record keeping data, forest inventories), and yet is flexible and robust enough to accommodate new technologies as they come on stream.

This layered architecture, which is itself object-oriented, includes three logical layers:

- the GLUE layer
- the GLASS layer
- the application layer

as illustrated in Figure 1.

4.1 The GLUE Layer

GLUE stands for "Graphically Layered User Environment" and is a logical layer containing all the tools required for exchanging information with the database and knowledge-base components (e.g., GIS, RDB, spreadsheets, models) in an integrated decision support environment.

The GLUE layer is the foundation layer upon which the other layers exist. This layer is largely invisible to users but it contains software objects which provide linkages (also referred to as "software ports") to existing forest industry computer databases and a variety of model-based forestry science and information. It can also link to corporate accounting and cost databases. Being object-oriented, the GLUE layer can readily be extended with links to new software technology and models as they are developed.

On top of the GLUE layer sits the next layer called GLASS.

4.2 The GLASS Layer

GLASS stands for "Graphically Layered Application Support Systems" and is made up of tools for manipulation and analysis of information (e.g., charts, graphs, spread-sheets, editors)

The GLASS layer contains generic objects which are necessary for all forestry decision support applications, but which themselves are not applications. GLASS objects are visible to the user and may be called up automatically or upon specific user request. GLASS objects provide a transparent access into the GIS and database components by handling the communications with the GLUE objects.

Like GLUE objects, GLASS objects can be copied and reused as many times as needed. Because they are objects, they can also be easily customized and enhanced as new requirements arise.

4.3 The Application Layer

Finally, at the top, lies the application layer, containing the shadow objects normally visible to the user. This layer may contain one or more user applications providing support for planning and scheduling activities related to long, medium and short term forest management tasks. The user should only ever need to learn one user interface. Access to GLUE objects should be transparent such that the user need not worry about database or GIS formats, nor data structures needed by various forestry models. Instead the user deals directly only with the shadow objects of the application layer.

Because this conceptual framework is itself an object-oriented design, the three layers, GLUE, GLASS and application, can be replicated or "cloned" in whatever combination suits a particular circumstance.

For example, a complete forest management application, illustrated conceptually in Figure 2, shows three parallel stages, long, medium, and short term, each containing three nested stages. Each application stage is designed to support a specific set of decision makers and a specific level of decision making. In order to support the decisions at these levels it is necessary to consider the information required to make those decisions and the impact of the decisions in short and long terms.

Note that the integrity of the three levels of planning and scheduling is maintained by providing links between them at the GIS and database level. Each application can also connect to an appropriate set of models to support that level of decision making. For example, the long-term planning stage would need to access growth and yield models, whereas the short-term stage may need to access a linear programming based log allocation model.

As distributed, network-based computer technology evolves, it is feasible to visualize these three applications residing on different physical computers, yet being transparently linked together(at any level in the layered architecture) through a local or even wide area network. Research is already under way in the Symbiotic Systems Group laboratory to exchange objects between applications in a local area network.

5.0 Forestry Examples

Two applications are described illustrating all three of the fundamental technologies described earlier, namely: Symbiotic Systems, object-oriented programming and layered architecture.

In the context of these two applications the distinction between a "plan" and a "schedule" should be clear. A plan aims to achieve an aggregate balance of raw material supply, mill demands and available resources. A schedule, on the other hand, deals with the deployment of specific resources, at specific times, to specific logging sites, in order to implement the aggregate plan. This distinction will become clearer in the next two sections.

5.1 Long Term Harvest Planning System (LTS)

LTS is designed to assist the forest planner in developing a five year plan which requires the allocation of logging sites to specific year and logging season. This symbiotic system, which is presently being field tested, was developed using the AUDITION object oriented environment. It has been partly integrated with a GIS database (a GLUE object) as well as with a short term scheduling application described in the next section.

The objective of the planning exercise is to allocate these logging sites to specific seasons in such a way that a targeted volume of logs required by the consuming mills becomes available for that season and year. The mill demands include the desired total volume as well as species, grade and size composition. (Overall quantities and aggregate production capacities of crews and equipment will be implicit in certain targets specified, but actual crews and equipment are not explicitly considered here since this is a planning tool and not a scheduler.)

The planner must also satisfy all the regulatory requirements and must ensure that the plan is not only practical but also affordable (taking into account the cost of roads, logging and hauling and so on).

A typical computer screen is shown in Figure 3. and includes a map of a forest management area, divided into sections, and showing individual logging sites as small coloured squares. The entire map, as well as information about the map area and about each individual logging site, is created by importing data from a GIS[4]. Referring to Figure 3, the planner simply selects a logging site by clicking on it with the mouse. Any selected logging site displays its properties in the top row table, called the SiteSheet, just below the map. The labels just below the SiteSheet identify all the properties for the logging site and serve as headings for the main spreadsheet, referred to as the DataSheet.

The planner may choose to alter any of the properties of the site by directly editing the values in the SiteSheet row. He may also allocate the selected site to the desired year and season (represented by the rows in the main DataSheet) by simply pointing at the row with the mouse. Immediately, the main DataSheet is updated to reflect its impact on the totals. In addition, the logging site icon on the map picks up the colour representing the selected season and year. The planner may also compare the updated totals for the season with the target numbers shown in the target row at the bottom.

In this manner the planner may allocate and de-allocate the various logging sites to the desired year and season until a balanced plan is produced. He may electronically save or load any plan at will. The table on the top right corner, called the SiteList, shows the list of all logging sites allocated to any selected season or of all logging sites on the map.

The planner may select a site either from the map or by name from the SiteList. Either way the site is highlighted on the map and its properties are displayed in the

---

[4] The map shown was created by LTS by reading into LTS two ASCII files generated from a GIS, one file containing all the map lines, the other one containing the logging site attributes. This was achieved using a simple GLUE object for ASCII files. Full network integration can also be achieved, via more complex GLUE objects, without requiring the planner to learn the GIS interface.

SiteSheet table. The planner may also "zoom" in and out of any area on the map to get a close-up look at the sites in that area.

Facilities are provided in the system to add new logging sites and to "roll-over" the whole 5-year plan to another year thus providing a perpetual 5-year planning environment.

LTS maintains separate lists of all allocated logging sites for each season it contains. Via these lists, the LTS software has been integrated with another Short Term Scheduling software package, called STS, for detailed scheduling of crews and equipment to implement any desired season's harvesting activities. This STS software is described in the next section.

LTS, because it is simple to learn and use, assists the planner to quickly assess the impact of many alternatives. In addition to creating a complete site allocation plan, the LTS software has been designed to be particularly useful for making and evaluating small changes, involving a few sites; changes of the type often required to compensate for the unforseen events that frequently occur in the midst of executing a part of a plan (such as wash-outs, slides, breakdowns, etc.).

5.2 Short Term Scheduling (STS)

The Symbiotic Systems Group, in collaboration with several forest companies and research groups, has developed a software simulation system called STS to assist logging division planners to prepare and modify short term harvest schedules, and to help manage felled and bucked inventories. From the outset it was intended to develop STS as a 'symbiotic system', and it was to be a decision support software tool and not a decision-making tool.

The objective of the STS software is to provide planners with the ability to:

1. Define the sites to be logged and the available crews and equipment.
2. Create a logging plan, by:
   - Deploying Resources and assigning logging tasks,
   - Simulating daily production,
   - Projecting the wood inventories and deliveries.

3. Evaluate the logging plan, by assessing:
   - Daily production and deliveries, against targets,
   - The resulting wood inventories,
   - Equipment utilization and production reports.
4. Modify the plan, by:
   - Considering alternative deployment schemes,
   - Repeating steps 2 and 3 until acceptable.

By using the symbiotic approach, the software also facilitates, and thus encourages, the development and comparison of several possible alternative harvest plans. All too frequently in the past, with other technology, the first plan achieved was adopted simply because it was far too laborious and expensive to consider alternatives.

In order to meet the above objectives, shadow objects (in this case AUDITION performers and stages) are visually presented to the harvest planners for the following real life objects which need to be scheduled:

1. A logging division (an AUDITION stage)
2. Logging sites within the division, with (AUDITION sub-stages on the divisional stage)
   - wood inventories by species and grade
   - cost tables associated with harvesting operations
3. Equipment and crews available, (AUDITION performers) including:
   - Falling crews
   - Log yarders
   - Log loaders
4. Log consumers, (AUDITION performers) such as
   - Sort yards
   - Mills

A facility is provided to import all the logging sites allocated to any single season directly from the 5-year plan created by the LTS software described in the previous section (an example of a GLUE object as defined in the layered architecture concept of section 3.1) Or, alternatively, a logging site may be created manually. Similarly, equipment and crews can be easily created and customized to represent the actual equipment and crews available.

Tools are included to create other types of equipment, and even logging contractors, as needed. A clock/calendar performer is also included to permit logging activities to be time and date stamped and to control creation and "playback" of harvest plans.

A variety of other tools are provided within the STS software to assist the user to create and evaluate short term harvest plans and to save and replay plans. Written reports can also be easily generated once an acceptable plan has been developed. These tools are examples of the GLASS objects defined for the layered architecture.

This relatively simple object-oriented model of the logging division was easily created within AUDITION and yet has proven to accurately represent the planners' scheduling environment. It closely mimics the real life activities in the logging division and is readily recognized and understood by harvest planners.

STS's generic design can be easily customized or enhanced for specific applications. GLASS objects can readily be added or modified to accommodate different perspectives which may be required by different users.

6.0 Conclusions

This paper has described two symbiotic forest management applications featuring a layered architecture and implemented using an object-oriented design and language. These applications, which are focused on specific planning problems, have proven to be intuitive to use and easy to learn by expert forest planners. They also provide a simple and consistent user interface to the decision maker. They have been linked via an ASCII file GLUE object to forest inventory data generated by a GIS and associated databases.

These technologies will be further developed and applied to a much wider variety of forest and land use management applications in the PROGERT project. In PROGERT, NRC's Symbiotic Systems Group will specifically provide its expertise in rapid prototyping of the GLUE, GLASS and APPLICATION layers and their integration with other technologies.

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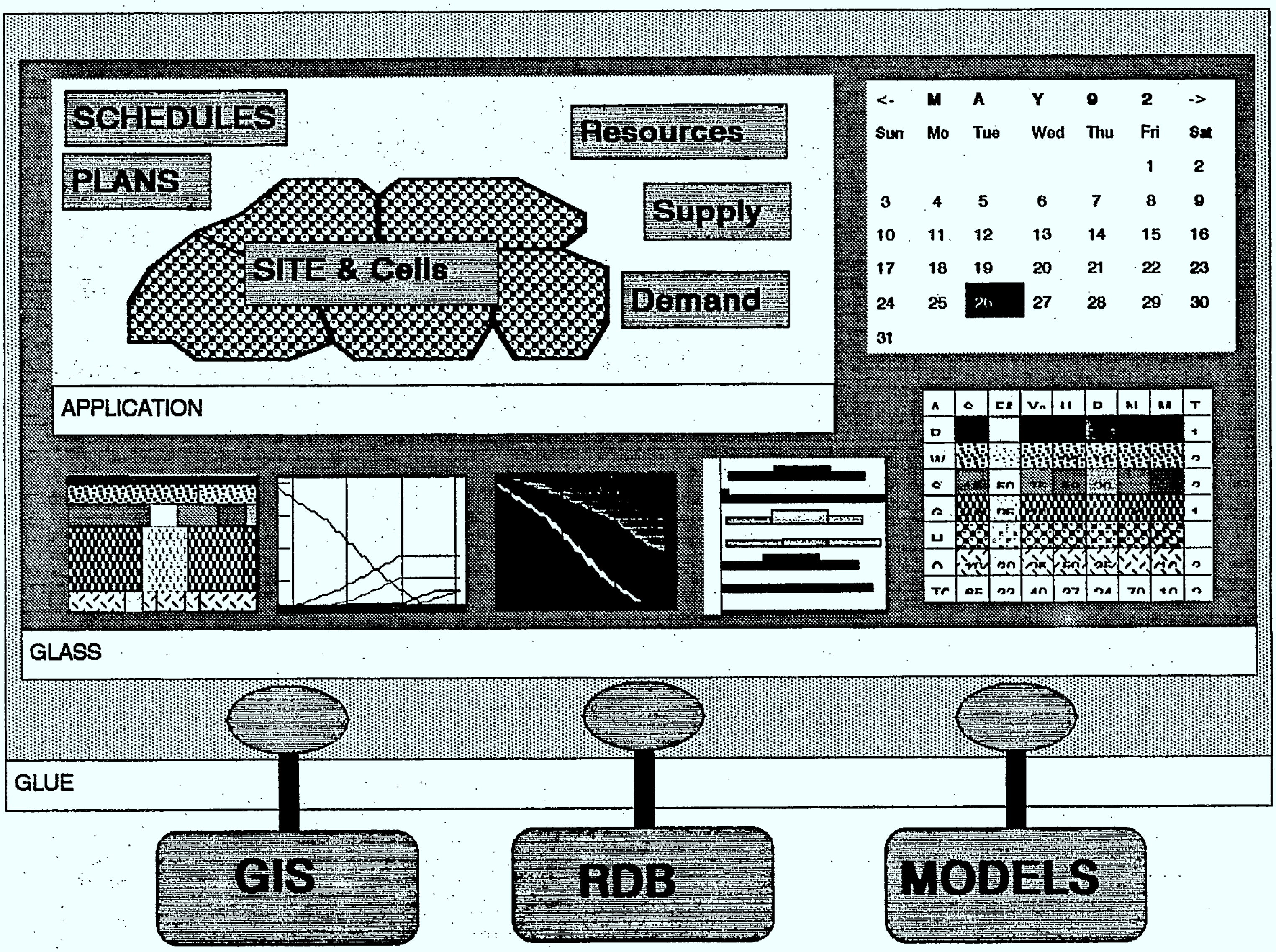


FIGURE 1 Layered Architecture Concept

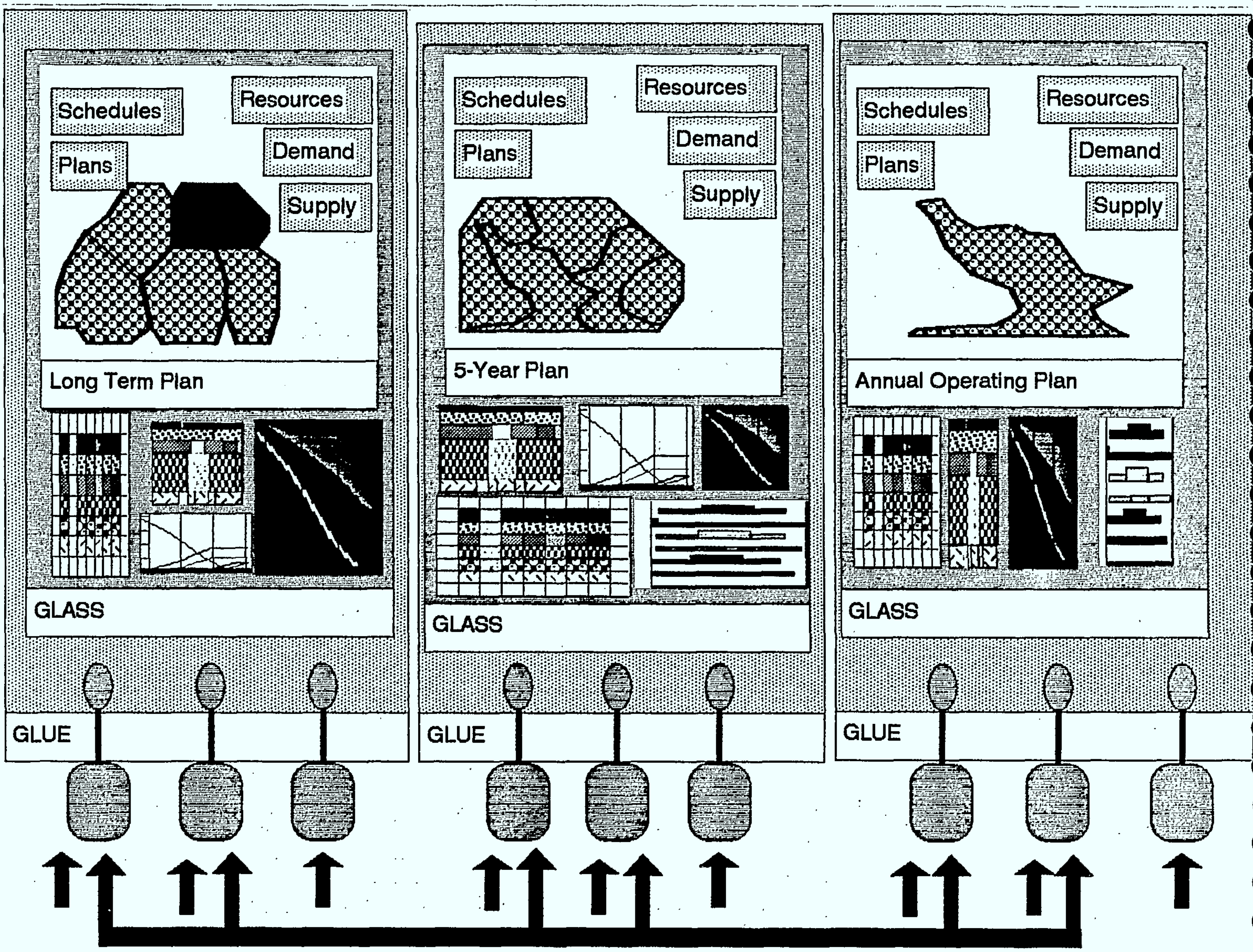
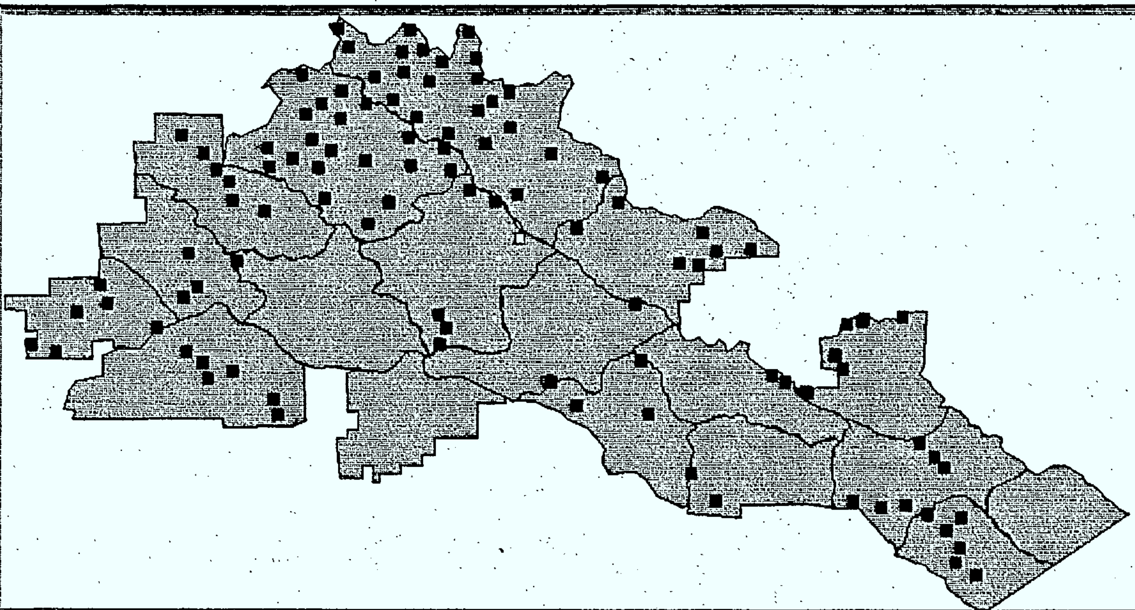


Figure 2 Forest Application Framework

STS | new | load Sites | save Plan | restore Plan | Full Plan | print | quit



Sites on Map

3-12
6-42
4-18
11-2
14-30
14-33
14-31
15-4
15-14
15-6
15-12B
15-11B
3-10
3-13
5-55

8-42	79.0	19500	19500			13650	5850	975	975	53.00

Yr	S	Mha	Mvo	Conv	Cable	RdSide	LargeW	SmallW	Pulp	Resid	Cost
91	W										
91	S	198.5	117186	117186			71103	46082	6332	4702	603.20
92	W	707.1	377973	341796	16457		256962	121011	19041	17868	1082.20
92	S	269.6	63960	51165	26770		46896	17063	3812	3564	277.40

Total	7955	2039912	1849254	212945		1401270	637441	119946	102658	5079
KGWTE!		2000000	1900000	200000		1500000	500000	150000		

Figure 3 LTS Application (Copyright NRC 1992)

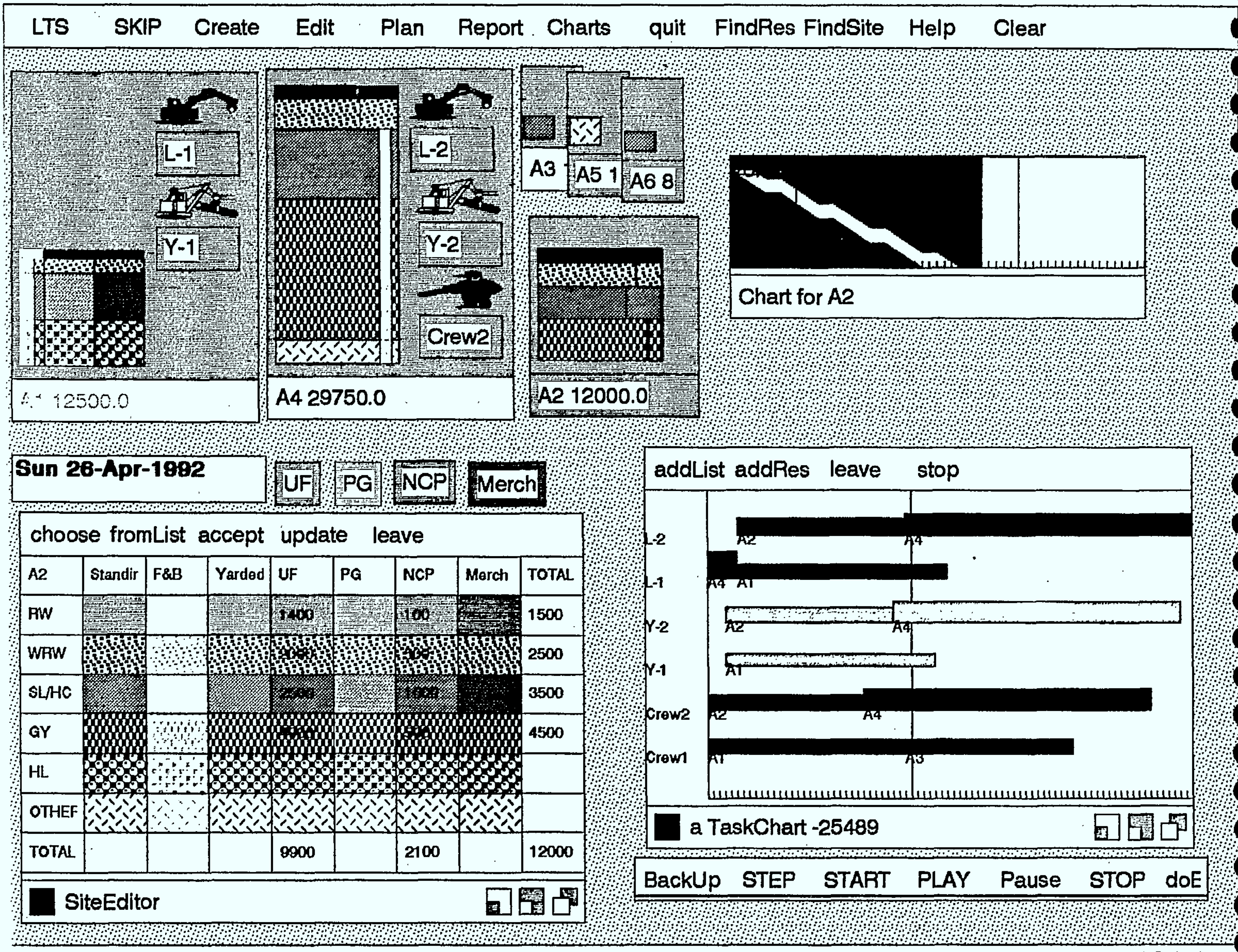


Figure 4 STS Application (Copyright NRC 1992)

New Technologies - Continuing Sensing of Pollutants

Thomas E. Muccino
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Abstract

Tom Muccino has, for the past three years, guided the evolution of the Lockheed Sanders business base into the non-defense arena by focusing on sensor development for environmental and counter narcotics applications. He has been involved in multispectral sensor development for twenty years in both government and business.

He provided -

- an overview of sensor technology
- a paradigm for transitioning the wealth of technical capability residing in government and industry to benefit the non-military marketplace

and addressed --

the problems
the variables
the obstacles
a solution to expedite cooperation between those who can use the capabilities and those who have them.

This overview was presented through the slides on the following pages...

Lockheed Sanders

NEW TECHNOLOGIES
Continuous Sensing of Pollutants

- The Problem
- The Variables
- The Obstacles
- The Solution
- OCELOT

Lockheed Sanders

THE PROBLEM

"So many choices, so little time."

Lockheed Sanders

THE VARIABLES

- Contact vs Remote
- F3
- Sensitivity
- Cost
- Accuracy
- Interactive
- Portability

Lockheed Sanders

THE OBSTACLES

- Ambiguous/Conflicting Regulations
  - Federal
  - State/Province
  - Local
- Lack of and/or Dispersed R&D Funding
- Lack of Adequate Scientific & Market Data

Lockheed Sanders

THE SOLUTION

Institutionalized Cooperation

Among Equal Partners

Lockheed Sanders

WHO HAS THE TECHNOLOGY? (THE MAVENS)

- Government
- Industry
- Academia

Lockheed Sanders

THE MAVENS' MOTIVATORS

- **Government:**
  Enacting Legislation for the Common Good
  Enforcement of the Legislation
- **Industry: Profit!!!**
- **Academia:**
  Advancement of Science
  (preferably via Research Grants)

Lockheed Sanders

THE CHALLENGES

- Who will lead, who will follow?
- How to make the different motivators synergistic?
- Who will pay for what?

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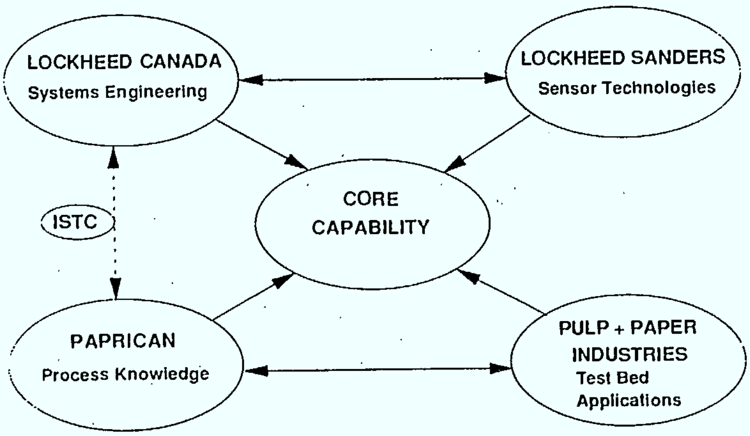
COOPERATIVE PARADIGM



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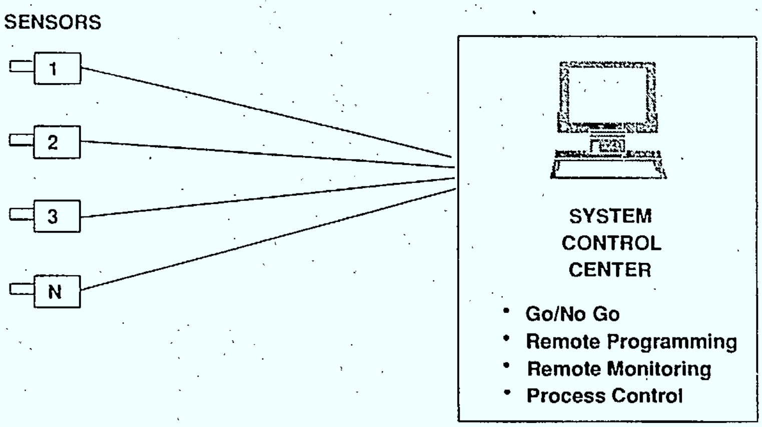
TARGET SYSTEM



Lockheed Sanders

WHAT IS THE OCELOT SYSTEM?

- Passive, remote, noncontact, real-time IR chemical vapor detection and identification system.
- Detects wide range of chemicals at ranges exceeding currently fielded sensors.
- System can be permanently mounted for area sensing/surveying or continuous monitoring of a single location.

The ESIS Project: An Intelligent Decision Support System Applied to Wastewater Management in the Pulp and Paper Industry

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Abstract

The objective of the **Environmentally Sensitive Investment System (ESIS) Project** is to provide the Pulp and Paper Industry as well as government departments and agencies with the means to assess the economic impact of environmental policies which require capital-intensive projects. More specifically, **ESIS** assists in choosing wastewater management alternatives that meet jointly considered techno-economic constraints as well as environmental regulatory standards in an efficient manner. The use of this decision support tool facilitates the systematic exploration of the quantitative implications of a range of options by managers and planners.

ESIS is based on a combination of Expert System and Operations Research techniques which together with database management and graphical presentation tools are integrated in a user-friendly interactive system. **ESIS** is targeted for top-of-the-line personal computers. A workstation version is planned at a later stage.

1. Project Objectives and Background

Primary industries, such as pulp and paper manufacturing, typically have a significant impact on the ambient air, water and land quality. Consequently, these industries have to find technologically feasible ways to deal with their waste, while acting under the financial constraints of market realities. New regulatory legislation will provide a strong impetus for the integration of environmental, technical and economic factors in the decision making process pertaining to industrial waste management.

The formulation of new environmental policies and emission (pollution control) standards also requires that government departments or agencies be able to assess how the stated criteria and objectives can be met by industry, given the available technology and resources.

ESIS, the Environmentally Sensitive Investment System, is designed to support complex decision making processes: its use will significantly enhance the ability of planners and managers to explore the implications of diverse options. Although the ESIS Project is scoped primarily at the economically mature (Canadian) Pulp and Paper Industry, its broader conceptual relevance is evident with respect to other capital-intensive industries which have a potentially large negative environmental impact.

The ESIS Project is supported by a consortium of industry, research, consulting and government partners. This group represents a broad range of interests, expertise and a variety of multi-disciplinary professional assistance to the Project.

The technical activities of ESIS started in July 1991. In this brief note only the main characteristics and stages of the work are highlighted. For additional details, reference is made to the relevant literature on environmental protection objectives and regulations (Environment Canada, 1990;1992) and the recent environmental applications of decision support systems (see,e.g. Fedra, 1991; Gray & Stokoe, 1988; Jaumard et al., 1988; Lewandowski & Wierzbicki, 1989; Makowski, 1991; Patry & Chapman 1989; Pintér, 1991), as well as the related industrial waste management (see e.g. U.S. Environmental Protection Agency, 1988; Ontario Waste Management Corporation, 1989). In particular, the ESIS working documents (Fels & Lycon, 1991; Meeuwig, 1991; Meeuwig, 1992; Pintér & Meeuwig, 1991) provide an extensive background, including many additional references.

2. ESIS Model Structure

As discussed above, ESIS will be a quantitative decision support tool that assists in finding harmonized economic-environmental policies, with long and short-term decisions. Figure 1 shows a generalized system outline; waste management in the Pulp and Paper Industry can be considered as one possible realization.

Figure 1 indicates that there are several system components which allow implementation of diverse types of management and control options. Because of the adopted scope limitations of the ESIS Project, particular emphasis will be placed on the selection of technologically feasible as well as available, environmentally satisfactory and economically efficient wastewater treatment alternatives. However, an attempt will be made to include - at least on the level of sufficiently detailed, quantitative sensitivity analysis - other management options; for instance, up-stream or production plan modifications, material recycling and reuse, non-standard waste treatment and disposal practices, adaptively chosen environmental (effluent quality) regulations, etc.

The basic objectives of ESIS can be summarized by the following constrained optimization model type:

GOAL (target, objective):

{Attain "best possible" or "satisfactory" environmental quality}

CONSTRAINTS :

{Explicit ranges of management decision variables (e.g. wastewater treatment equipment type and sizes)}

{Implicit technological interrelations and limitations}

{Resource availability}

{State descriptions of unit treatment processes}

{The effects of resulting waste streams on the environment}

Without going into more detail here, let us remark that a closely related problem statement can be formulated with the primary objective:

{Meet ambient environmental quality standards in the "most efficient" or "sufficiently effective" way}

The corresponding constraint set can be defined with appropriate modifications to the previously stated constraints.

The given examples induce a broad variety of possible specifications: these models can be quite different with respect to their scope and depth (accuracy), information (input) requirement, computational demand and the level of detail in which their results are presented. For that reason we need to construct a hierarchical system of interconnected software modules that provides the required flexibility in the adaptive, dialogue-based decision support process. In this manner **ESIS** may serve diverse purposes including the following:

- general information on environmentally sensitive planning (in the context of the Pulp and Paper Industry)
- general information on the range of available waste management alternatives
- feasibility analysis of (pre-)selected options
- screening of a (large) number of feasible alternatives
- fine tuning of chosen waste treatment configurations

- statistical verification (uncertainty analysis) of selected options

3. Functional System Software and Hardware Specifications

As can be seen from the above brief description, **ESIS** combines Operations Research (optimization and statistical analysis), Expert System, database management and visualization concepts and techniques in an intelligent decision support system. **Figure 2** shows the principal functional modules of the system architecture.

In order to find and construct appropriate "building blocks" as presented in this figure, a number of basic software products, several expert system shells, optimization, statistical analysis, data management and presentation packages were acquired for the Project. Our objective is to provide a "user friendly" system, which permits description, modelling and solution at different levels as required by the particular application of **ESIS**, by combining the strengths of the various tools.

The **ESIS** product is targeted for the top-of-the-line personal computer graphic user interface (GUI) environment (486-based DOS/WINDOWS). At a later stage UNIX based workstations (RS/6000 with AIX and X-WINDOWS) will be used, when the GIS component is incorporated. To provide the necessary hardware platform for system development, Dalhousie University - through a Joint Study Agreement with IBM Canada Ltd. - has purchased several PS/2 systems as well as a RISC workstation.

4. Status of Work

The preliminary basic wastewater treatment module descriptions have been completed (Fels & Lycon, 1992). This information will now be incorporated in the decision support system. Following testing and validation of the proto-type system, a production system will be developed. The evaluation of alternative treatment components or configurations, model versions and decision support systems will continue.

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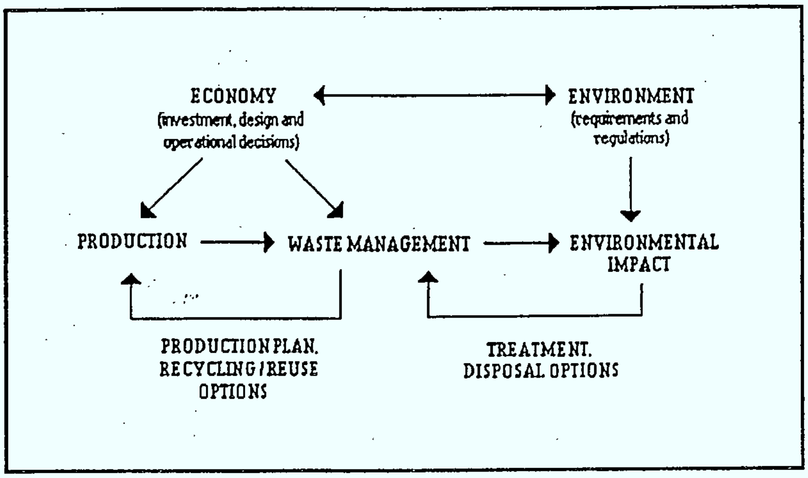


Figure 1

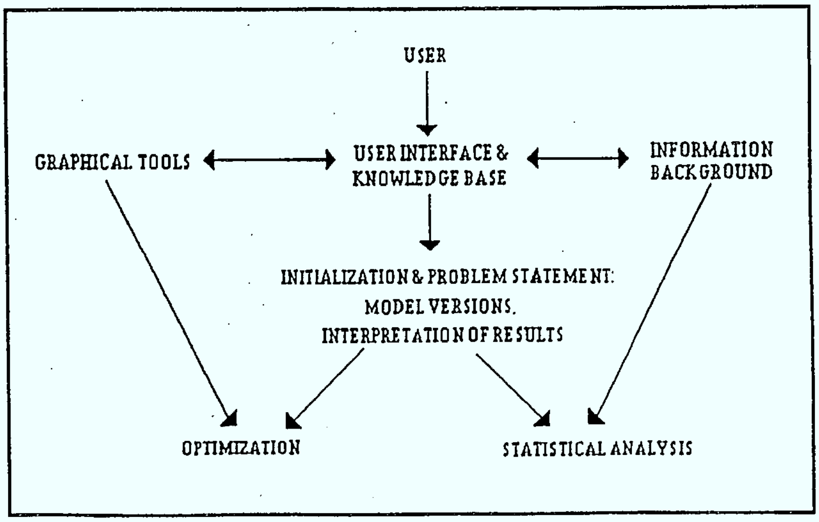
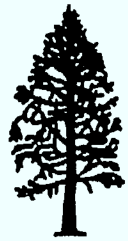


Figure 2

The Use of AI in Environmental Management



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Introduction

The G2 object-oriented real-time expert system has allowed new methodologies to be used in the construction of large-scale systems.[1] Among the new aspects are knowledge representations that allow graphical connection of objects which are understood by G2, and which automatically become a deep knowledge representation of the structure of interactions of objects.

The object-oriented representation allows definition of problem behavior to be expressed generically, applying to whole classes of objects, and the understanding of interaction structure by the expert system then allows diagnosis to proceed from the object instance for which the problem behavior is detected, looking upstream for problem sources or downstream for effects.

Another new aspect is the definition of knowledge of rules, procedures, formulas, dynamic models and other attributes in structured natural language.

The combination of these methodologies, together with advances in reasoning paradigms, have together allowed large scale complex real-time expert systems to be implemented. Several examples will be discussed, each with thousands of objects or other complex characteristics.

Process Plant Applications

The introduction of the G2 Real-Time Expert System technology has led to a broad range of on-line applications, including many with environmental significance. Many of the applications of G2 are in the process industry. For example, Fatih Kinoglu of 3M describes an application for monitoring waste incineration.[2] In this application, an incinerator is used to burn waste chemicals from many different plants. The burning characteristics can vary with each container on a minute-by-minute basis. The challenge is to optimize the burning process to minimize environmental pollution.

The containers of waste chemicals each have a bar-code which identifies the contents and origin. The bar-code is read into the system just prior to incineration. A model of the incineration process, developed by 3M engineers using G2, helps to optimize the incineration process. Close control is important, because there is only about 10 seconds delay from the start of incineration of a container and the resulting effect on emissions.

The general applications of G2 in the process industry may have other explicit purposes, such as improved quality, optimized production, or assistance in operating changes, but improvements in environmental impact may be a significant side benefit. For example, one area of application of G2 in the paper industry is for production quality.[3] In this area, a matrix of quality knowledge is used to advise operators of the effect of proposed control adjustments. It is a "what if?" operator support system. Improvements in paper quality give fewer reject rolls, saving not only production time, but also lessening the use of water, steam, and other resources.

The matrix quality advisor built on G2 is offered as a product by ABB. It is on line at the Norske Skog mill in Norway, and at the Kaukas Oy mill in Finland.

Another G2 application in the paper industry, on line at Quebec and Ontario Paper Company,[4] provides decision support for pulp blending operations. Such applications help to minimize grade change time, and reduce the problem of handling the material produced between the on-spec grades.

Diagnostic applications generally have positive environmental aspects. One of several Esso applications using G2, with an Exxon Chemical Company layered-application called "Real-Time Diagnostic Toolkit," built on G2, is on-line in Alberta.[5] The Exxon Diagnostic Toolkit allows plant operators to understand plant behavior better, with explanations of the behavior provided on request by the toolkit.

One of Monsanto's G2 applications with an explicit environmental purpose is on-line at their Krummrich plant near St. Louis.[6] In this application, 150 generic rules look for aberrant sensor behavior across a domain of 5000 objects including 1200 sensors in a chemical plant. Thus the generic form of knowledge provides a significant economy of representation, which is easy to implement and easy to maintain. The resulting system helps to avoid chemical spills, among other purposes.

Another process application with significant environmental importance is reported by Ciments Lafarge, who are in the process of implementing closed-loop intelligent control systems based on G2 in 25 cement plants[7] including several in Canada. One of the specific purposes of the G2 installations is to reduce emissions.

Other Environmental Applications

Transportation is another area of application of G2 which can have environmental importance. A European project to provide intelligent control of ships in crisis situations[8] provides a way to prevent ship collisions with other ships or with fixed obstacles. This could reduce the probability of oil spills or other negative environmental impact due to ship accidents.

The Biosphere II is probably the most extensive environmental application.[9,10] Biosphere II is a totally enclosed structure in Arizona (Figure 1), with interacting Biomes designed as forest, desert, ocean, cropland, and others. Eight humans entered the Biosphere II in September 1991, for an experiment at sustaining life independent of the earth. Only energy and information are allowed to cross the boundary to the outside world.

In Biosphere II, G2 is used to monitor the individual biomes, to allow a better view of current conditions. Because of the small scale (compared to the planet earth) the interactions and speed of changes require close monitoring and control.

Summary

The combination of technologies in G2, of object-oriented definition of structure and relationships, with graphic definition of object connectivity, together with generic definition of knowledge about behavior, integrated into a structured natural language development environment, has allowed large real-time expert system implementations. Examples in the environmental area are presented. As of this writing, over 1000 G2 installations are deployed.

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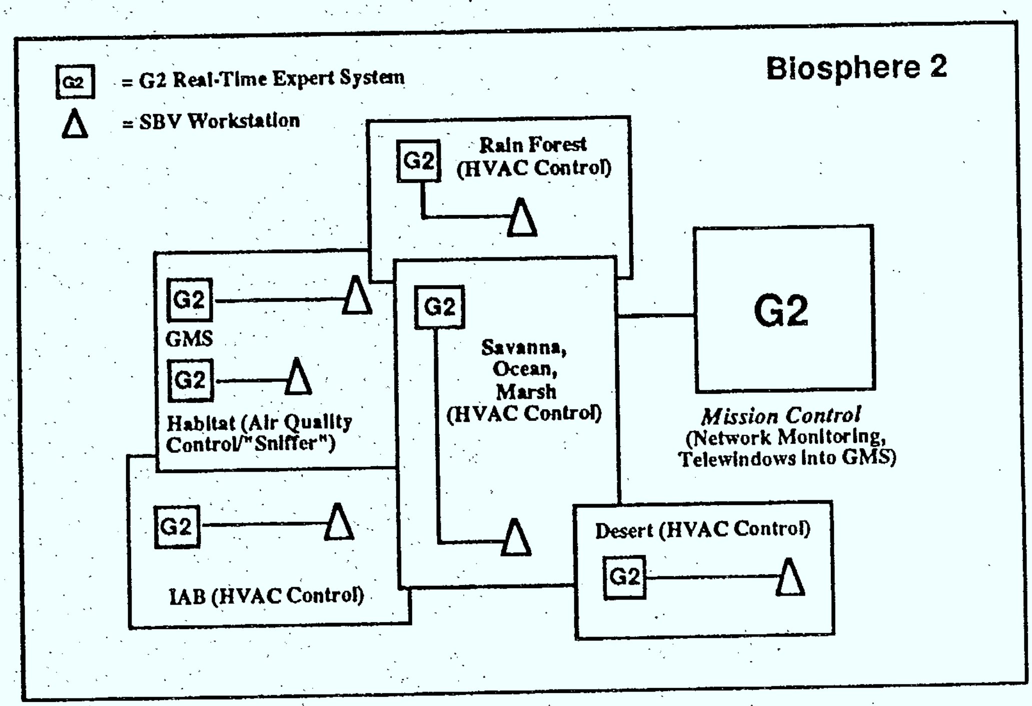
Fig. 1. G2 in the Biosphere II



Intelligent Decision Support Systems in Forest Land Management Planning

Robert E. Everitt
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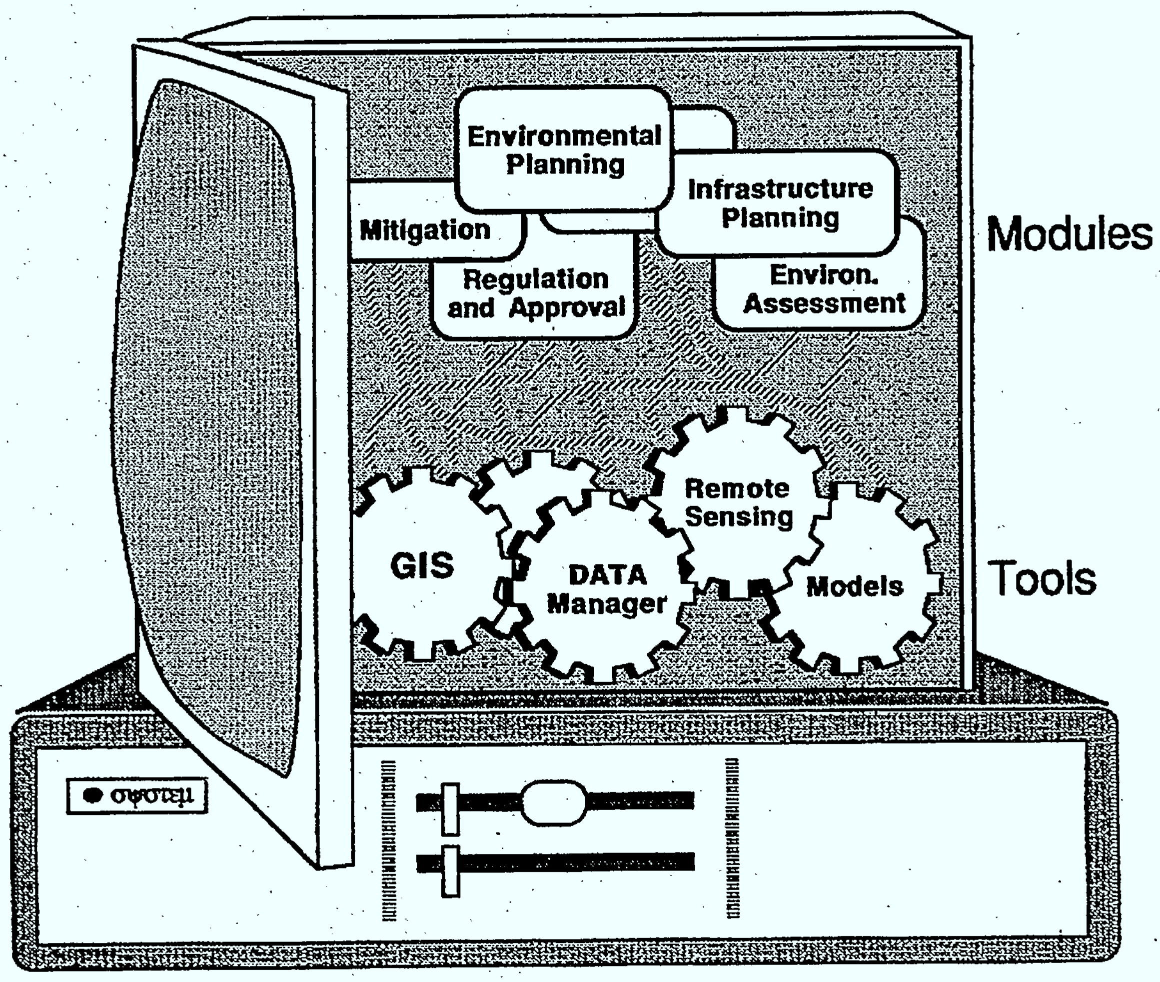
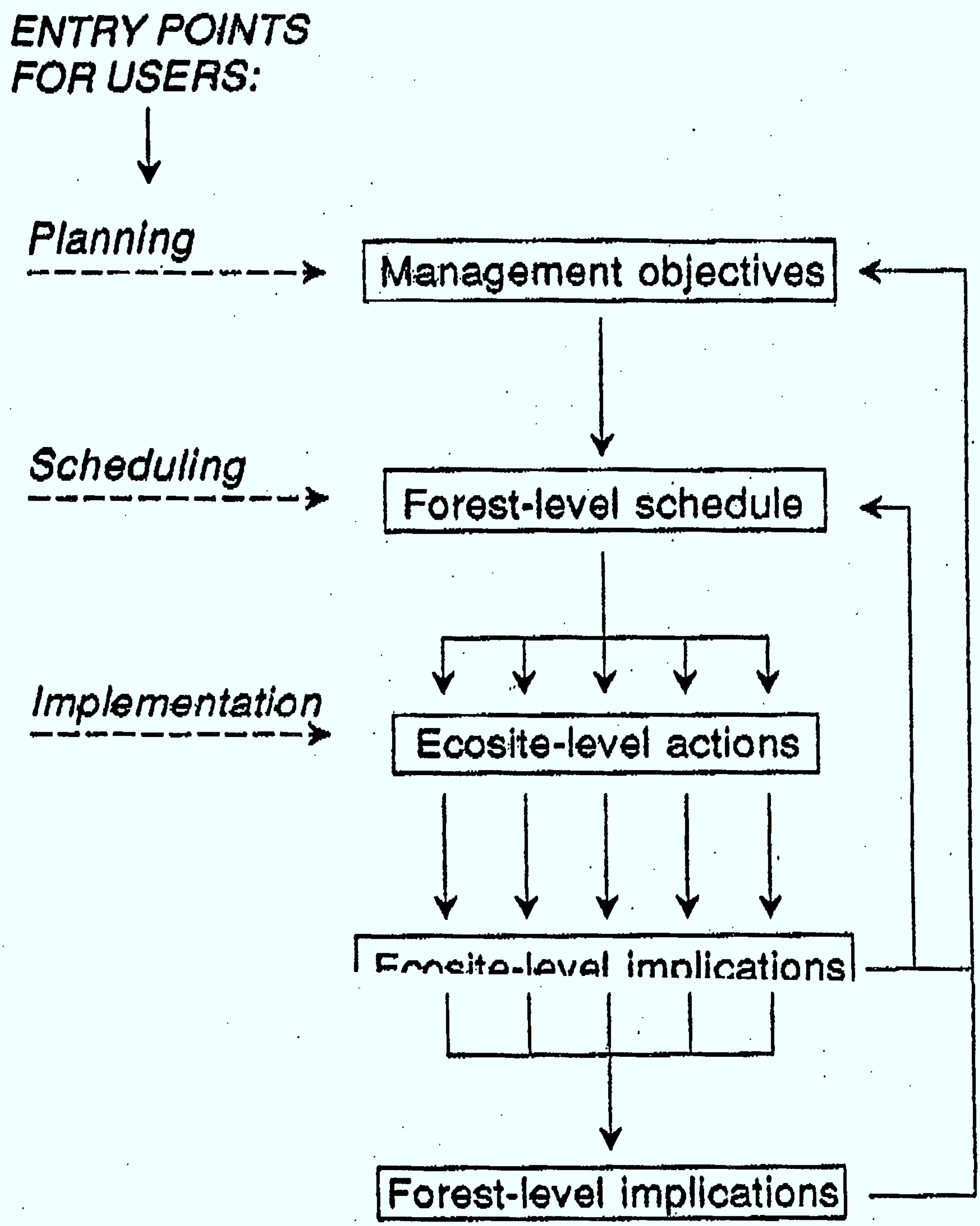
R.E. Everitt used the following slides to guide him through the main points of his presentation:



Problem Solving Strategy	Reports	Models/DSS	Data Bases
infer wildlife habitat	wildlife habitat	terrestrial and aquatic habitat supply model	habitat needs by wildlife type

Intelligent Decision Support Systems

1. Problem solving strategy
2. Models
3. Databases
4. Knowledge bases
5. Data acquisition systems
6. Reporting systems


ENTRY POINTS
FOR USERS:
Planning
Management objectives
Scheduling
Forest-level schedule
Implementation
Ecosite-level actions
Ecosite-level implications
Forest-level implications

Elements of an Intelligent Decision Support System

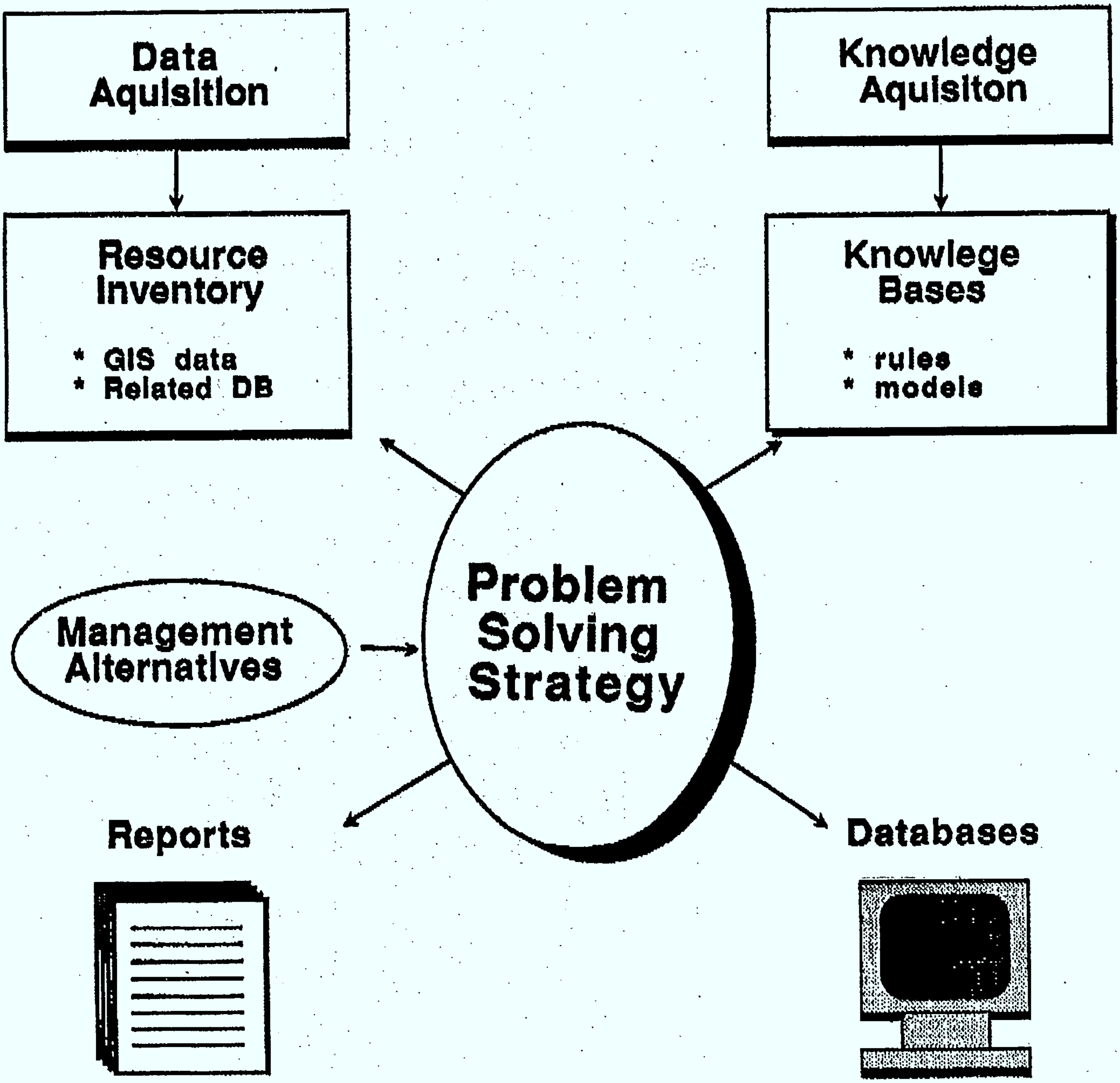


Table 5.1: An example of a problem-solving strategy employed by a DSS for the developement of long-term forest land management plans.

Problem Solving Strategy	Reports	Models/DSS	Data Bases
Goal: To develop a 20 year plan. 1. Define objectives	Objectives		
2. Define indicators	Indicators including measures of sustainability (site productivity, health)		
3. Determining management schedules	Set of alternative harvest schedules	Wood supply model	• Forest Inventory • Growth and Yield Tables • Roads and access to mill • Site characteristics
4. For each stand in the harvest schedule -- determine silvicultural prescription	For each harvest schedule: silvicultural prescriptions, management costs	Silvicultural DSS	• Site characteristics • Present stand conditions
5. Simulate stand dynamics based on prescription, fire and pest hazard	Timber yield Stand level indicators	Ecosystem model that simulates understory and overstory dynamics	
6. Infer wildlife habitat	Wildlife habitat	Terrestrial and aquatic habitat supply model	• Habitat needs by wildlife type • Site characteristics
7. Infer recreation potential	Recreation potential	Recreation and tourism supply model	• Recreational needs • Recreational facilities
8. Infer water supply	Water supply (quantity, quality)	Water supply model	• Site characteristics • Climate
9. Integrate stand level indicators	Wildlife habitat inventory Recreational potential Water supply	Integration algorithms	• rules for aggregation

Modelling, Simulation and Control of Wastewater Treatment Plants in the Pulp and Paper Industry

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Hydromantis, Inc.
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1. Introduction

The Canadian pulp and paper industry is one of the most important industry in Canada. However, the industry is facing tremendous technical and economic challenges not only because of increasing competition, but also because of pressures that are being placed on the industry to reduce the environmental impacts of its operations. While significant efforts have already been made by the industry to reduce pollutant loadings to receiving waters from wastewater treatment plants, the advent of more stringent regulations (provincial and federal) is forcing the industry to develop and implement more effective and innovative technologies, both *in-plant* and at the *end-of-pipe*. Sinclair (1990) provides an excellent overview of the industry and the environmental challenges it faces in the 90s.

The purpose of this paper is to provide some insight into technological development geared at improving the planning, design and operation of wastewater treatment plants in the pulp and paper industry. The basic components of the Integrated Computer Control System (IC^{2}S) will be described briefly.

2. Background Information

Wastewater treatment plants consist of a sequence of inter-dependent biological, physical, and chemical processes operating under time-varying hydraulic and organic load conditions. While treatment plants are usually designed under steady-state conditions, their performance is sensitive to both the time-varying loads they receive as well as a number of environmental factors, both of which are beyond the control of the operators.

There is a well documented need to improve the performance of both municipal and industrial wastewater treatment facilities, since many plants are regularly out of compliance. Experienced operators often develop a "*feel*" for the performance and the operation of their facility, allowing them to cope reasonably well with a number of unusual conditions. However, treatment plants are known to experience transients in hydraulic, organic, and chemical (toxic) loads. Such transients frequently result in short and medium-term effluent quality excursions. It is also well documented that because of the complexity of wastewater treatment facilities (the inter-dependencies of process operations), many plants are operating under non-optimal conditions. Wastewater treatment plant audits have often demonstrated the benefits associated with an improved understanding of plant operation and control.

The premise of this paper is that an **integrated computer-based approach to wastewater treatment plant operation and control** can have a significant impact on the performance of a plant, including:

- reduction in the duration and frequency of water quality effluent excursions;
- reduction in energy costs;
- deferred capital expenditures;
- optimal use of the existing facilities;
- ability to cope with unusual plant operation conditions; and
- reduction in the overall pollutant loadings to the receiving water bodies.

Over the past 5 years, Hydromantis has developed a *state-of-the-art* computer programme for dynamic modelling and simulation of large-scale wastewater treatment plants. Referred to as the General **P**urpose **S**imulator (**GPS**), this computer programme makes use of the latest developments in mathematical modelling and computer simulation, including simulator-based technologies and object-oriented modelling. The **GPS** is designed to assist engineers in the planning, design, and operation of wastewater treatment plants. One of the unique features of the GPS is that it provides users with interactive control of the simulation *as the simulation proceeds*, allowing the user to assess the impact of a change in operational strategy. Because of this, the GPS can be used effectively for operator training and operational control. For example, the GPS allows plant personnel to experiment with operational strategies without interfering with the normal operation of the plant. Details of the GPS are provided in Patry and Takács (1991).

The **GPS** has already been applied to a number of large-scale municipal wastewater treatment plants in Canada and abroad, including:

- Hamilton wastewater treatment plant (Hamilton, ON);
- Dundas wastewater treatment plant (Dundas, ON);
- SkyWay activated sludge plant (Burlington, ON);
- Gold Bar wastewater treatment plant (Edmonton, AB);
- Coleshill activated sludge plant (Birmingham, U.K.);
- Seaway plant (Port Colborne, ON);
- Main plant in Metro Toronto (Toronto, ON); and
- Saint-Hyacinthe plant (St-Hyacinthe, QC).

In addition, the GPS has been applied to industrial wastewater treatment plants, including:

- organic chemical wastes;
- brewery wastes;
- petroleum-based waste; and
- pulp and paper waste.

Specifically the goals and objectives of this project are to develop and integrate all of the basic components of a real-time computer control strategies for optimal wastewater treatment plant operation such as described later in this document (Patry and Olsson, 1987).

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3. The Integrated Computer Control System (IC^2S) and the GPS

Each component of the proposed integrated control system (IC^2S) implements a model of some aspect of a process, namely the process itself or its operation. Figure 1 shows the relationship between deterministic, stochastic and linguistic model types and process or operation models. Extensive work has been completed on deterministic modelling of process as exemplified by the GPS (Patry and Takács, 1991). *Deterministic* models (both *mechanistic* and *empirical*) are either built from the bottom-up based on first principles or result from careful observation of phenomena, thus they are robust and general. They are effective provided that data are available to support the theory and for calibration of model parameters. *Stochastic* models of processes, the result of data-driven, top-down approaches to modelling can also be prepared and, because they reflect information contained in the data used to prepare them, can give highly accurate predictions (Hiraoka *et al.* 1990). Stochastic models are useful but are data intensive and require that data be representative of the behaviour of the process. *Linguistic* or word models are qualitative and have as their main advantage, the capability of representing incomplete states of knowledge as well as other types of higher-level system knowledge not explicitly represented in deterministic and stochastic models (Beck, 1989). However, because the requisite knowledge is not always available or is highly uncertain, it is not easy to prepare robust linguistic models.

Each model type has its strengths and weaknesses and examples can be given of how they have been employed in wastewater treatment as process models and as models of how to operate a process. Table 1 provides a partial list of examples. Within the wastewater treatment field an extensive literature documents the use of each model type. For the purposes of developing an Integrated Computer Control System (IC^2S), it is necessary to examine ways to combine these models in an optimal manner.

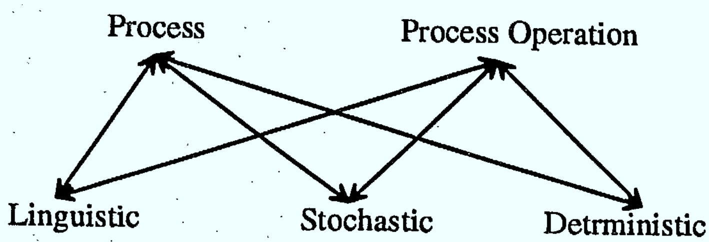

Figure 1. Model Types and Their Use

3.1 Elements of An Integrated Approach

The system architecture shown in Figure 2 was developed as a logical means of integrating the various modelling approaches, to achieve a more stable, efficient and cost effective way of controlling wastewater treatment processes (Patry & Olsson 1987). The elements of this integrated approach are:

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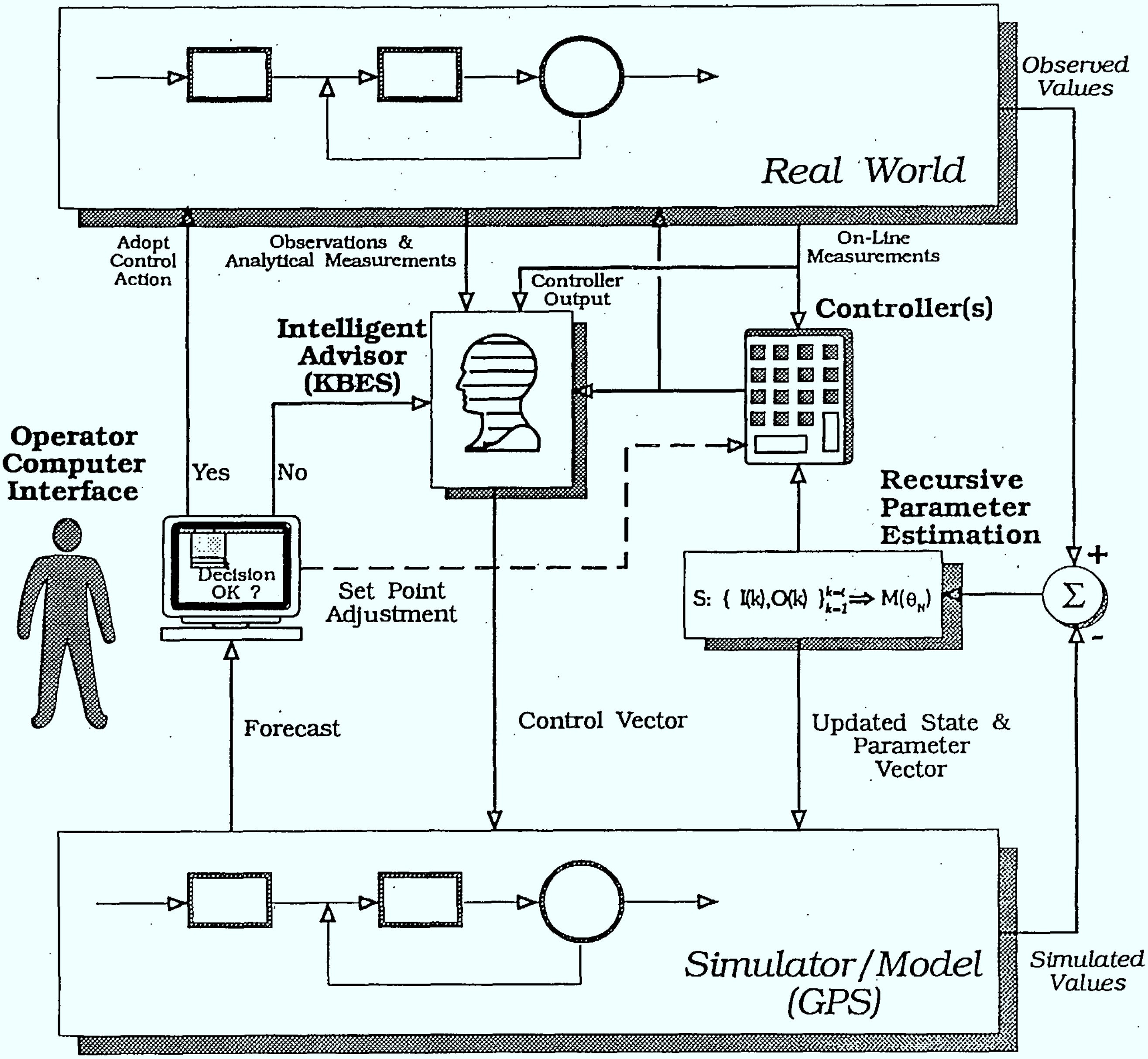

Figure 2. An Integrated Approach to Wastewater Treatment Plant Operation and Control.

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- wastewater treatment plant (*real world plant*);
- General Purpose Simulator (GPS);
- Recursive parameter estimation algorithms (RPE);
- Programmable Logic Controllers (PLC's);
- Decision Support System (DSS);
- Operator-Computer Interface (OCI).

The primary objective of the proposed concept is to implement the integrated computer control system (IC^2S) within a distributed, hierarchical control scheme as shown in Figures 3 and 4.

Table 1. Types of Models.

Model Type	Example
Linguistic Models	
◆ of process	Qualitative Simulation Models[1]
◆ of operation	Diagnostic and Control Knowledge Based Systems[2]
Stochastic Models	
◆ of process	Time Series Models[3]
◆ of operation	Statistical Quality Control Models[4]
Determinsitic Models	
Mechanistic	
◆ of process	Qantitative Simulation Models[5]
◆ of operation	PID Control Models[6]
Empirical	
◆ of process	Lumped-Parameter Models[7]
◆ of operation	*ad hoc* Control Models
1. Barnett (1991) 2. Gall and Patry (1989) 3. Hiroaka et al. (1990) 4. Berthouex (1989)	5. Patry and Takács (1991) 6. Stephanopoulous (1984) 7. Lacroix and Bloodgood (1972)

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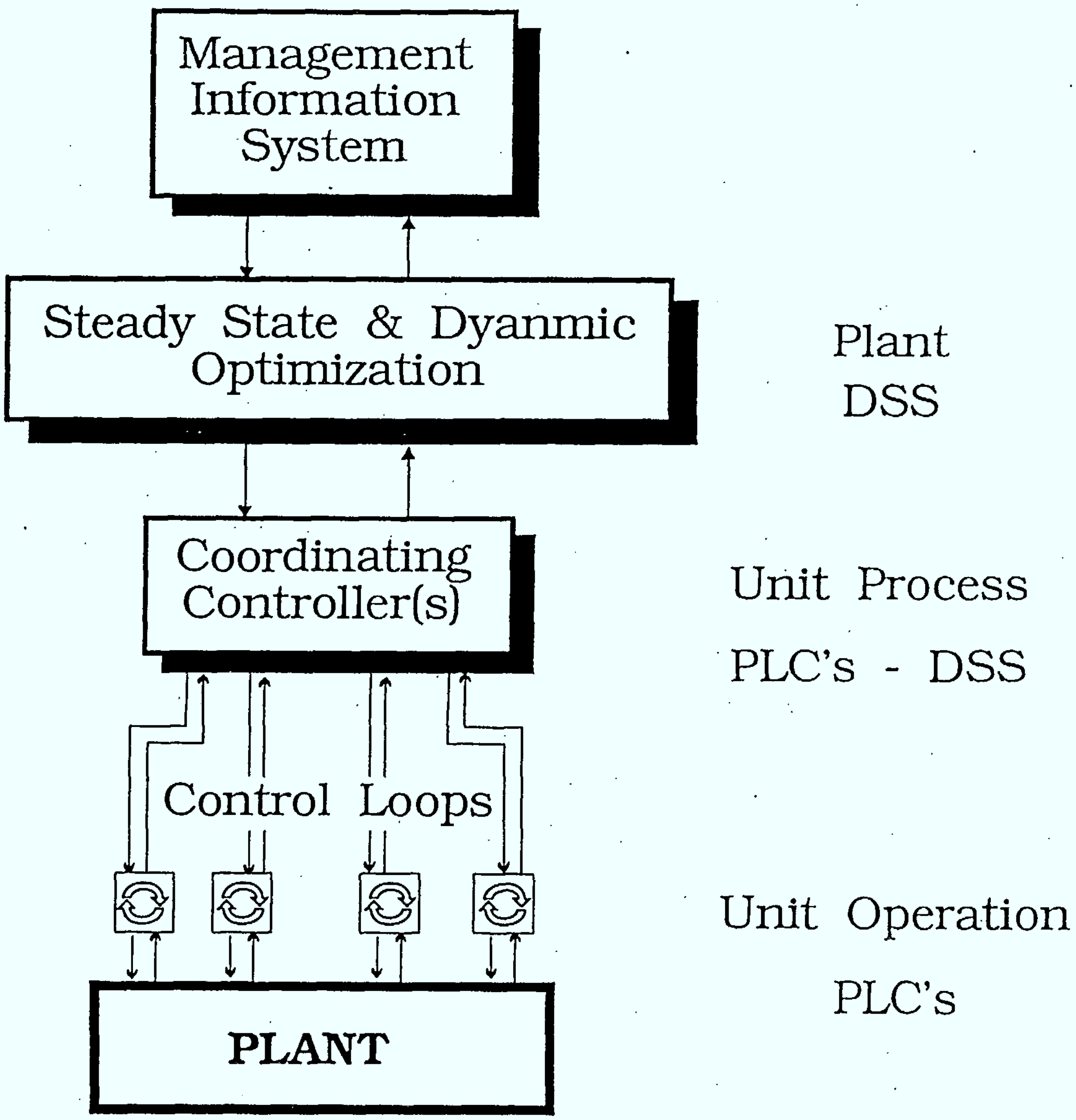

Figure 3. A Hierarchical Control Scheme

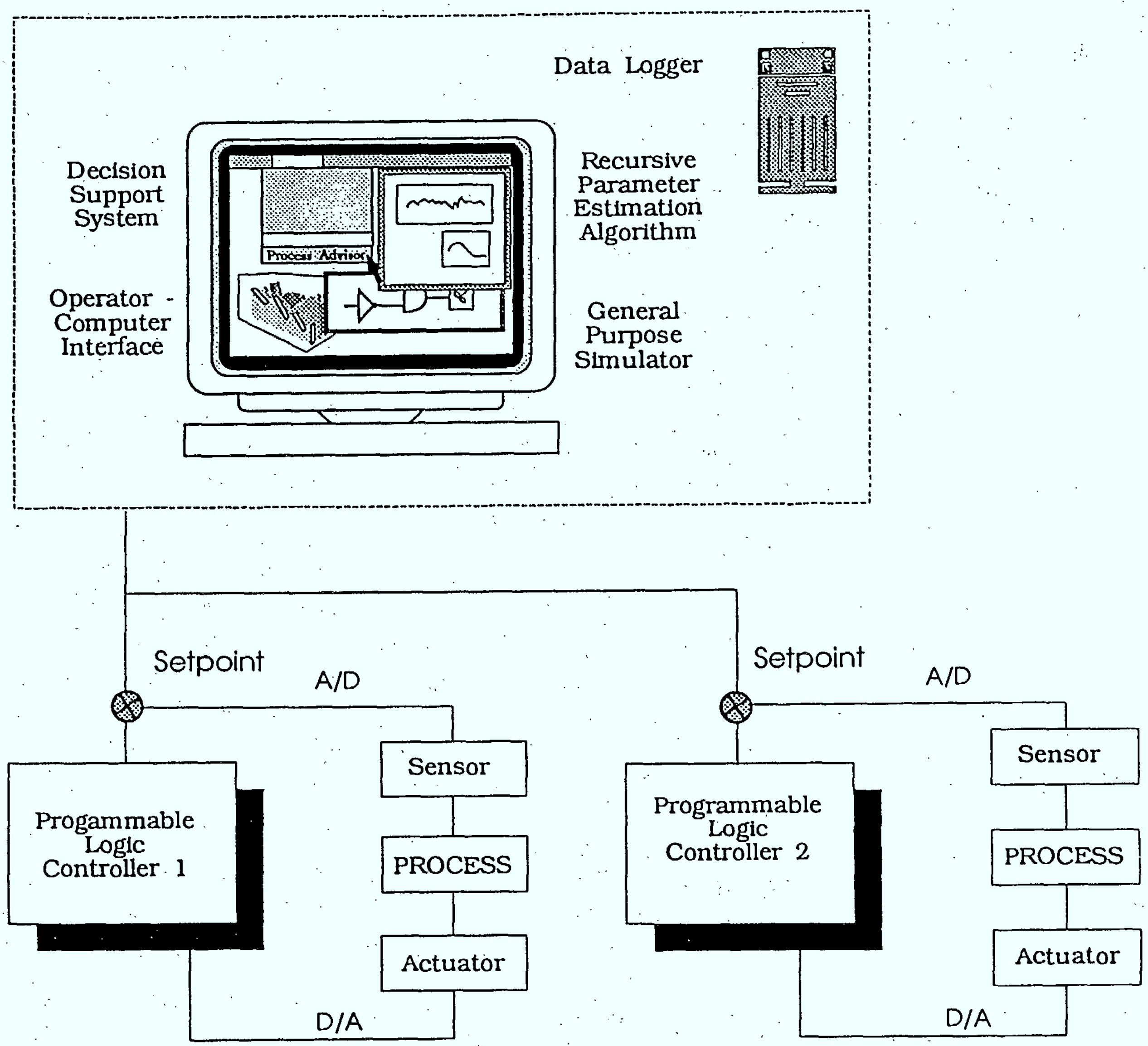

Figure 4. A Distributed Computer Control System for Plant Operation

3.2 A Hierarchical Approach

The General Purpose Simulator is a central component of the Integrated Computer Control System (IC^2S) *model-based* strategy for assisting in *operational control* of the plant (Kunz 1989, Gillblad and Olsson, 1977). The GPS represents the deterministic component of the IC^2S. Several enhancements to the GPS are planned before it can generally be used in the pulp and paper industry, including:

- comprehensive waste assessment and characterization;
- process library enhancements and developments, including aerobic and anaerobic processes structured to address the specific characteristics of the wastes generated in the pulp and paper industry; and
- special toxicity modelling.

These enhancements are currently being addressed by Hydromantis.

At the lowest level in the hierarchy of Figure 3, dedicated controllers distributed throughout the plant function to regulate specific unit operations. At the next level, general control strategies identified from the literature are implemented to handle interactions between process units and to resolve conflicts which arise in attempting to meet the overall control objectives. These strategies are implemented for the most part in interacting PLCs but also to a degree within the decision support system (DSS) module.

All information available to controllers at the first level, including sensor, actuator and setpoint values as well as data generated in the General Purpose Simulator (GPS) and the recursive parameter estimation (RPE) modules are available to the decision support system (DSS) module. The DSS module, the third level in the hierarchical scheme of Figure 3, oversees lower level systems and functions as an intelligent advisor for diagnosing the plant state and indicating, when appropriate, changes needed to optimize plant performance.

The system also incorporates a graphical user interface (GUI). Since the IC^2S is constructed as a tool for operational support, it is dependent on many human factors. Thus, the specific needs of the end users, that is, the plant operator, manager or engineer, must be taken into account. The operator computer interface (OCI) software modules will be developed with this in mind.

Established interface design guidelines will be followed to construct an interface which is easy to use, visually appealing, consistent, and maximizes information transfer.

4. System Components

The software modules suggested for the IC^2S can draw on existing technologies for development of automatic control algorithms, recursive parameter estimation algorithms and decision support systems.

As mentioned previously, the General Purpose Simulator (GPS-X) is central to the IC2S. The GPS-X is an object-based dynamic simulation software providing an interactive modelling environment in the area of wastewater treatment (Patry and Takács, 1990). The GPS has already

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been applied to a large number of municipal and industrial full-scale wastewater treatment plants in Canada and abroad, as reported in Section 2.

One of the key components of the IC^{2}S, is the on-line calibration module referred to as the Recursive Parameter Estimation (RPE) module. The purpose of this module is to dynamically adjust key model parameters so as to reflect the slowing time-varying characteristics of the systems. Patry (1983) has conducted an extensive literature review on RPE algorithms for use in real-time water quality and quantity forecasting. Similar tools will be assessed for use in the GPS-IC^{2}S.

Automatic control algorithms for many common control loops in the activated sludge process have been and continue to be develop (Andrews, 1974, 1992; Olsson, 1992). Conventional control technology can be employed in development of control systems for many of the lower level systems in the hierarchical scheme.

Development of a decision support module draws on previous work in the field of knowledge based (expert) systems (KBES). There is an extensive literature on this subject and although substantial progress has been made in development of KBES for process operation and control in related fields (e.g., chemical engineering), in the wastewater treatment field, application of these results has not been widespread. Barnett (1991) has reviewed recent developments in this field. Many of the systems prepared to date are rule-based, most are prototypes and few have been used in practice. Still, the state-of-the-art is sufficiently well-developed to permit the construction of robust knowledge based decisions support system for wastewater treatment process operation.

4.1 Recursive Parameter Estimation Module

Identification can be defined as the mapping of an input-output sequence into a model of the system:

$$S: \{I(k), O(k)\}_{k=1}^{k=t} \Rightarrow M(\theta_N)$$

in which $M(\theta_N)$ is a set of models parametrized by θ, and I(k) and O(k) are the input and output sequences, respectively. Recursive parameter estimation (RPE), on the other hand, implies that the parameters of the system, θ, are estimated on-line as the process develops. RPE can thus be represented by the mapping:

$$S: \left\{ \begin{array}{c} \theta(k-1) \\ S(k-1) \\ I(k-1) \\ O(k-1) \end{array} \right\} \Rightarrow \left\{ \begin{array}{c} \theta(k) \\ S(k) \end{array} \right\}$$

in which S(k) is a memory vector that provides a means of condensing all prior information to time k. This particular vector is of finite and non-increasing dimension. Moreover, calculation of this mapping is also finite and non-increasing in time (Ljung, 1981).

Recursive parameter estimation is advantageous in the context of the GPS-ICS because:
- it is well suited for real-time control;
- it is a convenient way of reducing computer storage requirements; and
- it is readily adaptable to microcomputer operation, as computational requirements are minimal.

Recursive parameter estimation algorithms are quite numerous. In fact, most algorithms reported in the literature have been developed on an "*ad hoc*" basis, which makes it difficult to get an objective overview of the tools available. Table 2 summarizes the different approaches to RPE. Most of those approaches have been developed from statistical considerations to overcome the problem of bias in parameter estimates resulting from recursive ordinary least-squares when the noise component is coloured.

Table 2. Approaches to recursive parameter estimation.

Approach	Example	Reference
Modification of off-line methods	Recursive ordinary least-squares	Young (1974)
Linean and nonlinear filtering	Kalman filter Extended Kalman filter	Kalman (1960) Kalman and Bucy (1961)
Stochastic approximations	Stochastic Newton algorithm	Ljung (1981)
Equation-error algorithms	Recursive extended least squares (RELS) Recursive maximum likelihood Bethoux's model	Panuska (1968) Finnigan and Rowe (1974) Dugard and Landau (1980)
Output-error algorithms	Fixed compensator method (FCM) Adjustable compensator method (ACM) Extended estimation method (EEM)	Landau (1976, 1978a) Landau (1978b) Dugard and Landau (1980)

The mathematical models described in the GPS can be structured in such a way as to allow us to evaluate recursively some of the most critical parameters. Table 3 provides a summary of some of the model parameters that will be identified recursively in the GPS-IC^{2}S

Table 3. Parameters to be estimated recursively.

Module	Parameter
influent	$f_{ss},f_{bod},f_{nh},i_{cv},i_{vt}$
BOD degradation	mu_h, ks_h,i_{vt},i_{cv},b_h
nitrification	mu_a,ko_a,b_a
denitrification	eta_g,eta_h
bio-P	mu_p,b_p
settling	
◆ effluent suspended solids	v_{max}, r_{floc}
◆ sludge blanket	v_{max},r_{hin}

Note: The parameters listed above are described in Takács *et al.* (1991)

4.2 Decision Support System: A Model-Based Approach

Many problems with KBES result in part from the use of inappropriate knowledge representations (Barnett, 1991). Formalisms such as rules alone are insufficient for representing the many different kinds of knowledge required for diagnosis and control of wastewater treatment processes. Research has shown that much richer ways of representing knowledge and more effective methods for integration of the different kinds of knowledge are needed. A good way to address the deficiencies of past systems is to concentrate first on development of a framework for knowledge. The framework must be flexible and have sufficient expressive power to facilitate the capture of different types of knowledge as well as the manipulation of knowledge in the inference process. These criteria can be met by using an object-oriented, model-based knowledge framework (Kunz *et al.* 1989).

The model-based framework has the advantage of being flexible, extensible and highly modular in design, thus knowledge acquisition is facilitated, a variety of different inferencing schemes can be implemented and future modifications can be made quickly. This type of conceptual framework is a recent innovation within the applied artificial intelligence field. It has not been used in KBES in the wastewater engineering field. An outline for a model-based KBES is shown in Figure 5 (Dym and Levitt, 1991).

In a model-based scheme, the KBES is prepared as a model in the usual engineering sense, i.e., effects propagate among objects representing system components in order to establish causal chains. In reasoning, in this case involving a qualitative "simulation", the KBES generates causally linked states that can be checked against actual or numerical simulation data to validate the model or reasoning. In a backward mode, the KBES can be used to determine past conditions that could have resulted in a current (perhaps upset) state and, in a forward mode, the KBES can determine which actions taken in the present state will result in desired future states. A high level of expertise for correcting problems in operation and control can be achieved by encapsulating within the KBES generic information contained in operating manuals such as MOP 11 (1990) and plant specific knowledge obtained on-site. The KBES serves as a repository

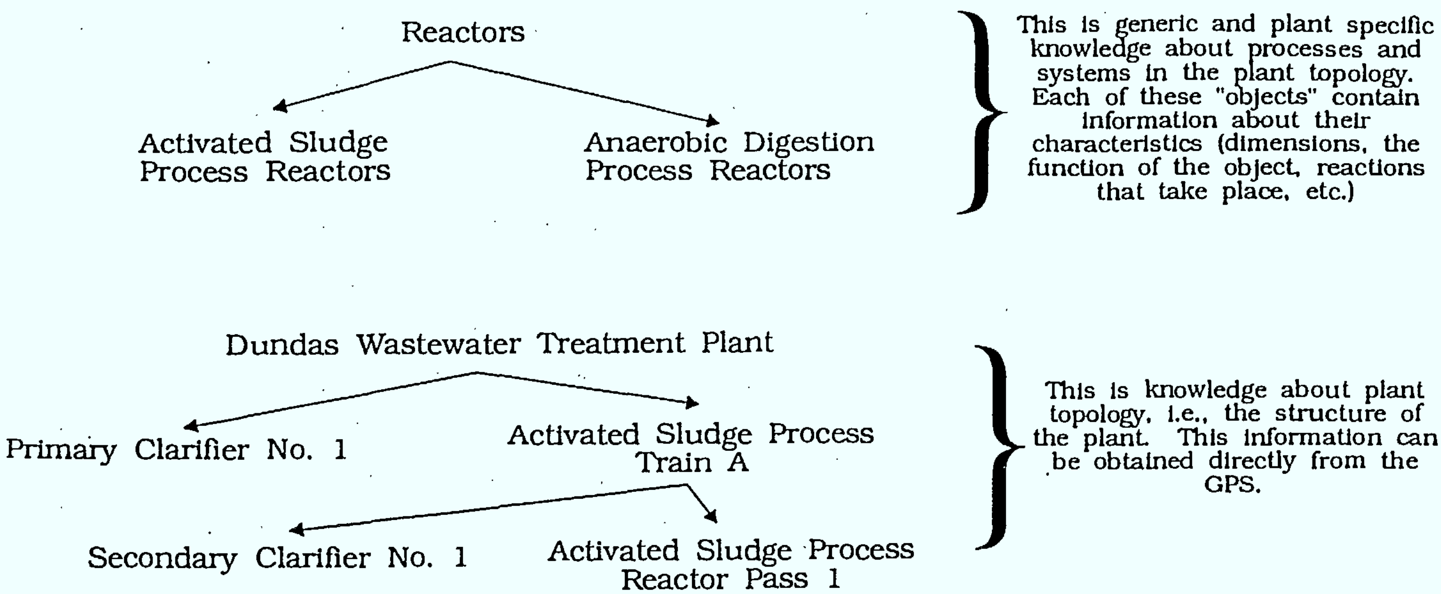

Figure 5. Elements in a Model Based Reasoning System (adapted from Dym and Levitt, 1990)

for higher-level knowledge about processes and systems. Moreover, the ability of the proposed KBES to be tailored to different plant configurations - a benefit deriving from the use of an object-oriented paradigm and linkage with the GPS - is unique in the wastewater engineering field.

The DSS is designed to fit within the overall integrated environment in Figure 2. An object-oriented, model-based KBES as described above which represents system *structure*, *function* and qualitative *behaviour*, fits well into this integrated environment and is made more robust by the quantitative mechanistic knowledge represented in the mathematical model in the GPS. The GPS can also benefit from interaction with the KBES in tasks such as expert selection of model parameters and intelligent analysis of simulation results (Nolasco and Patry, 1989).

4.3 Operator Computer Interface (OCI)

The Operator Computer Interface (OCI) does not incorporate analysis modules, rather it serves as a bridge for the operator, manager or engineer to obtain information from the system and communicate information to the system. The OCI will be prepared as a separate unit and it must interface with the PLC's, the DSS, the RPE algorithms and the GPS. Existing technologies will be used to prepare interfaces to each of these components. The OCI will:

- display the actions of controllers and setpoint, sensor and actuator values and permit operator intervention to make changes to setpoints, actuators and control strategies;
- enable a dialog with the DSS for obtaining additional data from the operator as well as explanations or conclusions/interpretations from the DSS;
- monitor the RPE algorithms and guide the estimation process;
- enable a dialog with the GPS for the purposes of investigating the effects of recommended changes; and
- display the results of post-processing of plant or model data.

5. Conclusions

The development and application of advanced computer-based technologies to the planning, design, and operation of wastewater treatment plants can provide significant benefits to wastewater treatment industry in general, and to the pulp and paper industry in particular. The concepts presented in this paper reflect some of the latest developments in process engineering and computer-control system.

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Hydromantis, Inc.

Automated Lumber Species Sorting Using Ion Mobility Spectrometry

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Introduction

The economy of the Canadian Wood Products Industry is heavily biased toward the export of commodity products. Over the past decade, political, demographic and environmental factors have combined to make specialty softwood lumber markets more attractive to Canadian producers.

The physical plant of the Canadian Wood Products Industry evolved around the manufacture of commodity lumber. Marketing strategies for these products stress the uniformity of the resource, rather than its variability. In the early 1970's, species combinations were developed by the Wood Products Industry to maximize harvesting and manufacturing capabilities along with simplifying the marketing and selling tasks. Four mixed species groups were created to de-emphasize inter-species differences in physical properties. This strategy was successful, but it resulted in further reduction in the flexibility of manufacturing facilities.

Recent industry indicators show that in today's changing market it would be desirable to produce more valuable single species products, but most mills are no longer designed to do this. While it would be impractical to redesign mills to produce these products, it would not be unreasonable to add additional equipment to sort either logs or lumber by species. Automated species sorting will provide a less expensive means for retrofitting these mills.

Benefits to the Industry

The current market predictions show that the volume requirement for engineered products will double over the next 10 years. Sales of U.S. millwork will also grow an average of 5% per year through 1998 to exceed 13 billion dollars. Current supply options for these products from traditional lumber sources will not keep up with the demand. This provides an opportunity for producers with suitable alternate species, such as the sub-species found in the SPF mix, to enter these markets.

Single species lumber will have better access to markets for engineered products, joinery and even some conventional framing uses. Separated lumber will earn more for the manufacturer than the mixed species, yet cost less for the consumer than alternative materials or lumber grades currently used.

Although few millwork manufacturers have actually changed species to reduce their dependence on clear lumber, a wide range of species has been used as alternates to the primary species. Some examples are:

Primary Species	Substitute Species
Douglas Fir	Lodgepole Pine Red Pine Hemlock

	Hemlock
Ponderosa Pine	Red Pine Eastern White Pine Jack Pine White Spruce White Fir

Table 1 shows the estimated benefits from access to specialty markets resulting from automated species sorting.

Companies producing engineered products will benefit by offering non-traditional species specific lumber grades developed to meet special end use needs. These grades will fill the growing demand for raw material for new engineered products, such as I-joints, parallel chord trusses and light laminated beams. New methodologies for using "white wood" are currently being adopted in building codes and will make beams for different end uses viable products. With the availability of single species lumber, production of both high and low stress beams from white wood will become a reality.

Species separation will also allow manufacturers to improve processing efficiency arising from the ability to process both mixed and single species. With automated species sorting technology, existing mills can be modified to realize the benefits of finishing and marketing single species lumber, while avoiding the disadvantages of segregating and sawing logs by species. Most existing sawmills are designed to process a combination of log size and quality that can only be achieved with mixed species logs. Species sorting of lumber rather than logs avoids potential inefficiencies, while improving trimming, drying, planing and marketing of lumber (Table 2).

Changing harvesting and hauling practices to sort trees or logs disrupts established procedures and can add to wood costs. Without a balanced mix of log sizes, logs are inefficiently processed on headrigs with inappropriate sawing diagrams. This inefficient primary breakdown disrupts material flow, creating bottlenecks at secondary breakdown equipment. Further down stream, species specific trimming decisions will be possible. The efficiency of drying and planing will improve by tailoring kiln schedules and machine settings to the properties of individual species.

Project to Develop an Automated Species Sorting System

The need for automated species sorting has been recognized and solutions have been sought by the industry and various research centers for many years. Since the early 1980's Forintek has evaluated a number of modern laboratory analytical techniques for use in solving the species separation problem. Suitability of a technology has been judged on four key criteria which are essential for continuous operation in a sawmill environment. They are: speed, sensitivity, equipment reliability and ruggedness.

The evaluated technologies included:

- Gas Chromatography techniques (GC, CG-MS)
- Infrared Spectroscopy (DRIFT, FTIR, FT-NIR, NIR-RAMAN)
- Ultraviolet Spectroscopy
- Acoustic Emission Spectroscopy
- Ion Mobility Spectrometry (IMS)

This work resulted in a firm conviction that the Ion Mobility Spectrometry method satisfies all the requirements and has the highest potential to become a viable industrial device for use in the sawmill environment.

An alliance was formed between a consortium of eight Canadian wood products companies, the potential users of this technology; Barringer Instruments Limited, a manufacturer of a commercial Ion Mobility Spectrometer; and Forintek. The Alliance is providing financial and intellectual resources for execution of this research and development work. The project is supported by Industry, Science and Technology Canada (ISTC) and by the Government of Alberta. The interests of the Wood Industry Consortium are represented through the Lead Company (Weyerhaeuser Canada); Forintek acts as the Project Manager; and Barringer as the Project Contractor. The members of the Industry Consortium have significant input into the development of the technology.

Through a feasibility study using sawdust samples, it was quickly established that the IMS detector can reliably identify all wood species of interest. It was evident that the development work needed to focus on the sampling methodology rather than on the detector.

The project was structured into four logical phases:

Phase 1	•	Development of Sampling System
Phase 2	•	Development and Evaluation of Pilot Prototype
Phase 3	•	Construction of Precommercial Prototype
Phase 4	•	Prototype Evaluation by Consortium Members

The project started in February 1991. The first technical challenge was to devise a system for acquiring vapour samples directly from solid wood. A reliable stationary sampling system was demonstrated in September 1991.

The second technical challenge was to adapt the stationary sampling method to operate directly on lumber moving on a conveyor at mill speeds. A system for on-line sampling was completed and demonstrated in February 1992. It is capable of sampling lumber moving on a conveyor at the rate of 100 pieces per minute. Blind species identification test results have been very encouraging, surpassing the industry requirement of 98% accuracy.

The project is now moving into the second phase in which a pilot system will be constructed and installed for testing in Weyershaeuser's sawmill in Kamloops. It is anticipated that the final version of this system will be commercially available by the end of 1993.

Technical Concept

The concept of the species sorting system (Figure 1) is based on extracting a small vaporized sample from moving lumber surface by means of a remote infrared laser; transporting such a vapour sample efficiently to an IMS chemical analyses; rapidly analysing the sample for chemical compounds which are characteristic of each species; recognising the species-specific signatures with computer algorithms; and generating electrical signals for activating automatic sorting gates.

The current version of this system is using an IR CO_2 waveguide laser as a source of energy for sample vaporisation. The radiant energy is delivered repetitively in a precisely controlled manner as discrete packets of light following one another in a pattern optimised for given mill conditions (Figure 2). This energy is absorbed by the wood surface and converted to heat. Consecutive laser pulses increase the wood temperature where the laser beam interacts with the wood surface, until the species specific chemical compounds begin to vaporise. This heating process continues until a sufficient amount of vapour is generated and transferred to the IMS detector for analysis. The success of this method depends on the laser's capability to heat the wood surface extremely rapidly. The heating process is accomplished in the 0.2 seconds, required for practical application.

A very important aspect of this method lies in the ability of the laser beam and the sampling head to follow the moving lumber while the sampling is taking place. This was achieved by mounting the sampling head and a laser beam deflecting mirror on a carrier which travels on a track parallel to the conveyor motion (Figure 3). The carrier latches onto each piece of lumber and stays with it until the sampling is completed. Subsequently, it disengages and returns back to the starting position to pick up the next piece of lumber.

The most important aspect of this method depends on the ability of IMS to analyze and identify the species specific chemical compounds in a fraction of a second. This is achieved with a special IMS detector operating at a high temperature and with a specially designed airflow arrangement that back flushes and cleans the detector and the sampling system between consecutive samples.

The IMS detector produces an ionic current signal as a function of drift time. Graphical representation of this signal is referred to as a "plasmagram" (Figure 4). Each wood species has a characteristic signature consisting of one, or several peaks in the plasmagram (Figures 5, 6 and 7). Pattern recognition software is used to search for, and to identify these signatures.

Market Potential

Preliminary market studies have been carried out in Canada and the United States. The initial market potential for the Automated Species Sorting system is estimated at 100 units in Canada and 350 units in the U.S. Discussions with Asian industry representatives indicate additional potential markets.

Acknowledgement:
Economic and market information presented in this report was produced by K. Kahus of Woodmark-Wood Products Marketing of Scottsdale, Az. This work was done under contract to Forintek.

Table 1 Estimated benefits from access to specialty markets resulting from automated species sorting technology.

PRODUCT BENEFITS

SOURCE OF BENEFIT	ESTIMATED BENEFIT (1) (Per MBF Sold)
Engineered Products	$ 50.00 to $ 75.00
Export Joinery Products	$ 100.00 to $ 150.00
Export of Dimension Specialty Products	$ 75.00 to $ 125.00
TOTAL PRODUCT BENEFITS Dependent on New Product Mix	$ 50.00 to $ 150.00

1. Commodity dimension lumber typically sells in the $250 to $350/MBF range and the premiums or savings listed here would be added to the selling price or subtracted from production costs.

Table 2 Estimated benefits from improvements in processing efficiency.

IMPROVED PROCESSING EFFICIENCY

SOURCE OF BENEFIT	ESTIMATED BENEFIT (Per MBF Processed)
Consistent Log Diet	$ 1.00 to $ 1.25
Dry Kiln Costs	$ 3.00 to $ 6.00
Planer Efficiency and Improved Grade Recovery	$ 0.50 to $ 1.10
TOTAL MILL BENEFITS	**$ 4.50 to $ 8.35**

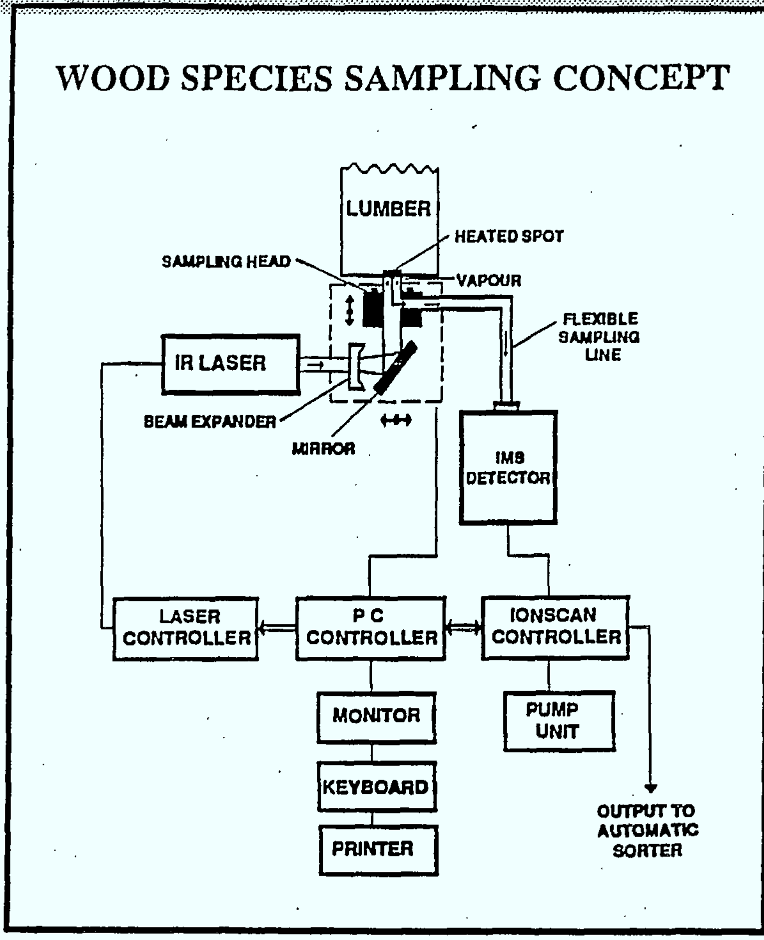

Figure 1

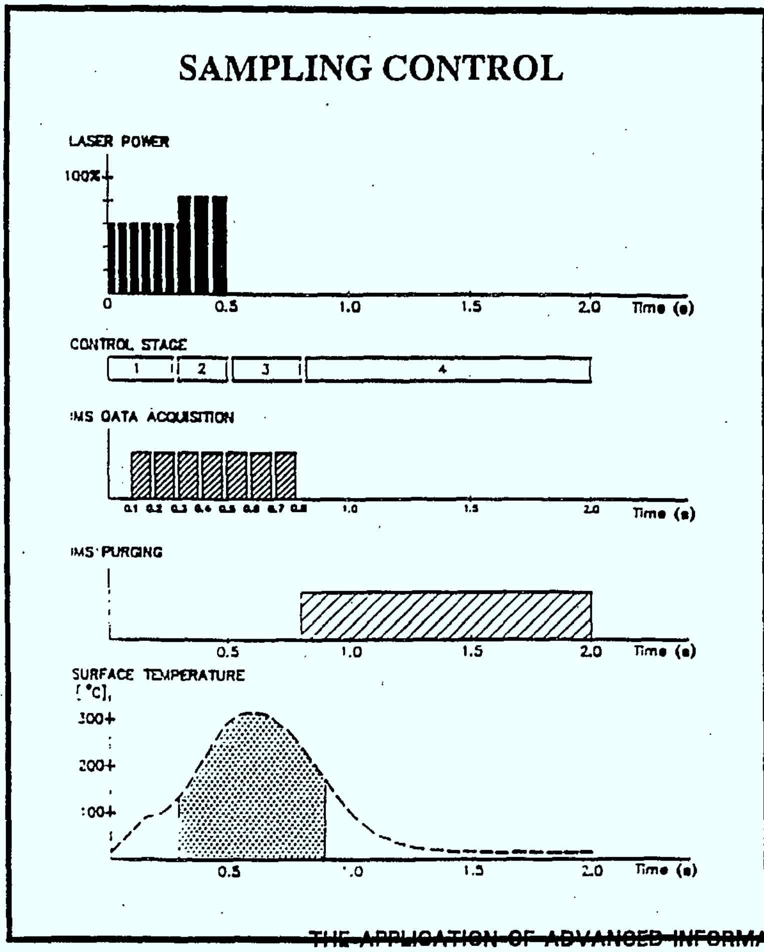

Figure 2

ON-LINE SAMPLING CONCEPT

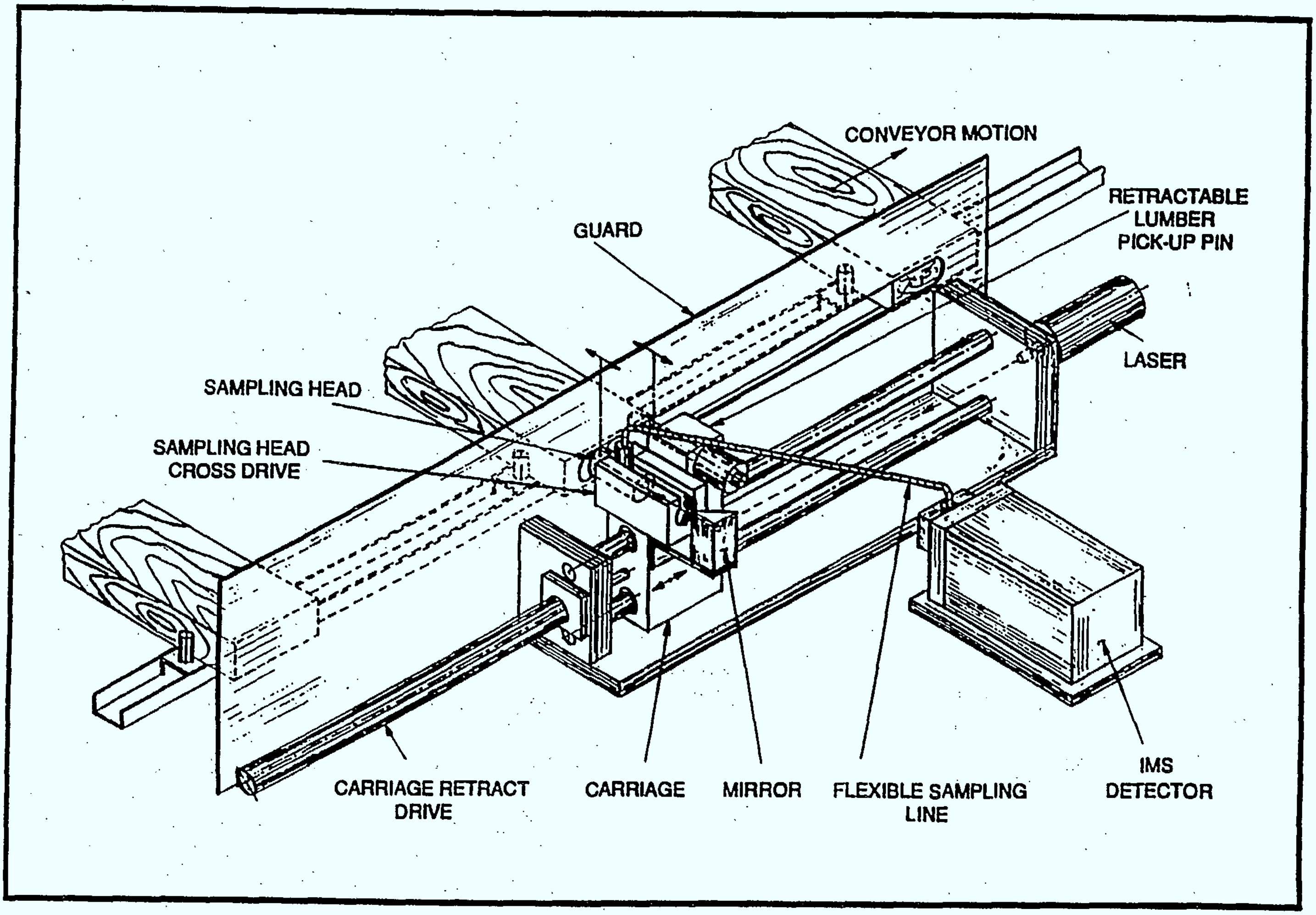

Figure 3

LODGEPOLE PINE PLASMAGRAM

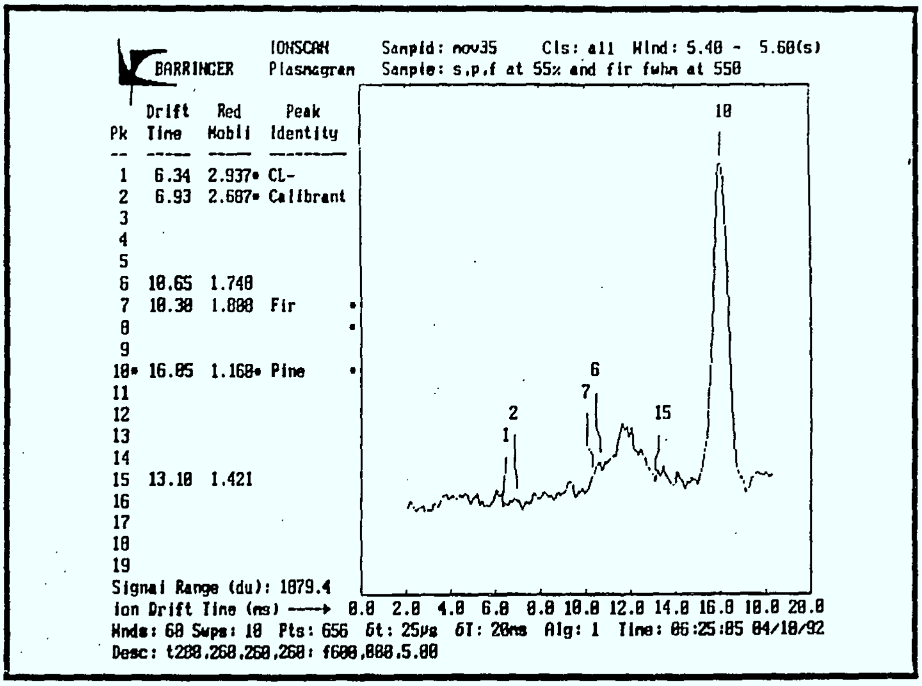

Figure 4

ALPINE FIR PLASMAGRAM

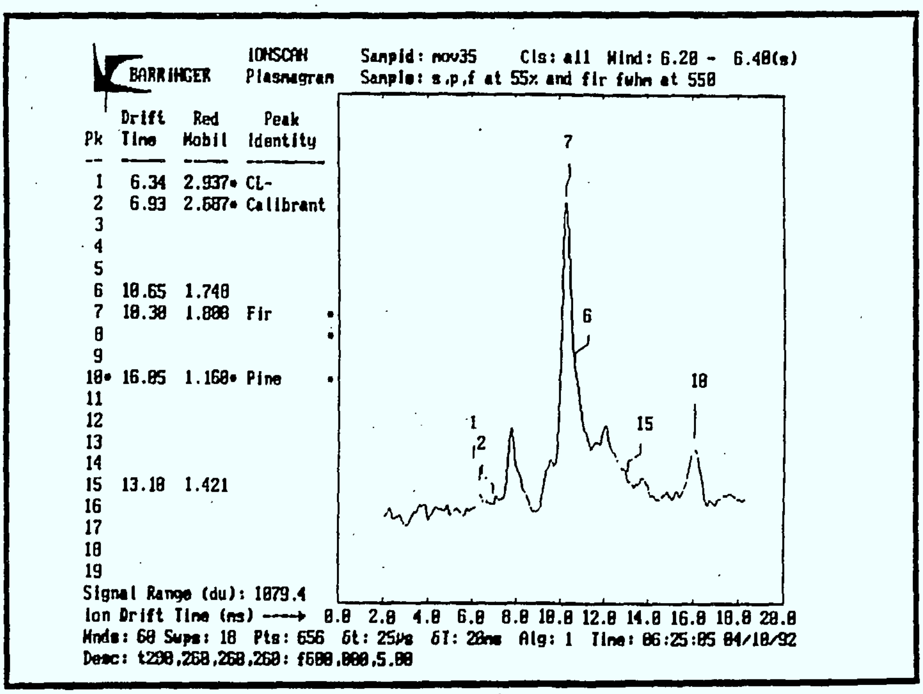

Figure 5

SPRUCE PLASMAGRAM

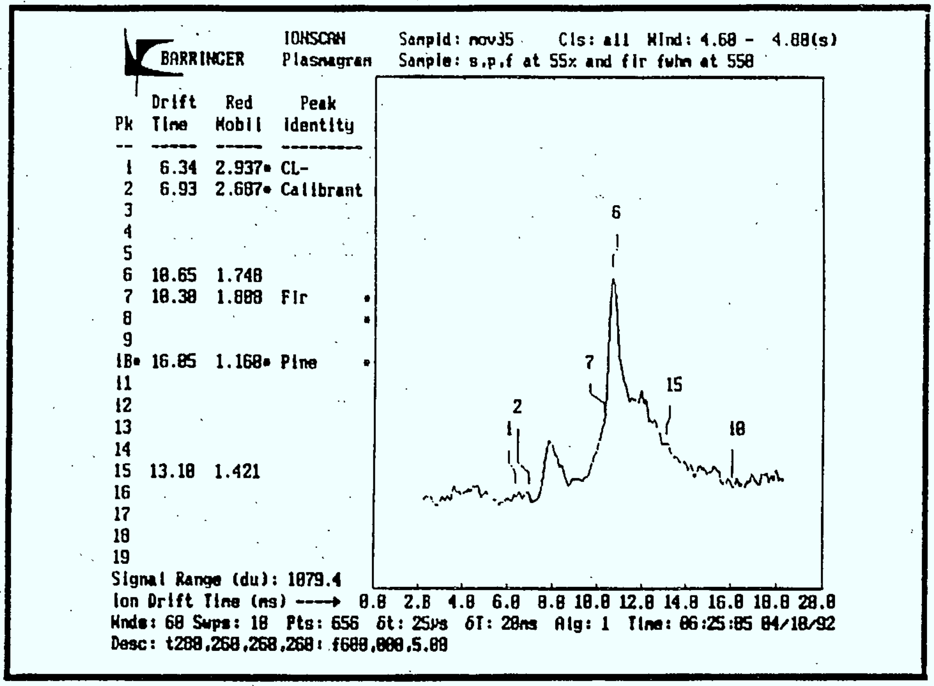

Figure 6

DOUGLAS FIR PLASMAGRAM

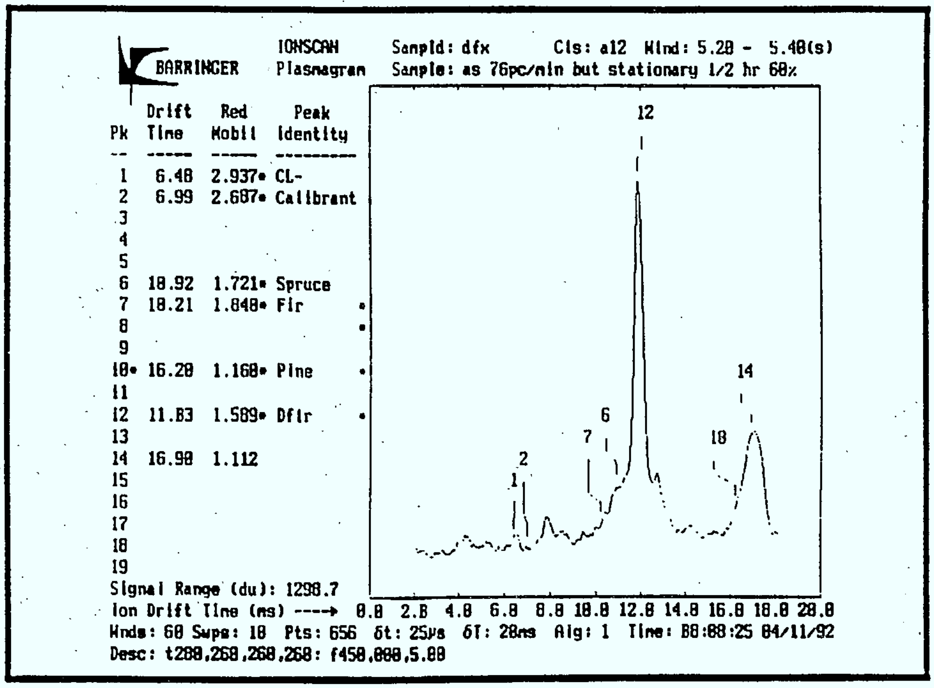

Figure 7

Automated Scanning for Lumber Grade

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Vision Smart
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Introduction

VisionSmart Inc. is the only company in North America with installed Grade-Based Lumber Optimizers. The installations at Fort St. John and Port Alberni are probably the largest, most complex Grade-Based Scanners currently installed in the world. The Alberni installation has been in place since early 1989. The Fort St. John installation occurred about 18 months later. Both systems were novel, and both have required some time to achieve full operational status. Since the Port Alberni system has had a longer operating history, most of this paper will concentrate on the details of the Alberni application, although conclusions will be drawn on the basis of experience at both mills.

Port Alberni Requirement

MacMillan Bloedel Alberni Pacific Division (APD) cuts hemlock and douglas fir. Its main products are cut for export with an emphasis on obtaining grade. Logs are delivered and sorted in the water. After merchandising, they are sawn into flitches and cants in two lines by a headrig and log quad. Average log diameter at Port Alberni is 20"and typical bucked log length is 20'.

The quad is the main feed to the edger optimizer. APD's primary breakdown can handle logs up to 60" in diameter and 26' in length. The lumber produced by APD is sawn into a mixture of high grade and merch lumber for offshore and North American markets. APD is a grade mill, in that it cuts for the highest grade clear lumber.

The Edger Optimizer requirements were therefore:

- To deal with wet green hemlock and douglas fir flitches and cants.
- To deal with pieces varying from 8' to 26' in length, from 6" to 42" in width and from 2" to 8" in thickness.
- To operate at rates of up to thirteen lugs a minute.
- To control an eight saw edger.
- To cut to meet any of 240 product specifications. There are more than 240 different grade-length-width categories of commodity sold from APD.
- To edge each piece for the highest recoverable value.

Optimization Test

Prior to its installation, measurements of actual grade recovery by the edger operator at APD were made by Jan Aune and the MBR staff. These tests were performed by sampling the lumber on the edger deck during Friday lunch breaks. A half dozen or so flitches were pulled in each test and "pencil-graded" by the mill's best graders. The test graders had adequate time to carefully examine each piece and look for the highest value edging solution. The pieces were put back and the lumber was edged by the operators. These tests were ran many times and an average value recovery of 80% was obtained. It was also determined that the majority of the available value gain could be obtained if knots were detected and properly handled.

The Basis of The Optimizer Design

As shown in Figure 1, the optimizer scans pieces sideways. After scanning, the pieces feed into a skewing infeed (which changes direction and includes sharp chains and press rolls), and from there into an eight saw edger (with no chipping heads). In more detail (as shown in Figure 2) flitches are singularized and turned wane up in lugs by the edger operator. At that time the operator can indicate that there are non-scannable features which will limit grade recovery. The pieces then enter a laser triangulation based wane scanner operating on 4" centres. Profile data is sampled every 1/10th of an inch at 1/10th of an inch accuracy. The pieces are then scanned by the X-ray system (see Figure 3).

Knots are denser than the fibre in the stem, they always cast a dark X-ray shadow. This shadow is picked up on array of 2880 sensor diodes. There is one diode every 1/10" across the entire 26' (except where blocked by chains). As the flitch moves sideways across the sensor array, the knot shadows form a complete image of the projected area of the knot, set in a image of the board. Since each board image involves a large amount of data (approximately 1 million pixels) and not much time is available, massive data processing is required. Figure 4 shows the data gathering connections and processing hardware. The signal originates in the X-ray photodiodes which are clustered into six arrays. Each of these arrays transmits digitized data via fibre optic links to the inputs of 8 transputers, responsible for correction of the array data. The data is regrouped and transferred into five frame buffers via the VME bus. From there it enters a bank of pipelined video and image processors. Video data is shared on a high speed 20MHz common data path.

The reduced feature is passed via the VME bus to a 68020 where it is merged with the wane information and optimization takes place. Other 68020's on the bus control I/O and police the bus traffic. A Sun 3/180 operates as the file system/development interface. Infeed and saw control is performed on a Multibus system. The flow of the image processing and is outlined in Figure 5. As is evident, a large number of operations are performed, including pixel by pixel correction for sensor noise, 4x4 smoothing, and histogram equalization to adjust the contrast level of the image area over a wide dynamic range.

Optimization

Despite the complexity of the hardware and software systems, the conceptual operations are very simple (as shown in Figure 6). Initially, feature information is obtained from the X-ray and laser data. This feature information is turned into geometrically identified defect boundaries. The computer then finds an optimum skew and edger solution to obtain the highest value in the piece. Usually this involves grouping knots into merch pieces and cutting long clears around them.

Post Installation Tests

Following the installation of the optimizer a second set of value recovery tests were performed. Value recovery with the operators had been established at 80%. The Edger Optimizer achieved 92%. This 12% improvement in value recovery has meant improved performance of 150,000 to 200,000 dollars per month at the edger, as documented by MacMillan Bloedel (see "X-ray Edger Optimizer Makes Money at MacMillan Bloedel's Alberni Pacific Division" by Jan Aune).

Conclusion

The system at Port Alberni has been on-line for more than 2 years. It has been an outstanding success for several reasons:

- Grade-Based optimizers make money where there is grade to recover. Prior to the APD development it was clearly established that 20% recovery was available.

- The grade recovery could be achieved by concentration on a small number of defects: wane, knots, splits, and through rot. Detectors for a limited defect set can be implemented at a reasonable cost.

- The available recovery could be easily captured. Since APD was already marketing high value commodities, all the required handling, sorting and marketing functions were in place.

In general, this suggests that for Grade-Based optimization, the maximum benefit is gained by the strategically applied detection of a limited feature set. APD also proved the viability of X-ray knot detectors. Bearing this in mind several basic application types seem to offer the best opportunities:

- Grade-Based sawmill edgers or trimmers in mills organized for grade-recovery.
- Grade-Based sawmill edgers or trimmers in mills where defect reduction will improve efficiency.
- X-ray detection of knots for chopping of high value commodities like cedar.
- Clear Finders or Hi-Graders in planer mills where shops or clears would otherwise be sold as dimension. These systems detect only clear material.
- Grade-Based Rip or Chop-Saw optimizers or scanners in re-mans dealing with grade lumber.
- Grade-Based trimmers or sorters in board mills where decision making is based on a small number of predominant defect types.
- Grade-Based trimmers or sorters in stud mills where the decision making is based on a small number of predominant defect types.
- Hardwood optimizers which maximize the number of clear cuttings.

Each of the above rely on the detection of a limited feature set or the detection of clear material.
In conclusion, Grade-Based optimization is now proven and dramatically successful. It is now ready for broad and diverse application throughout the industry.

Acknowledgements

This report is based on the work of many people:

At MacMillan Bloedel Alberni Pacific Division- Willis Marsh, John Hutchingson, Randy Young, and Dave Blake.

At MacMillan Bloedel Research- Terry Arden, Charlene Yap, and Jan Aune.

At Canfor, Fort St. John- Rick Reinbolt, Mila Maisonneuve, Tim Maisonneuve, and Ted Maisonneuve.

And of course, the entire team at VisionSmart.

Reference:

1. Aune, J.E., "X-ray Edger Optimizer Makes Money at MacMillan Bloedel's AlberniPacificDivision". Proceedings of the 4th International Conference on Scanning Technology in Sawmilling, 1991.

Scanning Layout

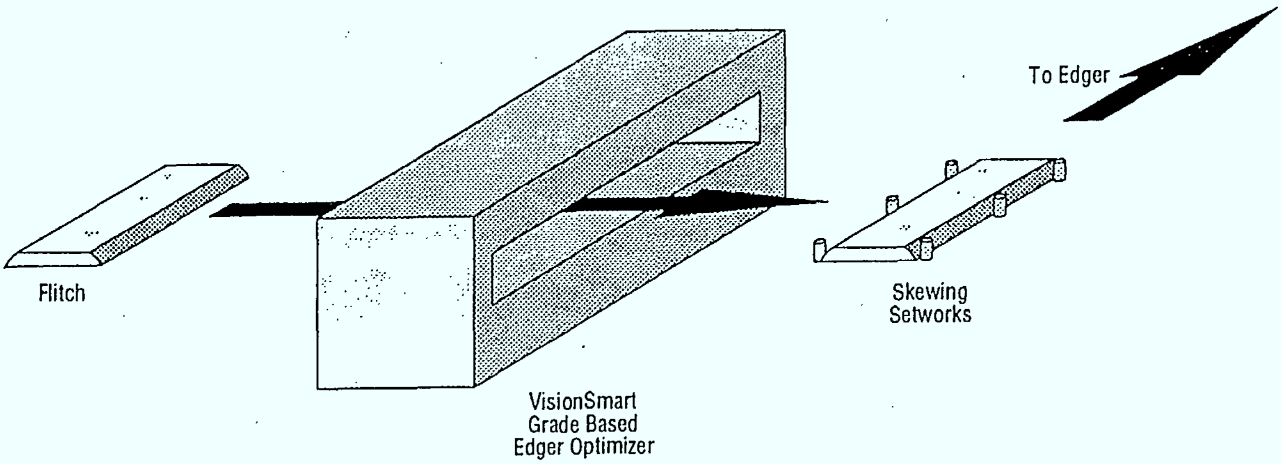

Figure 1

Port Alberni Installation System Layout

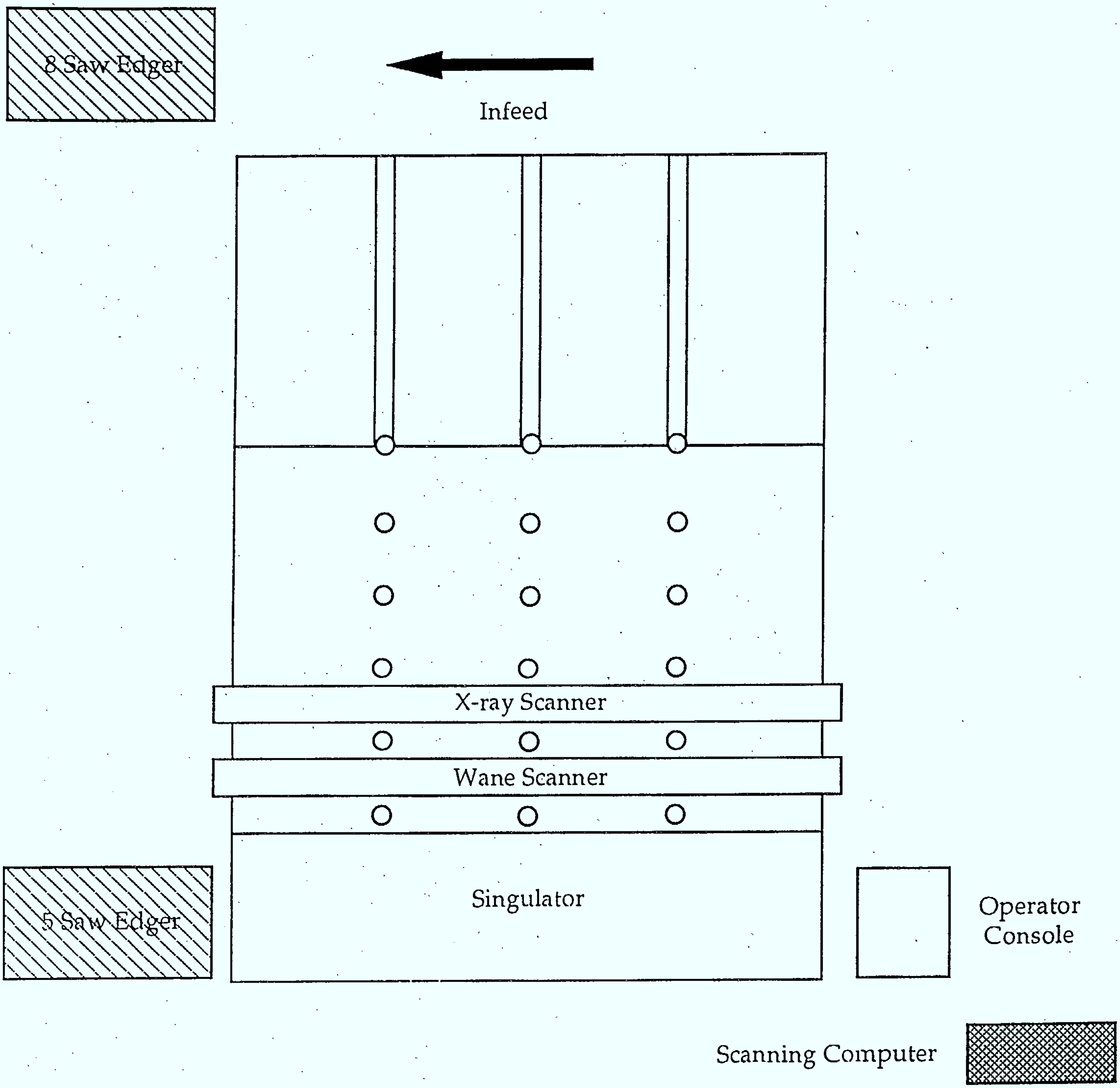

Figure 2

X-Ray Scanning

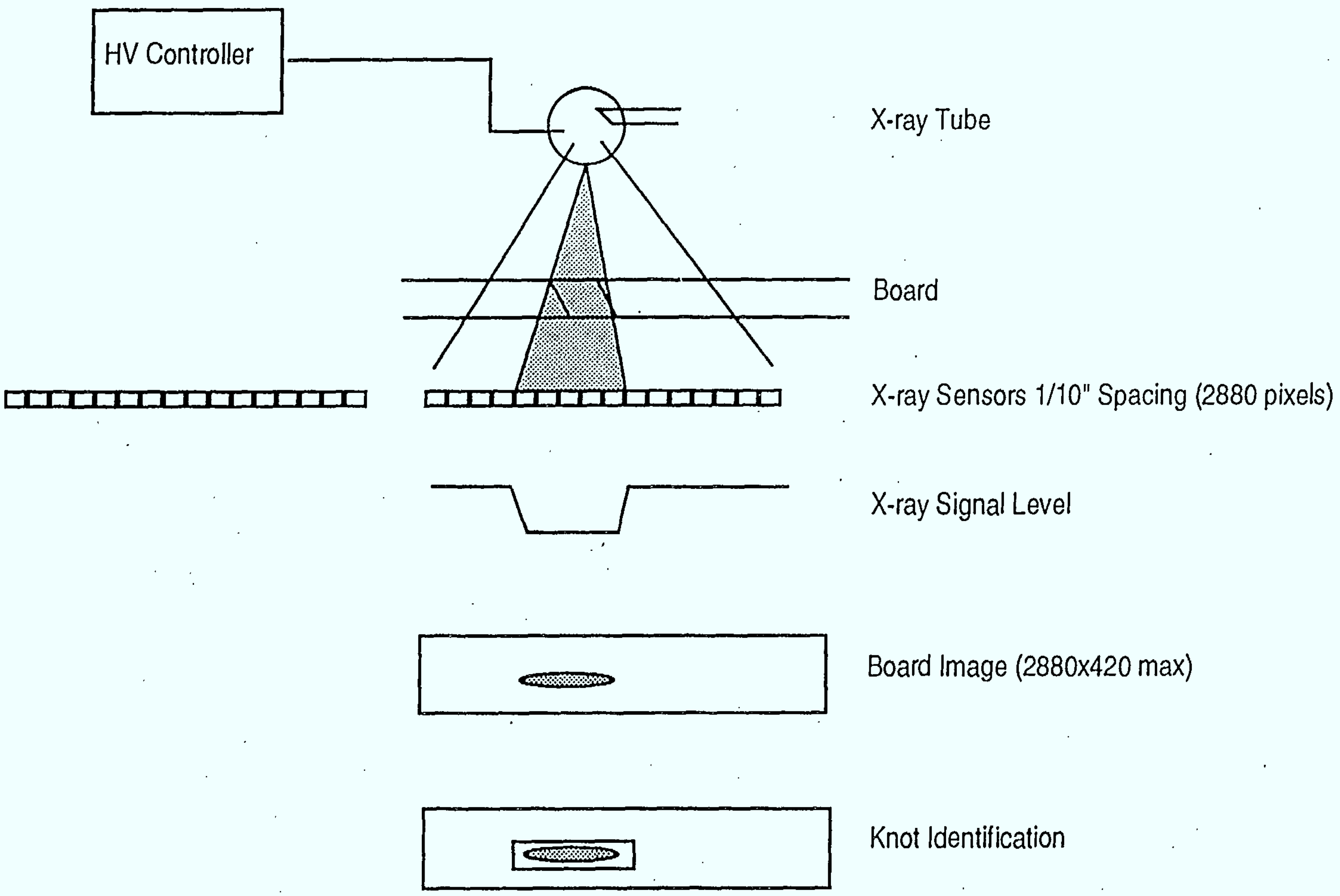

Figure 3

Imaging Hardware

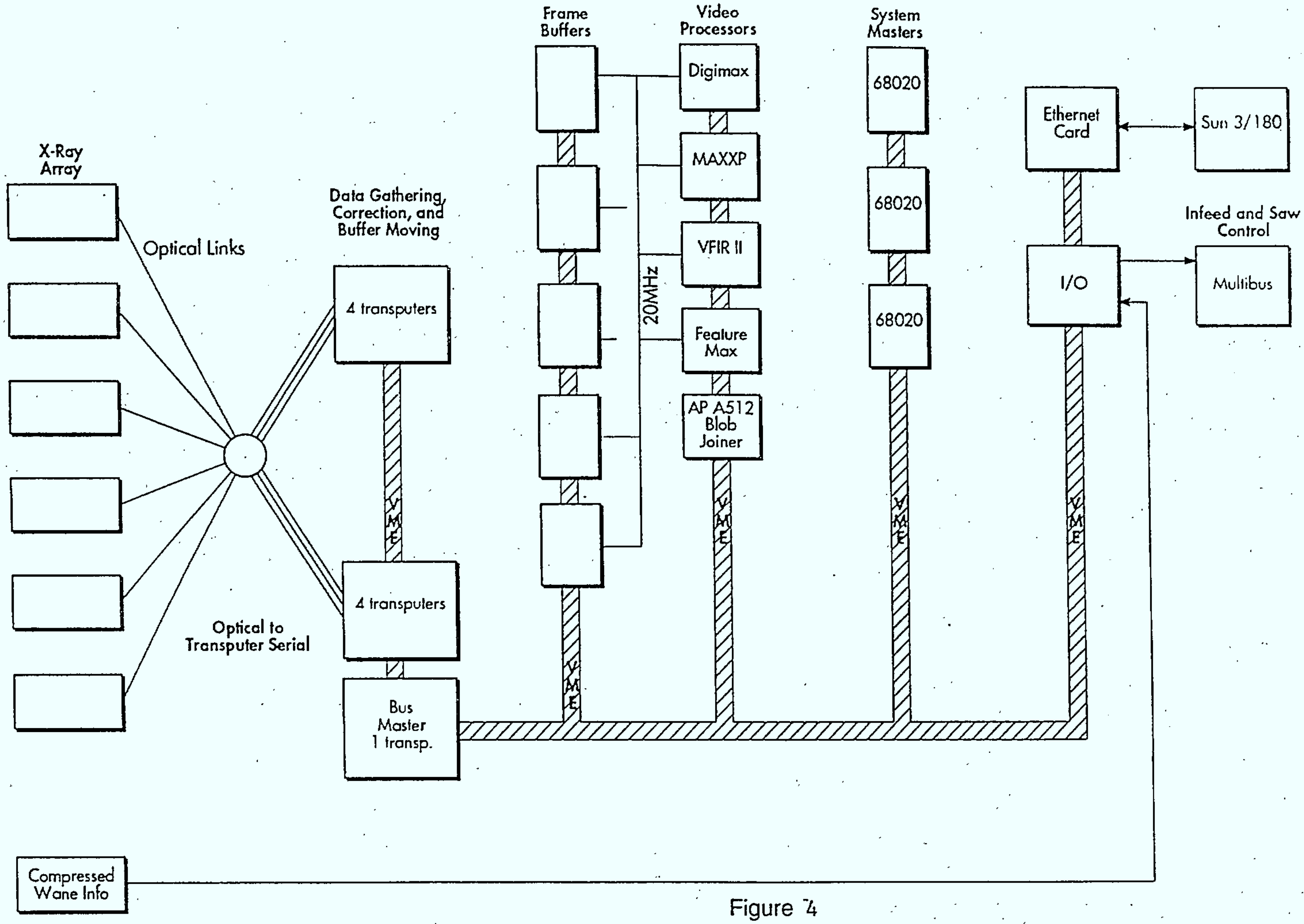

Figure 4

Image Processing Flow

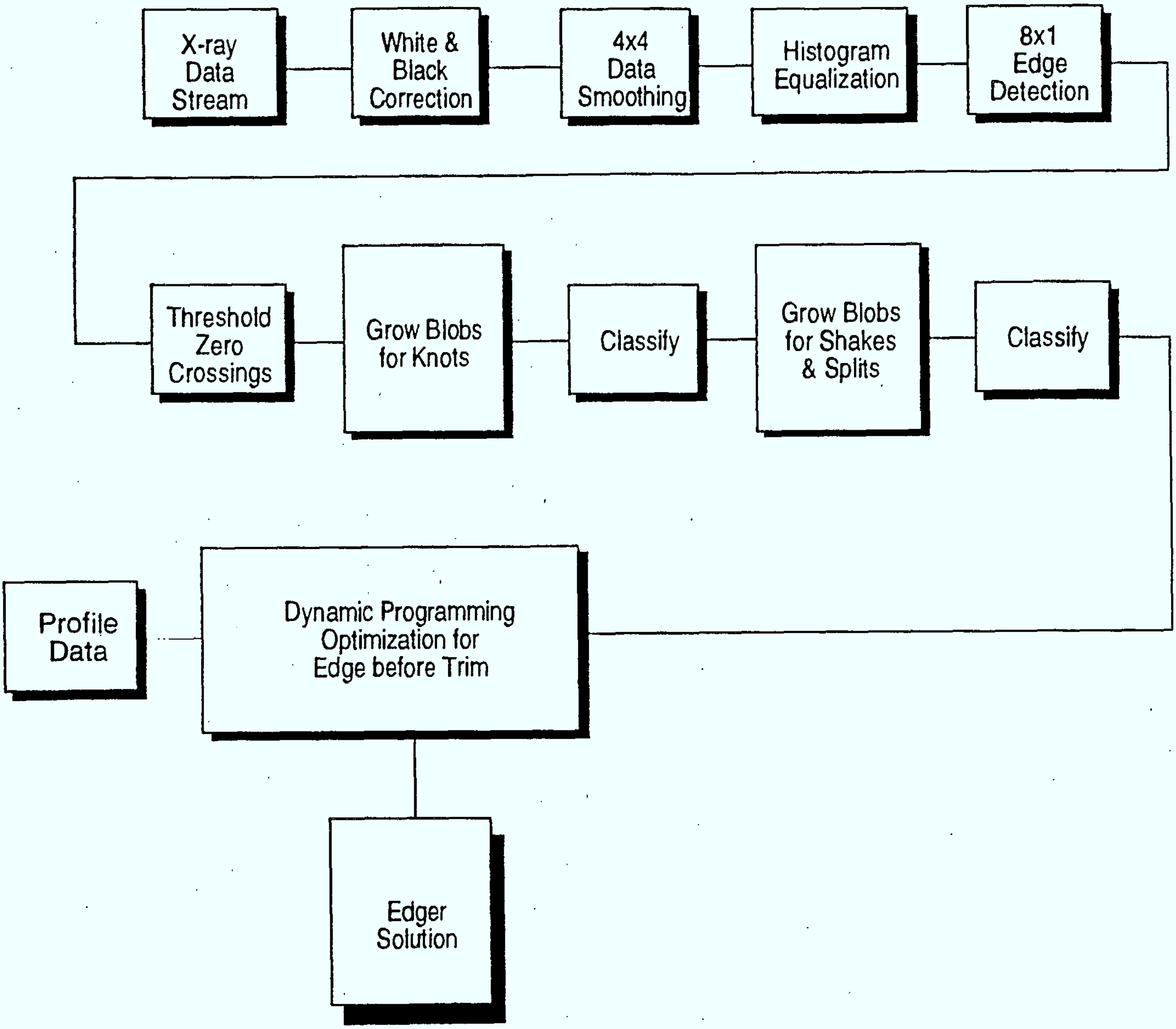

Figure 5

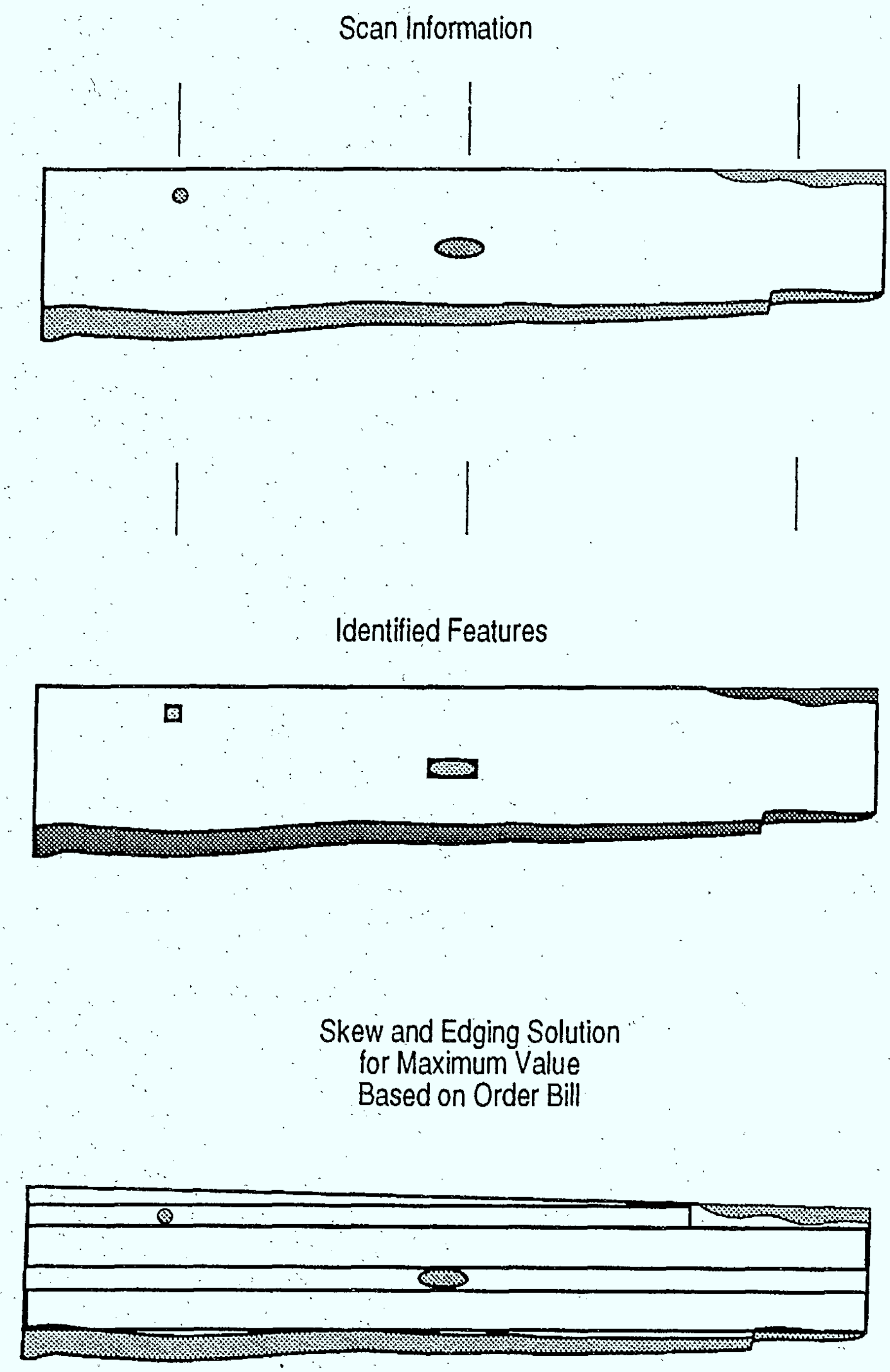
Scan Information
Identified Features
Skew and Edging Solution
for Maximum Value
Based on Order Bill

Figure 6

Secondary Manufacturing Applications and Opportunities

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1. Introduction

The Computer-aided Design and Manufacturing Laboratory at the University of Victoria has been involved in a wide variety of applied research, development and secondary manufacturing projects. In many of these applications it has been interesting to observe how each project has had much wider application than originally envisaged, and also that information and knowledge generated in one project is directly applicable to other projects in other industries. In a sense the process can be considered self perpetuating.

The primary building blocks of advanced secondary manufacturing systems are automated and numerically controlled machines, including CNC machine tools and robots. These computer controlled and programmable machines are in many ways motor drives so that cutting tool positions are controlled by computers. Programs for producing parts are arranged in the form of coded blocks of information. This code is interpreted by the machine tool controller in order to control the workpiece table, tool spindle movements and all auxiliary functions. These simple changes have had a dramatic effect on manufacturing capability. A recent and relevant quote from the Wall Street Journal is, "if we want to be competitive in the international marketplace we must continuously and rapidly conceive, design, manufacture, and market new and improved products. It is not just a matter of producing things."

Examples of recent projects, some within the forest industry, resulting in secondary manufacturing opportunities, are discussed below. All projects have been carried out in collaboration with industrial partners and have been supported in part by NSERC, IRAP, ASI and the Science Council of B.C.

2. Applications

2.1 Automated Laser Scanning and CNC Machining

In engineering design, where style, ergonomic and/or aerodynamic factors are important, prototype sculptured clay models are often created by hand in design studios. Rapid prototyping of such models is then needed in order to manufacture the product in minimum time. Ideally, this entails automatic surface digitization, conversion of data to computer based models (compatible with current CAD/CAM systems) and numerically controlled, CNC, manufacture in the most appropriate form. Currently, this prototyping is accomplished through measurements taken manually from coordinate measuring machines, CMM. This process, while accurate, is very laborious and is not ideally suited for defining intricate curved surfaces or defining patch boundaries. The surface shape in the majority of these applications (from automobiles through to household appliances) usually contains many separate and distinct features, including free-form surface patches as well as planes, cylinders and other quadric surfaces, all blending together to create a stylish effect.

Laser scanners have many features which can be adapted to this process. For example, they offer the advantages of rapid surface digitization, non-contact measurement, and lend themselves to computer-based automation. Laser scanners, however, have a number of limitations which have prevented their adoption as the basis for rapid prototyping. Firstly, there is noise associated with the signal which if magnified, when for example cutter offsets are determined, render the data useless for CNC machining purposes. Secondly, with laser triangulation methods there is an inherent trade-off between the accuracy of measurement on the one hand, and width and depth of field on the other. For an accuracy of 0.05 mm (a typical CNC machining tolerance) the working volume of a scanner may be limited to a 100 mm cube with a standoff distance of 150 mm. For larger or deeper objects the scanner must be able to do multiple passes across the surface, with some automatic accounting for standoff distance. Thirdly, it is often important to scan around 3-D shaped objects and this requires repositioning of the laser scanner with respect to the prototype model. The resulting data from these types of procedures is random, unformatted, inconsistent and requires extensive processing to reconstruct model surface patches suitable for manufacturing purposes.

The technical long-term objective of this research is to be able to place any object within the confines of an intelligent laser measuring machine, have the part fully and automatically scanned, the data processed and a numerically controlled machine replica of the object produced shortly thereafter.

2.1.1 Laser scanner and CNC interface

The Hymarc 45-C laser scanner used in this work provides a dense surface digitization of an object by means of a sophisticated opto-electronic head, interfaced to a real-time data collection computer. The synchronised scanning arrangement employed is unique in that it allows high accuracy data to be collected with a physically small triangulation base (although an effectively wide optical base), thus enabling the scanner head to be kept physically compact, which is particularly suitable for CNC installations. A focused helium-neon laser spot is linearly scanned across the surface, by means of a galvanometer driven mirror assembly, and imaged onto a linear CCD array. The galvanometer position and imaged spot location, on the CCD, are used by the real-time data collection computer to compute range values. The scanner head is moved within a 3-D work envelope by the CMM or CNC machine tool. Multiple passes may be made at any depth across the prototype surface until complete digitization is achieved. A mounting attachment also allows the viewing angle of the scanner head to be altered according to the surface form being digitized. This enables scanning to be made around 3-D shaped objects and minimises any occlusion problems. The X-Y-Z position encoders of the CNC or CMM update the scanner computer as data is collected. Multiple views of an object are referenced to one global or part based coordinate system. The 3-D laser scanner system has been successfully integrated with both a CNC machining centre and a programmable CMM, as illustrated in Figure 1.

2.1.2 Rapid prototyping system

For the reasons given above the mass of raw scanned data, called cloud data, is unsuitable for surface definition, CAD/CAM database integration, and for generating cutter offsets and associated CNC toolpaths. Approaches to analyze and handle this data are embodied in a software package recently developed at the University of Victoria. The software currently runs on a Sun SparcStation and utilises the Phigs 3D graphics libraries to display the object, interactively select surface patches, and display CNC toolpaths.

A block diagram of the steps for segmenting and reconstructing surface patches on the surface of the prototype is shown in Figure 2. The input cloud data file is displayed on a workstation screen, using four standard viewing angles. Surface patches are interactively defined and cloud data points, within the patch boundary, are segmented from the overall data file and stored for subsequent modelling or editing. An appropriate modelling entity (such as plane, cylinder etc.) is selected from a menu and used to reconstruct an individual surface patch through the maximum likelihood estimation (MLE) theory. If the accuracy of fit is below a predefined level other modelling entities may be attempted. Once a satisfactory fit is obtained, the relevant patch parameters (radii, centres etc.) are stored. With free-form patches a Hardy multiquadric technique is adopted to smooth and model the surface. When all patches are complete, cutter offsets, for any generalised shaped milling cutter, are calculated as shown in Figure 3 and tool paths for direct CNC machining are generated. The surface data may also be exported to an external CAD or CAE program using the DXF or IGES graphics file transfer protocols.

The immediate application of this work is in the manufacture of injection moulding dies. However, it may be applied to replication of native indian art forms, replacement of damaged honeycomb aircraft body material, anatomical part replication (for example in reconstructive plastic surgery or dental applications), flexible keyboard key underpad manufacture, decorative bottle manufacture and for developing CAD models for movie animation applications.

2.2 Automated Cabinet Door Making

Cabinet doors, of the type which are fitted into kitchen and bathroom cabinets, are frequently made on copy router machines in small batch manufacturing runs. Each door consists of a curved top rail, two tennoned side rails, a tennoned base rail, and a raised central panel, as shown in Figure 4. The copy router machines consist of a high-speed, vertical spindle, cutter head mounted within a fixed worktable. A movable worktable is mounted above the fixed worktable and adjacent to a copy fixture attachment. Workpieces are clamped to the movable table and can be moved manually past the cutter head at a distance determined by a copy template.

In this application the automation process is undertaken using a personal computer as the central controlling component, both for design and manufacture. The door components are defined using a standard, readily available CAD package such as AutoCAD An automation software package is used to calculate the required cutter offset location files, and this data is used to generate the information necessary to direct the motion control hardware (which consists of three stepping motors and associated drivers together with a stepping motor controller board inserted into an expansion slot on the PC).

All cutter motion is controlled by the menu-driven automation package. The set of commands for producing a specific component (called an application program) is simple instructions that avoid the control codes (G-codes) associated with normal CNC machine tools. Excellent graphics capabilities for door design and cutter path images are provided by the PC as well as a large off-line data storage capability.

2.2.1 Automated woodshaper

A photograph of the modified woodshaper and computer controller unit is shown in Figure 5. The woodshaper has been retrofitted with an additional movable table, which is mounted on top of the existing table by means of two linear raceways. The additional table contains two pneumatic clamping rams that secure the workpiece to the table top. Both movable tables are fitted with leadscrews and ballnuts. Stepping motors are attached to the leadscrews via flexible couplings. Control of the rotation of the stepping motors can thus be used to position the workpiece relative to the cutter head. This arrangement allows positioning anywhere in a workplane size of 100 cm by 46 cm. The cutter head crank mechanism is also retrofitted with a stepping motor drive so that the cutter height can be automatically adjusted relative to the workpiece.

Stepping motors were selected in preference to DC servo motors on the basis of price and torque requirements. They were also selected because of their simpler interfacing and software needs; motor shaft position encoders and a feedback loop to the position control system are not required. Each stepping motor has a driver, which provides voltage pulses. The total number of pulses determines the distance travelled, while the frequency of pulses determines the speed of movement.

Interfacing each stepping motor, plus driver, to the PC is via a stepping motor controller board. The controller board fits into an expansion slot in the PC and replaces the dedicated controller found on CNC machining centres. Dual port, random access memory (RAM) allows two-way data transmission between controller board and PC; commands that specify form, position, and speed of motor movement flow from PC to board, whereas, motor position updates flow in the opposite direction. Commands transmitted to the board are in a CNC G-code format and are downloaded line-by-line to the controller board.

2.2.2 Automation software

The AutoCad drawing output, in HPGL format, is converted into a cutter offset location file and then into a G-code machine file. The user's application program, which contains all the machining instructions to produce one component (i.e., the curve to be machined, feedrate, cutter height, and position in workplane), is merged to form one final G-code file. A library of application programs, as well as a library of curve profiles, can be assembled as the integrated system is used.

The automated woodshaper proved to have good control over the workpiece in terms of positional accuracy and maintaining a steady feedrate. The machined workpiece shapes were found to be within 0.15 mm of the AutoCAD curves. The automation package has been used extensively by a cabinet door manufacturer who has shown production time savings (to design, setup, and manufacture a cabinet door) of seventy-five percent. A quote from Gary Steele, the president of Steele's Cabinets, is that the project, "has increased my profitablilty because now I can manufacture the cabinet doors cheaper than I can buy them. I've hired new staff to make the doors and run the machine. And, while our principal furniture market remains on Vancouver Island, we are confident that the market for the computer-driven routing machine will be far wider".

2.3 Integrated Ship Manufacture

An integrated computer aided design and manufacturing program, called ShipCAM,
was originally developed in conjunction with a local shipyard so that they would be able to apply CAD/CAM techniques without resorting to the 0.5M$ programs used by large international shipyards. ShipCAM has progressed rapidly from this point and has now been installed in a number of USA and Canadian shipyards and has been used to produce a range of tugboats, ferries and other vessels.

ShipCAM has been designed as an easy-to-use, Macintosh-style, program for ship manufacture. It enables hull lines to be defined and interactively adjusted (faired) through special B-spline lines and surface definition algorithms. Developable curved surfaces and internal structures can be generated automatically and, if required, can be exported to CAD packages. Numerically controlled instructions can be produced for CNC flame-cutting machines. An example of a 12-m tugboat, lofted and manufactured entirely using ShipCAM, is given in Figure 7. The initial menu of ShipCAM is shown in Figure 8.

The ShipCAM program is a classic example of applied university research. The original ideas and concepts were investigated with a Ph.D. student (who is now an assistant professor at Waterloo University) and NSERC operating grant funding. The research subsequently progressed to a fully functional user-friendly industrial program with two years of Science Council of B.C. funding. Program development was followed by a market study through a Science Council of B.C. MART grant. Since that time the new company, which pays royalties to the University of Victoria, has been totally independent and has just completed its first year of operation.

2.4 Curved Surface Machining

An interactive B-spline surface definition and curved surface numerically controlled machining program has been developed and used on a wide range of applications with industrial groups. These applications have included Francis turbine blade sand-casting mould shapes, propellor blades, artificial heart valve dies, contact lense dies, limb replication, 3-D chocolate bar moulds of Whistler mountain and 2-metre ship hull hydrodynamic models. The approach has proved much faster (reductions in machining time of eighty to ninety percent) and more flexible than conventional CNC approaches.

2.5 Other Projects

Other projects which have resulted in secondary manufacturing opportunities include:

- Centrifuge reverse osmosis desalination - a patented device for producing 3000 gals of fresh water per day from salt water. It has recently undergone stringent performance trials at DND and is now being installed on board a Canadian Navy vessel. It is hoped to manufacture much larger units for on-land applications.
- Ice-blasting - hard ice is used for cleaning surfaces through a shot blasting process. It is being commercialised by Re-Tech Ltd and has been used for cleaning non-metallic aircraft wing material and in nuclear power plants.
- Cavitation hull cleaning lance - a patented device, utilising the imploding bubbles of a cavitating water jet, has been used extensively for cleaning offshore drilling platforms.

Acknowledgements

The input, interaction and financial support from a diverse group of companies is gratefully acknowledged, as is the financial support from the Natural Sciences and Engineering Research Council of Canada, the B.C. Advanced System Institute, IRAP and the Science Council of B.C.

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12. Bradley, C. and G. W. Vickers, "Automated rapid prototyping utilising laser scanning and free-form surfaces", Annals of CIRP, vol. 41, no. 1, 1992.

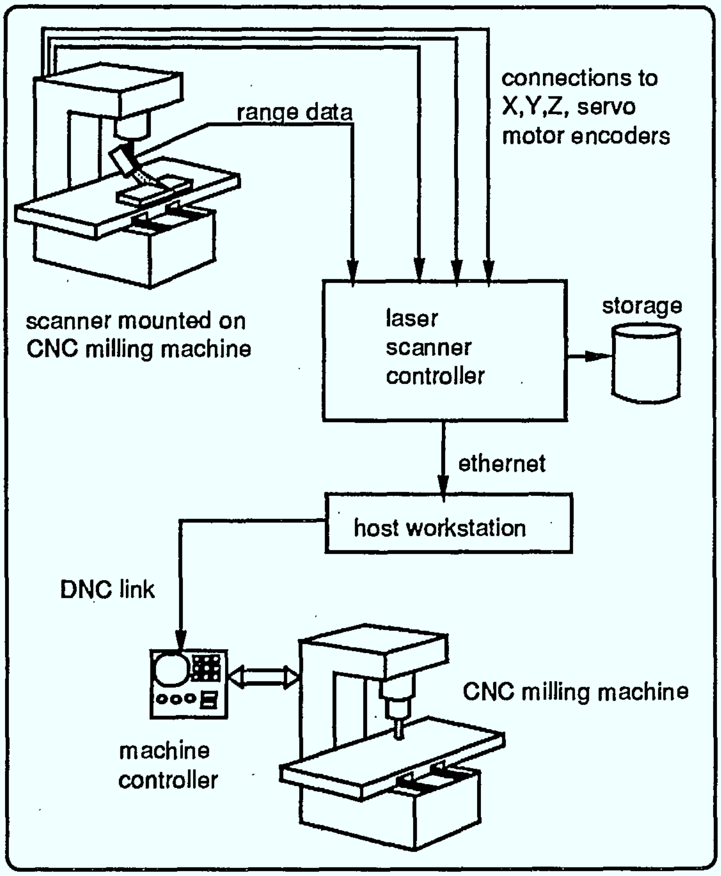


Figure 1 Integration of laser scanner and CNC Machine

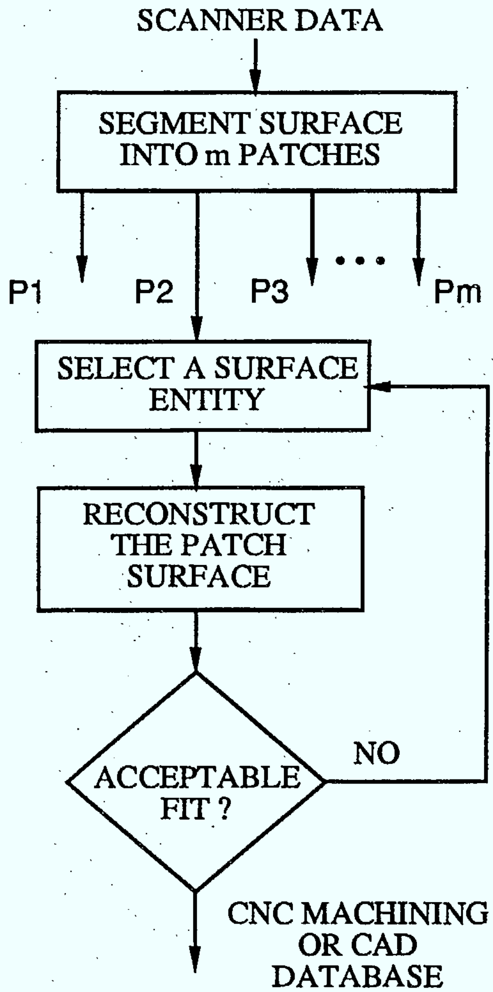


Figure 2 Flow chart of interactive surface fitting

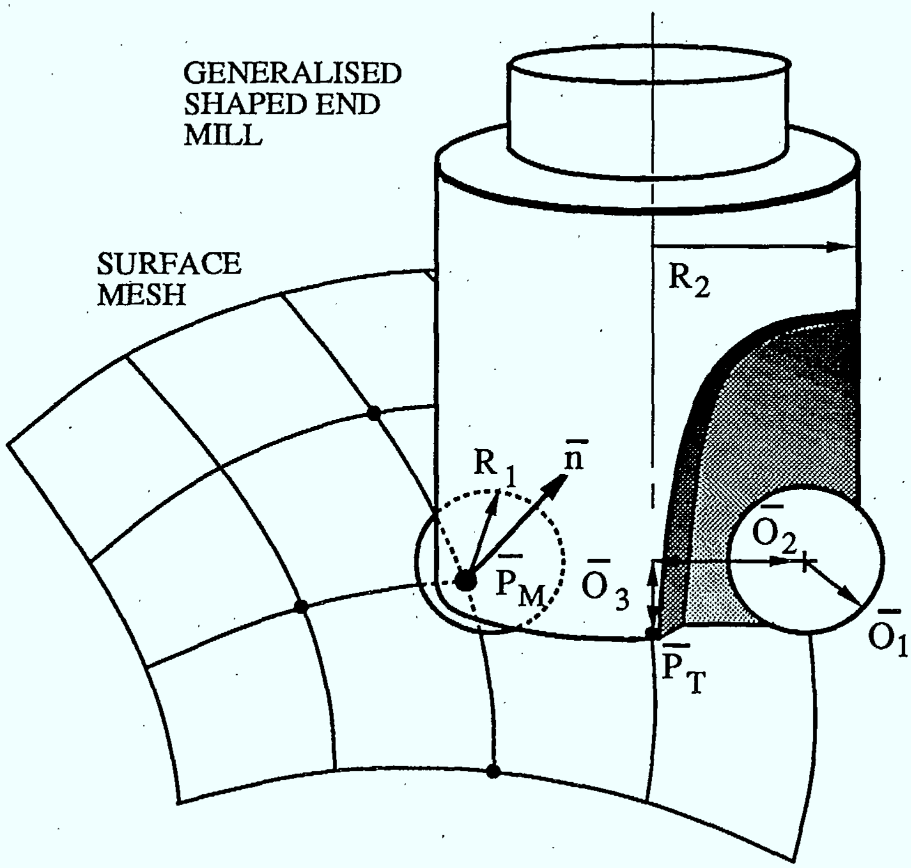


Figure 3 Cutter offset calculation

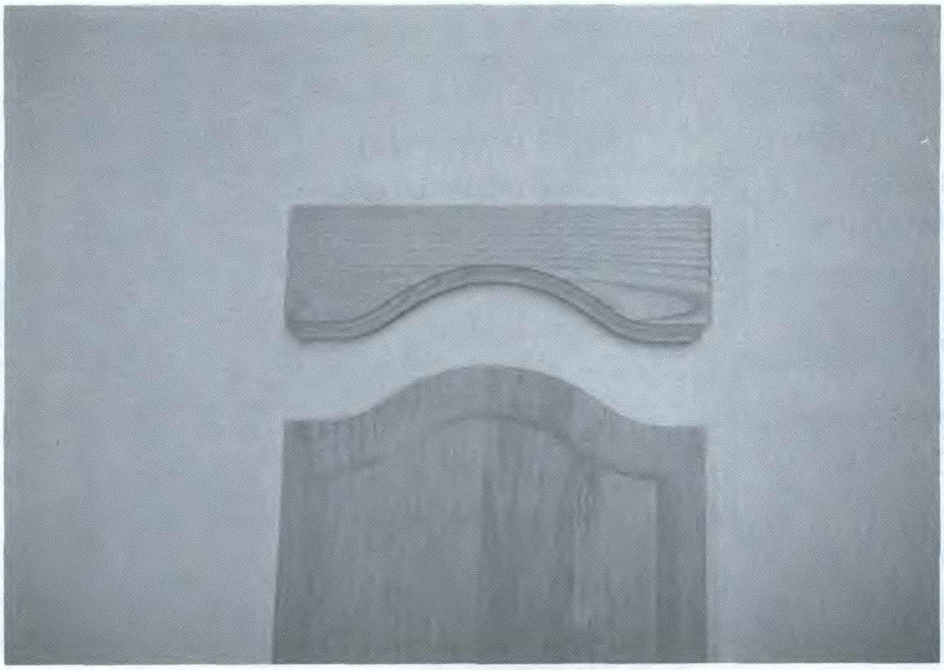


Figure 4 Exploded view of a cabinet door

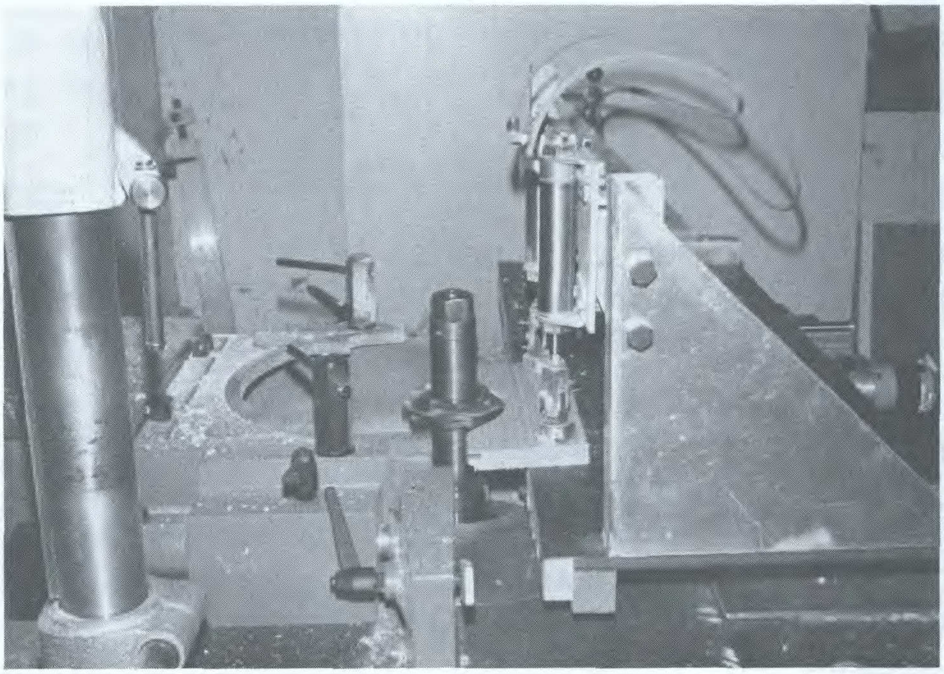


Figure 5 Automated woodshaper

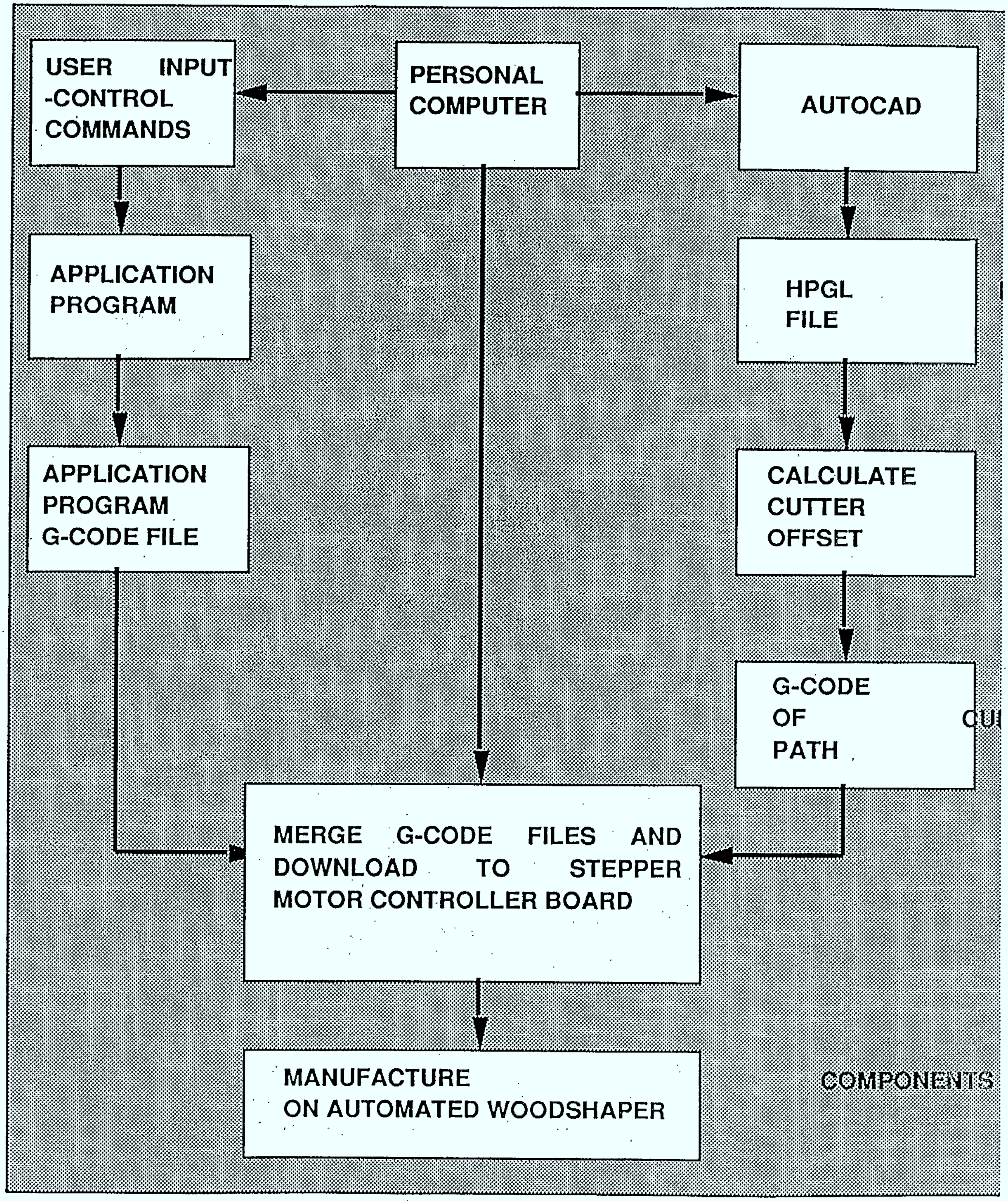


Figure 6 Overview of the automation software

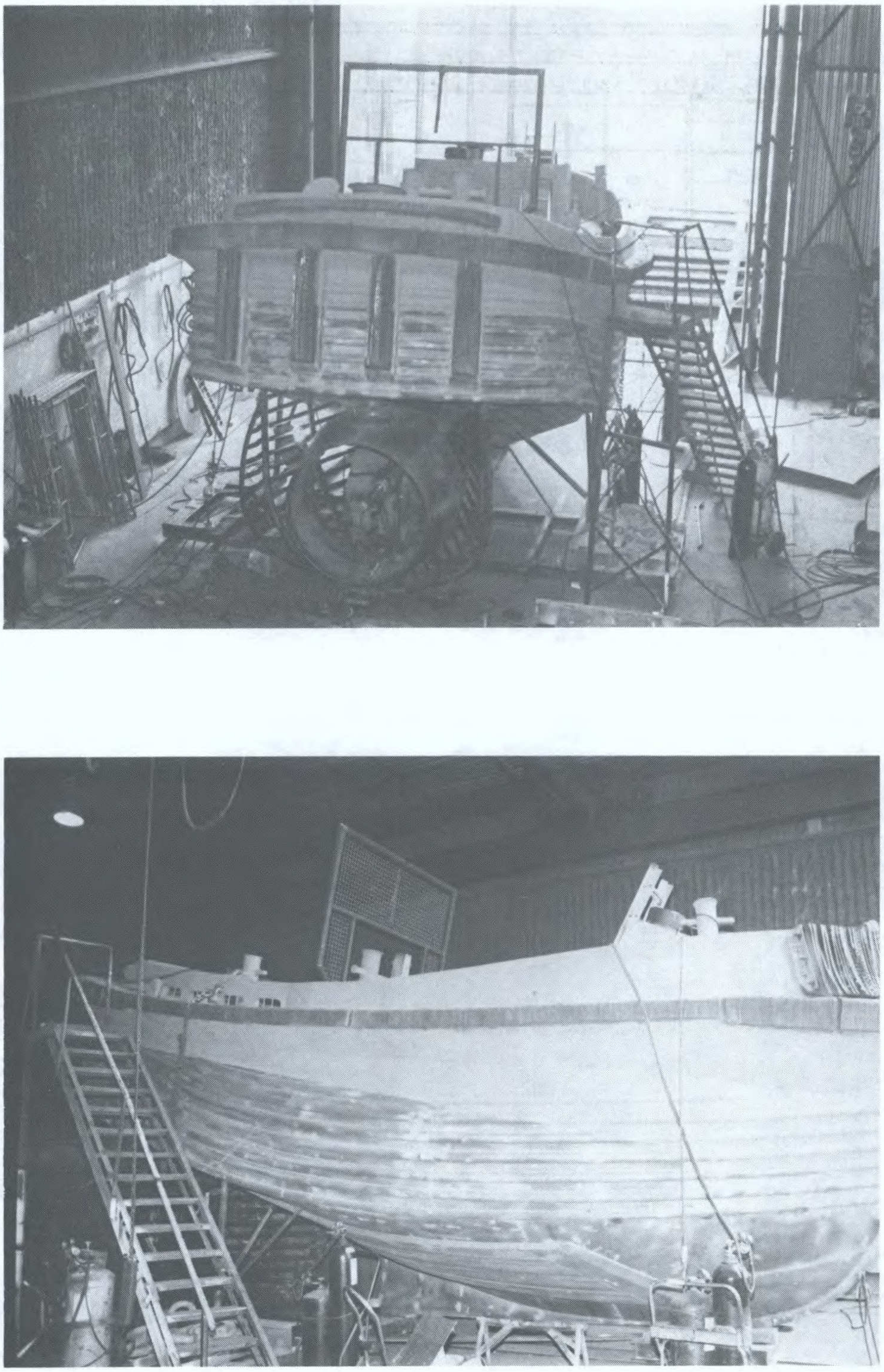


Figure 7 Views of a 12-m tugboat under construction

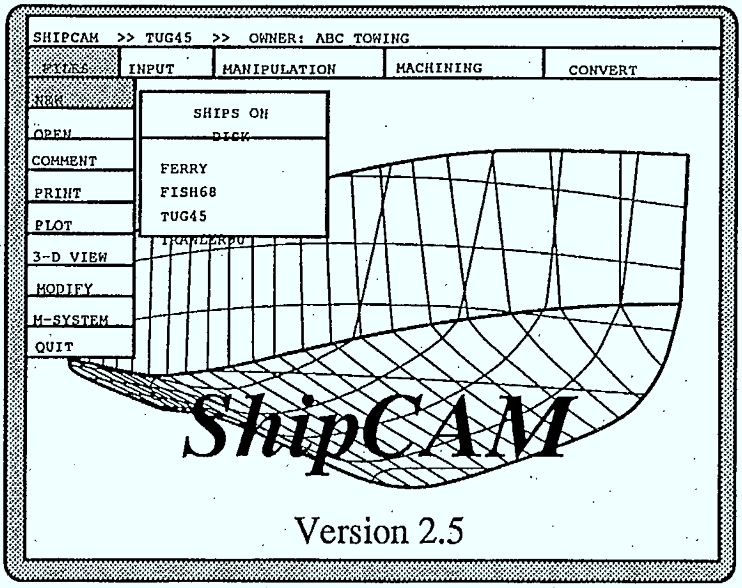
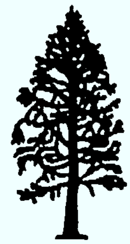


Figure 8 ShipCAM start-up menu

Scanning and Computing for Internal Log Sawing Solutions



J.E. Aune
Research Associate
MacMillan Bloedel Research
Burnaby, B.C.

Introduction

MB's customers who purchase solid wood pay four times more for clear wood compared to knotty wood. And if the lumber thickness increases to eight inches or more, they might pay up to six times more compared to knotty wood. Thus, we have ample motivation to invest in research directed towards sawing around the knots in the most effective way.

Background

Progress in internal log scanning has been slow in coming. Although Wilhelm Roentgen discovered X-rays in 1895, seventy three years went by before X-rays were put to use in a Swedish sawmill in 1968. A log grader viewed the X-ray image on a screen and judged the log quality.

Swedish researchers continued their effort and, in 1980, a two axis, gamma ray scanner was installed in Ala Sawmill. Again, the purpose was to assign a log grade index prior to log sorting. Sawing tests, completed in 1982, showed that there was a 20-30% probability that logs classified as high grade were, in fact, low grade. Recently, this scanner was upgraded to yield X-ray data points across the diameter as well as along the log length, and a second installation was completed at the Iggesund Sawmill.

North American research in this area dates back to around 1980 when Scientific Measurement Systems Inc. of Austin, Texas, proposed an industrial CT scanner for processing pine logs. Although the scanner was not installed in a sawmill, this early effort gave rise to a considerable amount of research into scanning for defects, particularly at the Mississippi, Louisiana, Virginia and Oregon State Universities. Proceedings of the International Conferences on Scanning Technology sponsored by Forest Industries are good sources for more detailed information.

The intent of my presentation today is to share with you some of the technology aspects of MacMillan Bloedel's efforts in obtaining more detailed log information prior to sawing as well as some of the financial rewards which I expect to see in future.

Log Scanning and Sawing

MacMillan Bloedel has invested in internal log scanning research since the mid 1980s. In 1989 we completed the construction of an off-line X-ray log scanner. The specifications were the following:

Linear log feed speed	36 mpm
# of 20-foot logs	4/min
Measurement resolution	5 mm x 6 mm
Maximum log diameter	1000 mm
Maximum log length	12,800 mm

Whereas much of the North-American research in the past focused on CT-scanning for which imaging for defects must take place in a large number of cross sections, our approach was to collect X-ray data for three side views of the log. Examples of log qualities range from large knots reaching the log surface to tiny knots close to the pith. Each side view is analyzed independently in a pipeline imaging process and reconstructed into a three dimensional log image.

The log positioning and sawing programs achieve:

- Log rotation to an optimum angle
- Log skew for full taper sawing
- Log set starting with optimum opening face
- Subsequent saw sets for maximum value recovery

The sawing program searches for the optimum combination of saw cuts based on sales price and grade parameters for each lumber product in the order file.

Benefits from X-Ray Scanning of Logs

X-ray scanning has given us additional data about the log resource. For example, our test sawing of high grade logs showed that log value varied more than plus/minus $100 per m^3. The X-ray scans revealed which logs could have been processed by more effective machine combinations at lower cost without any loss in value yield.

Benefits fall into these categories:

- Improved log allocation: Right log to right mill
- Better matched logs and order files
- Added value recovery from sawing: Process control

I have not seen public research results which document benefits from log allocation, order file matching or log bucking based on internal defect scanning. Francis Wagner of Mississippi State summarizes past research into added value from sawing based on scanning for internal defects in the Proceedings of the 3rd International Conference on Scanning Technology(1989).
Benefits appeared to range from eight to eleven percent of sales value for logs up to 20 inches in diameter. However, all studies were based on perfect knowledge of the log defects. As well, all past studies compare the best vs the average of 24 or less rotation angles with no discount for errors.

Tests with logs scanned in our installation revealed substantial reduction in benefits compared to the theoretical results from past studies. This was expected as our three axis scanning is less accurate than CT scanning, and the basis for comparison was skilled sawyers as opposed to a random log orientation. As well, the added value from X-ray scanning varied with log grade, log size and the frequency of defects which the scanner cannot see, such as shake, bark seams and ambrosia beetle attacks. These evaluations are ongoing.

Conclusions:

- X-ray log scanning has been thoroughly researched
- The technology can be implemented in the sawmill, but must have operator override.
- Payback from scanning high grade logs will be in the 18 to 36 month range.

EDGER AND TRIMMER OPTIMIZATION

John Booth
Newnes Automation Inc.
Salmon Arm, B.C.

Good afternoon ladies and gentleman. It is a pleasure to be hereto discuss trimmer and edger optimizing.

To begin our presentation we would like to show our company video which will give those of you not familiar with our company some idea of who we are, and our relationship to the forest industry. Immediately following our company video will be showing a video of operating Newnes edger and trimmer optimizer systems.

You can see from the examples of equipment shown in our company video that Newnes machine is not just a supplier of optimizing systems to the forest industry. In fact, our company which is celebrating its 80th year in business this year, has for many years been best known as a supplier of material handling systems for the sawmill industry. Equipment such as sorters, stackers and lug loaders to name a few were synonymous with our name and still are. However, our company which relies almost entirely upon the sawmill industry for its business could see that electronic control systems would play a larger role in the operation of mechanical equipment supplied to the sawmill industry of the future.

Our initial step into the electronic side of our business took place in 1980 with the formation of western industrial programming, to design and manufacture plc based control systems for our own machinery as well as sell control systems to the mills.

This was followed in 1987 with the formation of Newnes Automation which specializes in the design and manufacture of optimizing systems for sawmills.

We presently have sixty (60) edger and trimmer optimizer systems in operation throughout North America that have been delivered and commissioned from our Salmon Arm, B.C. facilities. Of the 270 people currently employed by the Newnes companies approximately seventy (70) are employed with western industrial programming and Newnes Automation.

Optimizer systems have been in use since about 1970 in North America. Some of the earlier equipment is still in use today but they too are being replaced with faster operating, more reliable equipment. As was depicted in our company video our optimizing system uses a combination of solid state lasers and light emitting diodes to determine the dimensions and shape of the board.

The industry until 1980 had largely relied on operator inputs for decisions affecting cutting decisions at both edgers and trimmers as well as other breakdown equipment in the sawmill. Demand for greater production and increased recovery from sawmills created the need for more sophisticated decision making and control systems. Board edgers and trimmers are examples of where optimization is being used today to good financial benefit. A typical non-optimized edger will have an edgerman who will feed flitches (or boards) into an edger which will typically have three to five saws. The edgerman will shift the saws in the edger by remote control to align with the flitch. To aid the operator in his decision the edger will typically have laser lines which correspond with the location of the saws. As the saws are shifted the lasers will cast a line on the flitch showing where the saws will cut. With the aid of the lasers line the operator will shift saws to what he believes to be the optimum location. About the best recovery one can expect from a manually operated edger as described is 80-83% of optimum. More typically you will see recoveries in the mid

70% range. By comparison our optimized edger systems are guaranteed to recover not less than 98% of optimum. Paybacks on an investment of $1mm dollars for an optimized edger system are typically less than one year.

Similar benefits are available from optimized trimming. Here again lug speeds (piece rates) which were typically in the 55 to 60 lug per minute range are no longer acceptable in the majority of sawmills. Trimming systems today must be capable of running 100 plus lpm and still achieve better recoveries than the older slower systems. With trimming performance we speak of percentages of over/under trim. Simply stated if you didn't trim enough off you undertrimmed and of course if you trimmed too much off you overtrimmed. Typical over/under trim percentages for manual trimming are in the 7 - 10% range.

We guarantee plus/minus 1% trim accuracy and typically see results at plus/minus 1/2 -3/4% . Here again the payback on investment for trimmer optimizers compares with edger systems.

The laser technology utilized in optimizing systems has contributed greatly to the improvement of canadian sawmill performance in terms of production, quality and recovery.

However, it is the combination of modern machine designs, modern control techniques, modern sensor designs and analytical optimization application that has permitted the high speed canadian sawmill process to maximize utilization of our timber resource and compete in a world wide market place.

TRIMMER OPTIMIZER ACCEPTANCE TEST

NORTHWOOD PULP AND TIMBER LTD
PRINCE GEORGE B.C.

Test Date: November 24, 1991

Conducted by: Tom Stoddart (NORTHWOOD)
Garry Gustafson (NORTHWOOD)
Ben Lemon (N.A.I.)

TEST RESULTS:

Test sample size ---------- 100 Boards

Total best board volume --- 1202.1 - F.B.M.

Total overtrim variance --- 5.6 F.B.M.

Total undertrim variance -- 0.6 F.B.M.

Percent overtrim ---------- 0.44 %

Percent undertrim --------- 0.05 %

Percent recovery ---------- 99.51 %

Signed:

Tom Stoddart
Project Manager
Northwood Pulp and Timber Ltd.
Prince George B.C.

Ben Lemon
Project Manager
N.A.I.

NEWNES AUTOMATION INC.

December 18, 1991

WEYERHAEUSER CANADA LTD.
P.O. Box 10
Lumby, BC
V0E 2G0

Attn: Doug Hauk

Dear Doug:

Re: Edger Recovery Test on Dec. 14, 1991

Here are the results of the 100 piece recovery test we ran on Dec. 14, 1991.

Total board volume was . . . . 964.8 b.f.

Edger system recovered . . . 959.5 b.f.

Recovery in percent 99.45%

Volume loss was due to an erroneous operator input calling for 60 inches of LL trim. Western Industrial Programming is investigating this error and will advise you of its solution. Newnes Automation has corrected your trim input configurations to limit operator trim to 2 ft. and 4 ft., near and far end trims.

Yours sincerely,

NEWNES AUTOMATION INC.

John Petty
Project Manager

CC: Steve Harms

/cas

P.O. BOX 114, SALMON ARM, B.C. CANADA V1E 4N2
TELEPHONE (604) 832-8821 • FAX (604) 832-98

Sawmill Headrig and Edger Optimization

Warren W. Thomlinson, P. Eng.
President
SOFTAC Systems Ltd.
Port Coquitlam, B.C.
Canada

Log-Calc Optimizing Setworks

Solid state video cameras (machine vision techniques) are used in the "Top Gun" Headrig Carriage scanning system to "snapshot" the shape of the log and produce an optimized sawing solution in 1 second or less (fig.1). When used on a conventional carriage this system increases productivity and lumber recovery. Other applications include end-dogging headrigs, sharp-chain headrigs, and cant/profile machines capable of half taper or full taper cutting.

The development of accurate and reliable hydraulic linear positioners (fig.2) and computer systems with multi-processors (fig.3) to give real-time log breakdown solutions has enabled SOFTAC to supply carriage setworks with:

- Higher setting speeds
- Greater accuracy
- Minimal maintenance
- Setting for opening face (B.O.F.)
- Maximizing recovery from a log (L.R.F.)
- Maximizing higher value lumber sizes
- Infinite tapering
- Full taper or Half taper solutions

With the SOFTAC system, utilizing existing control handle and pushbuttons, sawyer retraining has been minimal after retrofitting a carriage.
In the automatic optimizing mode, a program selection is provided with the following functions:

- Centre cant
- Side cant
- Side boards

The sawyer can select *full taper* or *half taper* solutions and the selected solution is displayed graphically on the CRT (fig.4).

The CRT also displays log diameter, cant sizes and log count. For grade cutting, the sawyer can alter the solution after opening up the log.

The CRT display is in colour and shows the cutting solution (fig.5).The display operates in "real-time" - when set is made, cut is cleared from screen.
The CRT Monitor will prompt rotation of log when last side cut is made.

"Top Gun" Camera Scanning

- Camera scanning saves time on each new log by eliminating the need to move the log forward through a photocell curtain. As "snapshot" is completed sawyer can commence feeding for the first cut. Setworks speed is suitable to reach desired set before the log reaches the saw.

- The camera scanning VME processor printed circuit board simultaneously processes the images from up to 4 cameras. Complete signal processing, analysis and software control allows easy "tuning" of the video images. An accurate digital image of the log is captured for the optimizer to process and arrive at the best sawing solution.

- Usually no modification is required to log loading area when Top Gun camera scanning is installed.

Cant Edger and Trimmer Optimization

SOFTAC exercised the definition of their name "State-of-the-Art-Controls" by developing leading-edge technology in multipoint lumber profile scanners used in Cant, Edger and Trimmer Optimizer Systems (fig.7 & fig.8). The MPS8600 Scanner uses all solid-state components, including solid-state lasers. It features non-contact operation, wane up or down scanning, providing true lumber profile scanning to as fine as 1 inch increments along the entire length of a board (fig. 8).

Scanners

Headrig, Edger and Trimmer optimizer applications, even though they share similar electronic hardware and mathematical calculation requirements, are supplied with scanners having different specifications (fig.9 - 11).

A strong argument for thickness profile every 1 inch along the board length on the Trimmer application has been previously justified[1] The Edger application can be readily handled using the same technology but with thickness profiles every 4 inches along the length of the flitch. Some factors affecting this include material thickness from 6 or 12 inches and reduced need for cosmetic defect scanning when compared to the trimmer application.

Electronic Hardware

High reliability components are found throughout the hardware used in these systems. Solid state laser and camera systems provide the scanning data (fig.12). Motorola 68000 family micro-computers are used as pre-processors on the VME bus to predigest information and optimization calculations. Communication with the process control computer is simplified by the use of a personal computer to download and upload software and information. Many commercially available software programs provide easy to use analytical spreadsheets and databases allowing the owner to customize reporting information and comparisons to suit his particular need without dependence upon a software supply company.

Installation and start-up of the equipment is simplified by the use of a video terminal which allows "snapshot" information to be used during initial stages of check out and calibration.

Hydraulic Positioners

At all machine centres, accurate positioning prior to processing is of extreme importance if one is to implement the optimization solution that has been calculated. For the Carriage and the Edger, hydraulic linear positioners are used with Temposonics position feedback transducers and servo valves to control oil to the cylinders. Target lumber sizes can be reduced because of high accuracy, high repeatability setworks.

Software

The software language 'C' has been selected for these process control systems. This high level language remains invisible to users interfacing with the equipment through a personal computer keyboard. Initiation of snapshot printouts, calibration commands to the scanners, management information reports, and self-diagnostic reports are all handled by simple, easy to use menu commands via the keyboard while viewing the CRT display.

Within each sawmill, for all optimizers, it is important to use optimizing parameters that have identical strategies.

In addition to production and recovery reports, the Edger and Trimmer systems include software for a quality control (QC) report that continuously monitors, such parameters as board-to-board thickness variation, board-to-board width variation and within-board variations. The customer can adjust alarm points, and machine shutdown levels to make maximum use of these QC tools.

Grade Optimization

Softac has provided Edger Optimization systems for applications in hardwood sawmills and pine/cedar board mills which combined profile optimization solutions with grader inputs. The operator specifies which regions of the flitch, in his opinion, meet the grade requirements and the computer calculates the best solution (fig.13).

[1]Wang, Steve J.,Forest Products Journal, Vol.36 (9),29-32

What will Optimization do for your Sawmill?

Studies show excellent benefits can be realized:

At the Headrig:

- recovery increases of 11% measured
- production increases of 25% or more measured

At the Edger:

- increase recovery efficiency to 98%, rather than less than 85% manually
- increase production by 25% or more (many edgers process 23 boards per minute)

At the Trimmer:

- reduce overtrim by 7% or more (fig.14)
- reduce undertrim by 6% or more (fig.15)
- increase production rates by up to 100% (many mills operate at 90-100 boards per minute, limited by the machinery, not the electronics)

Future Developments

So far, our discussion has related to geometric scanning-measuring the external shape of logs, flitches and boards to determine incremental value optimization. In 1988 MacMillan Bloedel research married a Softac Cant Profile Scanner to an X-Ray Scanner. The perfected system was put on line at the MacMillan Bloedel Alberni Pacific Division Sawmill in 1990, giving the added economic benefits of internal defect scanning. The system seeks out clear, high grade boards and produces optimum edging solutions for the edger to execute.

Future scanning systems will combine machine vision, X-Ray and profile techniques with reasoning technologies. Softac's research and development is currently focused on such systems. Some of these systems will become more attractive to sawmills when high volume production of the expensive technologies brings the price down, or the scarcity of fibre supply plus demand for higher grades of lumber increases, or a combination of both.

Summary

The evolution from the 1970's to the early 1990's of Sawmill Optimization Systems has seen the state-of-the-art reach levels where non-contact thickness profiles are taken frequently along the length of the board and video cameras accurately measure logs. Reduction in system cost versus scanning power and computing capability provides the Sawmill Industry with improved reliability, greater throughput and on-line quality control for maximum recovery.

SOFTAC is successful by supplying process control systems with accurate Hydraulic Positioners, reliable electronics, accurate scanners and software that gets optimum results. SOFTAC's technology is receiving widespread acceptance, as evidenced by our most recent installations in the USA and Australia.

FIGURE 1
Top Gun - Machine Vision
Scanner

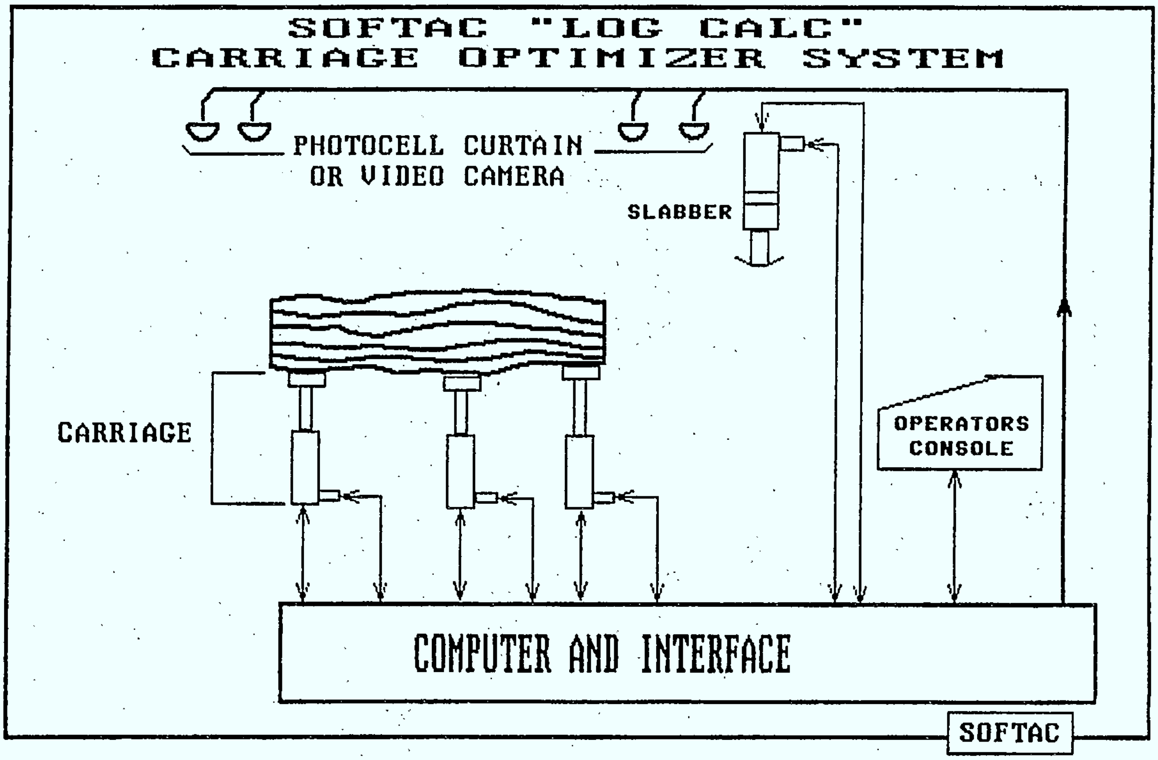

SOFTAC "LOG CALC"
CARRIAGE OPTIMIZER SYSTEM
PHOTOCELL CURTAIN
OR VIDEO CAMERA
SLABBER
CARRIAGE
OPERATORS
CONSOLE
COMPUTER AND INTERFACE
SOFTAC

FIGURE 2

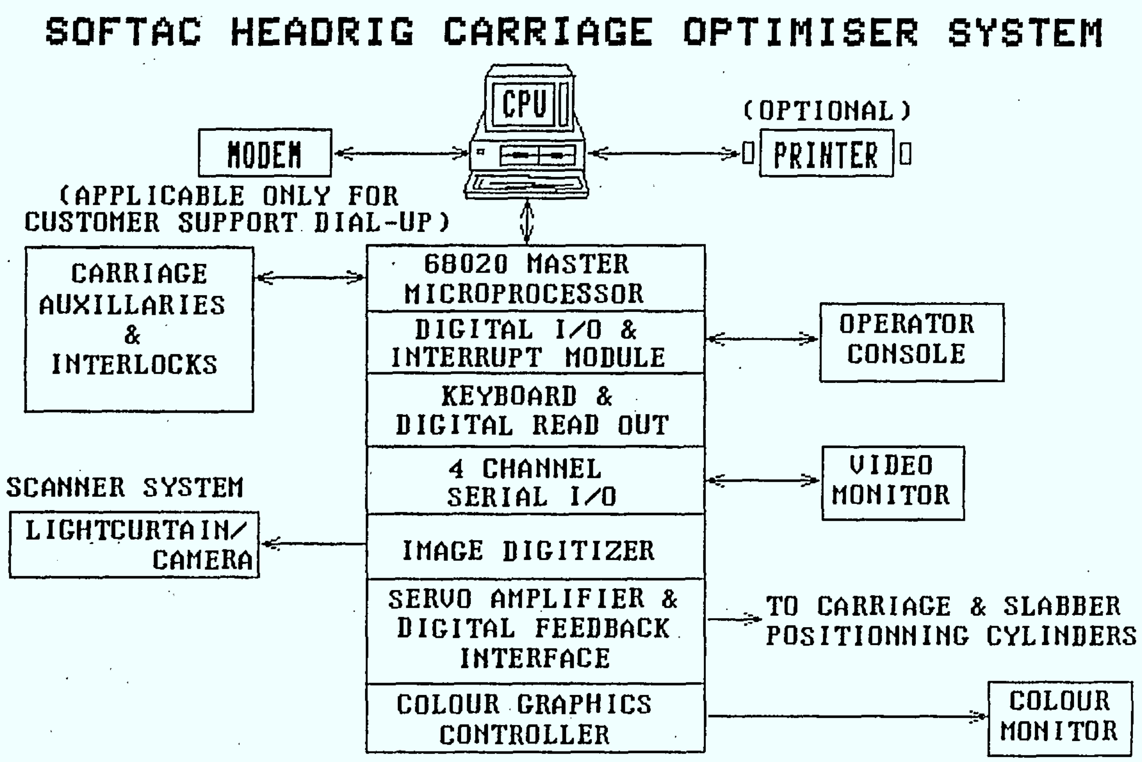
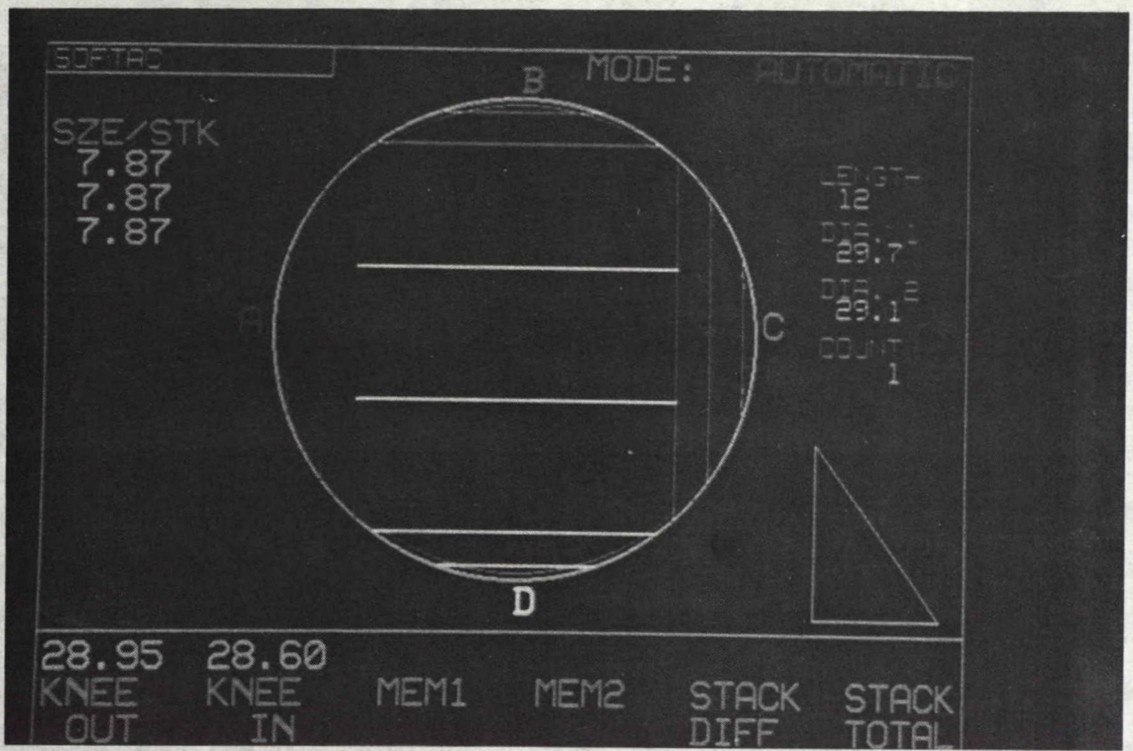
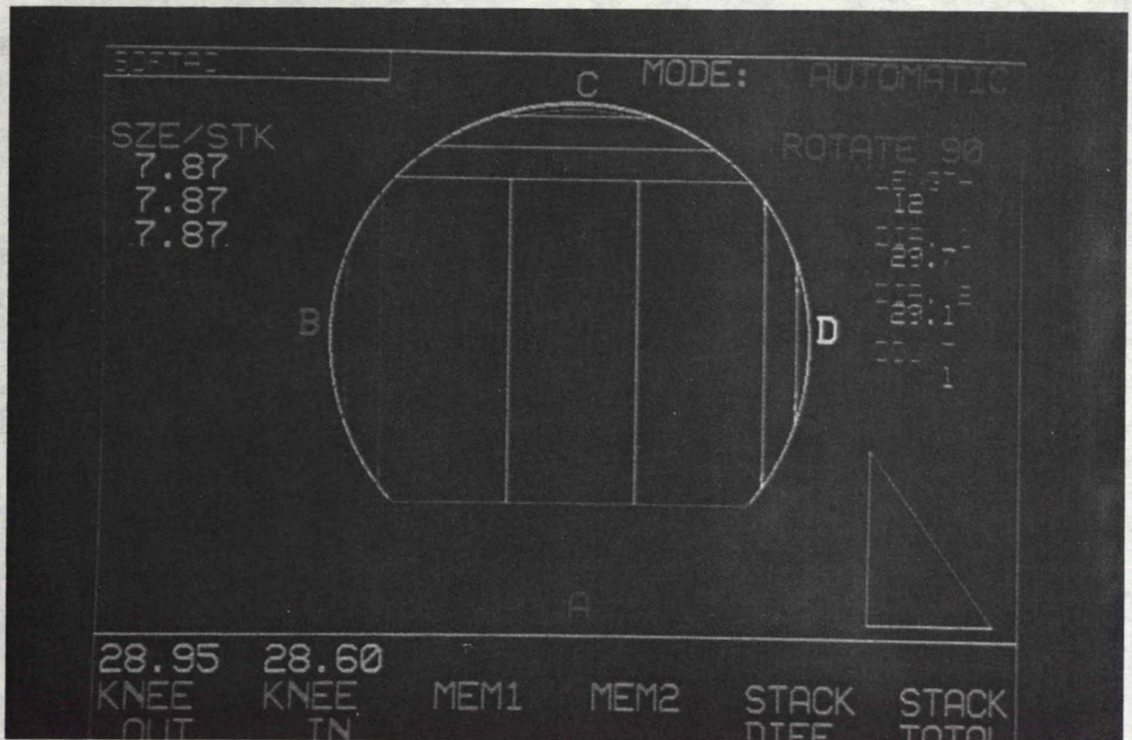

SOFTAC HEADRIG CARRIAGE OPTIMISER SYSTEM
CPU
MODEM
(OPTIONAL)
PRINTER
(APPLICABLE ONLY FOR CUSTOMER SUPPORT DIAL-UP)
CARRIAGE AUXILLARIES & INTERLOCKS
68020 MASTER MICROPROCESSOR
DIGITAL I/O & INTERRUPT MODULE
OPERATOR CONSOLE
KEYBOARD & DIGITAL READ OUT
4 CHANNEL SERIAL I/O
VIDEO MONITOR
SCANNER SYSTEM
LIGHTCURTAIN/ CAMERA
IMAGE DIGITIZER
SERVO AMPLIFIER & DIGITAL FEEDBACK INTERFACE
TO CARRIAGE & SLABBER POSITIONNING CYLINDERS
COLOUR GRAPHICS CONTROLLER
COLOUR MONITOR

FIGURE 3

4-Sided Canting with side flitches. Cant thickness 7.87 inches



Solution displayed after scanning. **"KNEE IN" & "KNEE OUT"** *show infinite taper setting.*
Triangle in lower right corner shows Knee.

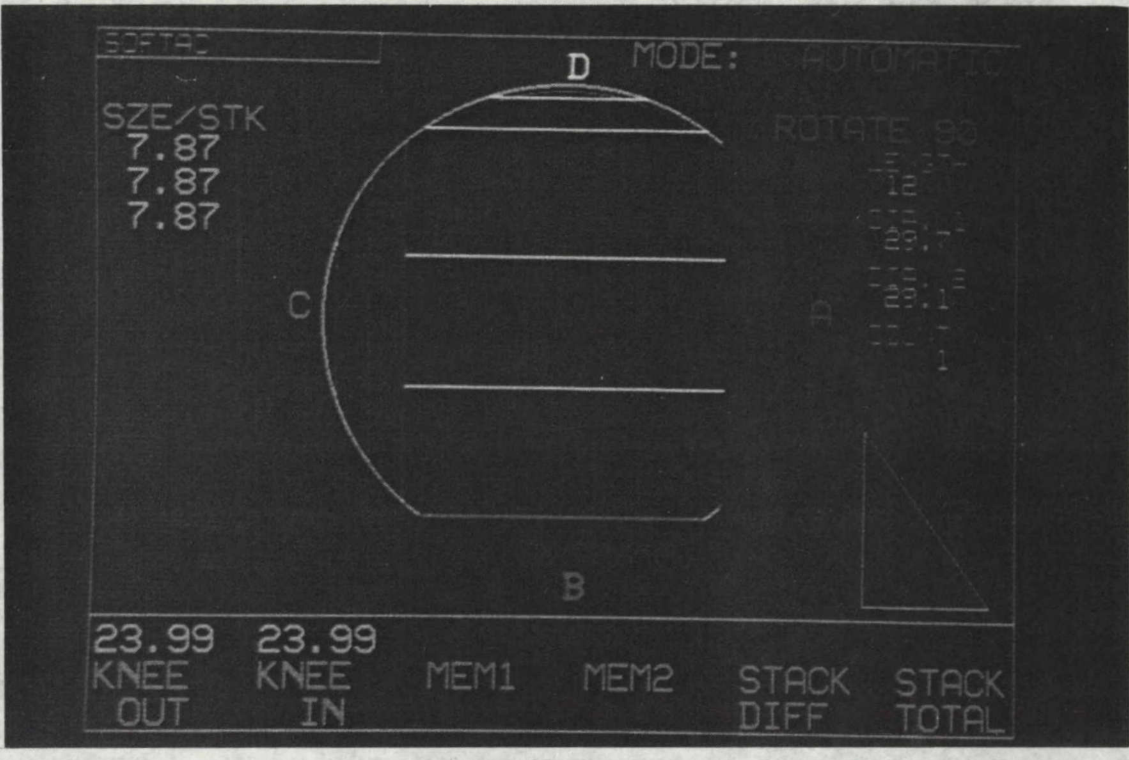


Solution **"Rotated"** *to prompt Sawyer to turn log after last line on face 'A' has been cut.*
Note tapers still in effect for opening face "B".

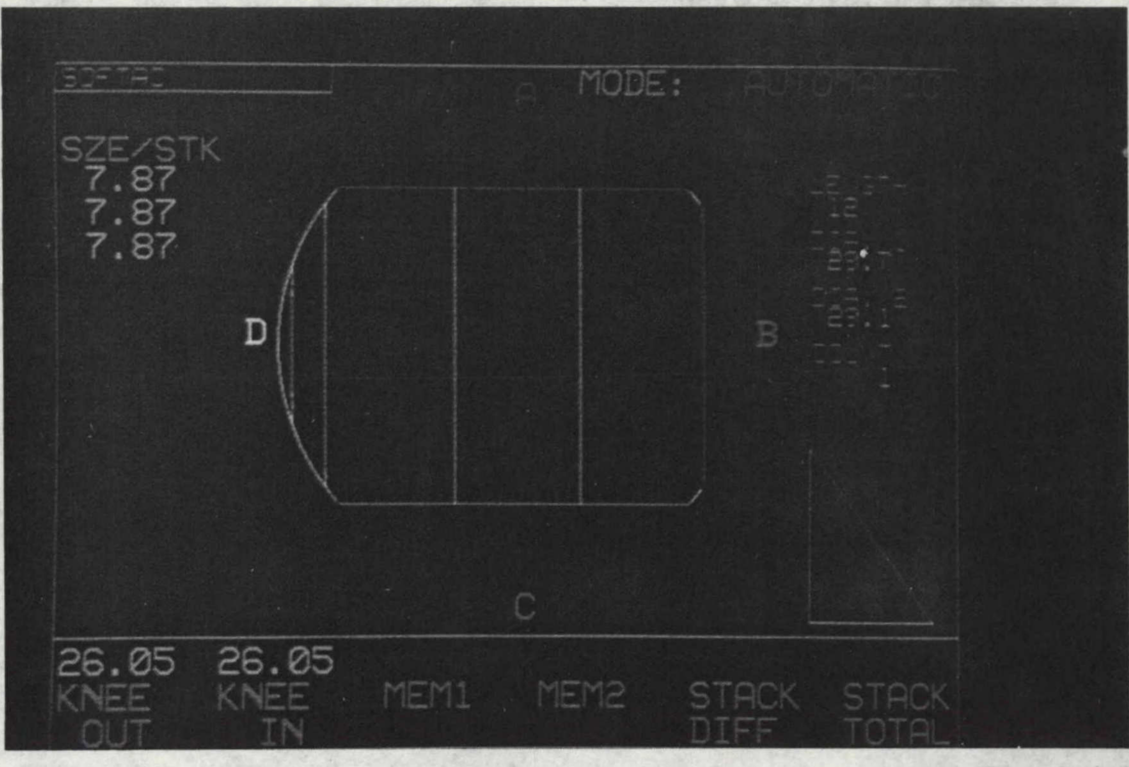
FIGURE 4

SOFTAC

4-Sided Canting with side flitches.



Solution **"Rotated"** *to prompt Sawyer to turn log after last line on face "B" has been cut. Note tapers now off.*



Solution **"Rotated"** *to prompt Sawyer to turn log after last line on face "C" has been cut. Note tapers now off.*

FIGURE 6

SOFTAC LASER SCANNER - MPS8600 - MILESTONES

1986

PROTOTYPE DEVELOPMENT MPS 8600

- WOOD EXPO '86

MARKETING COMMENCED - MPS8600

- CANADIAN PATENT APPLIED FOR

JAN. FEB. MAR. APR. MAY. JUN. JLY. AUG. SEP. OCT. NOV. DEC.

SOFTAC LASER SCANNER - MPS8600 - MILESTONES

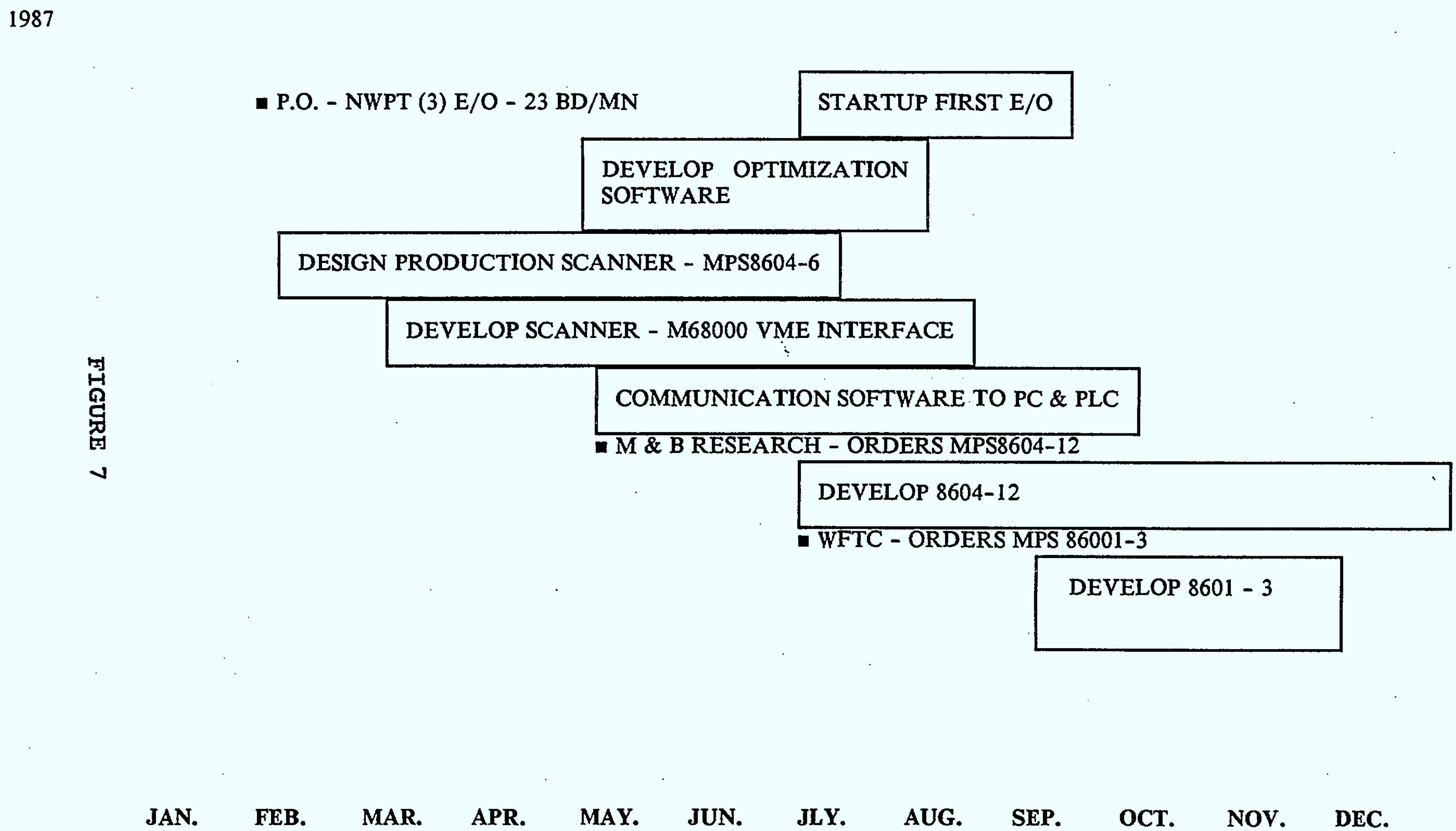


FIGURE 7

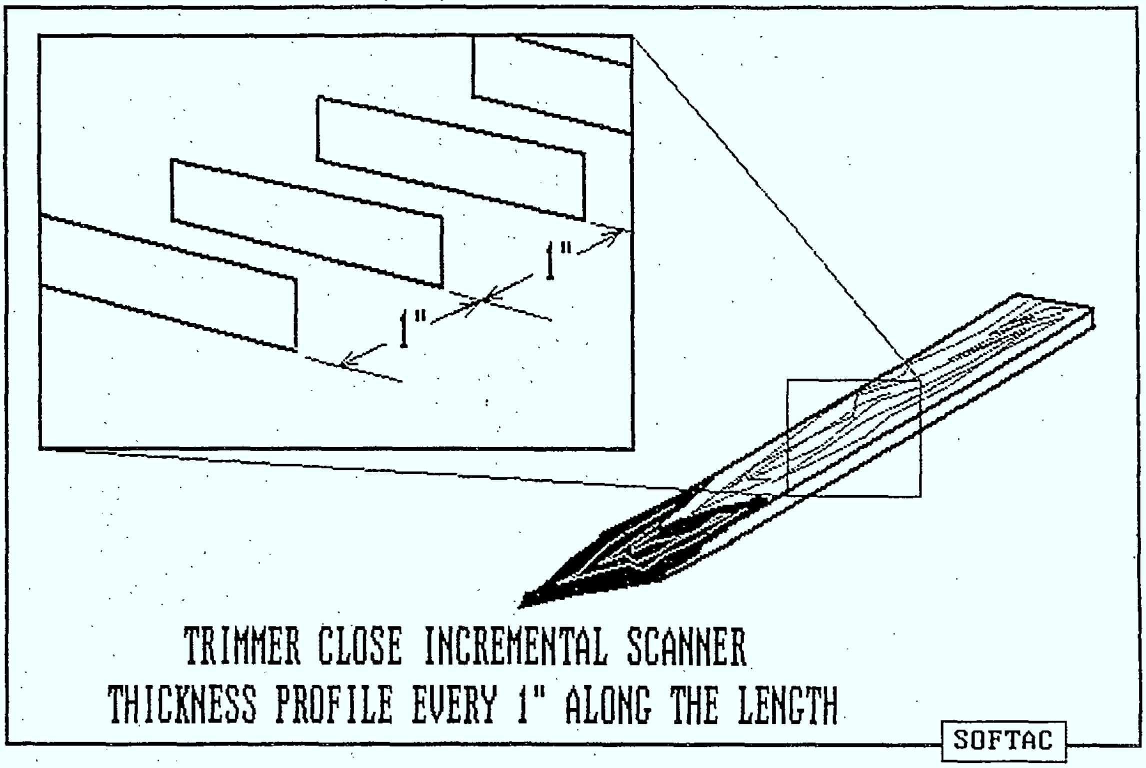

1"
1"
TRIMMER CLOSE INCREMENTAL SCANNER
THICKNESS PROFILE EVERY 1" ALONG THE LENGTH
SOFTAC

FIGURE 8

SOFTAC TRIMMER OPTIMIZER SYSTEM

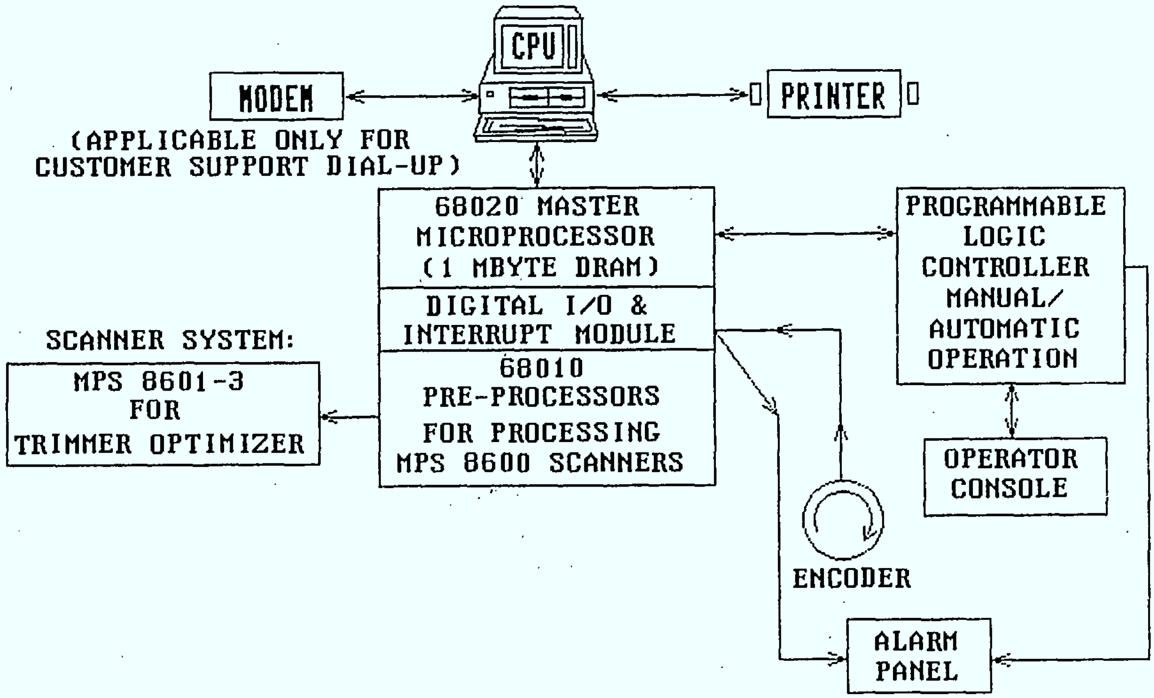


FIGURE 9

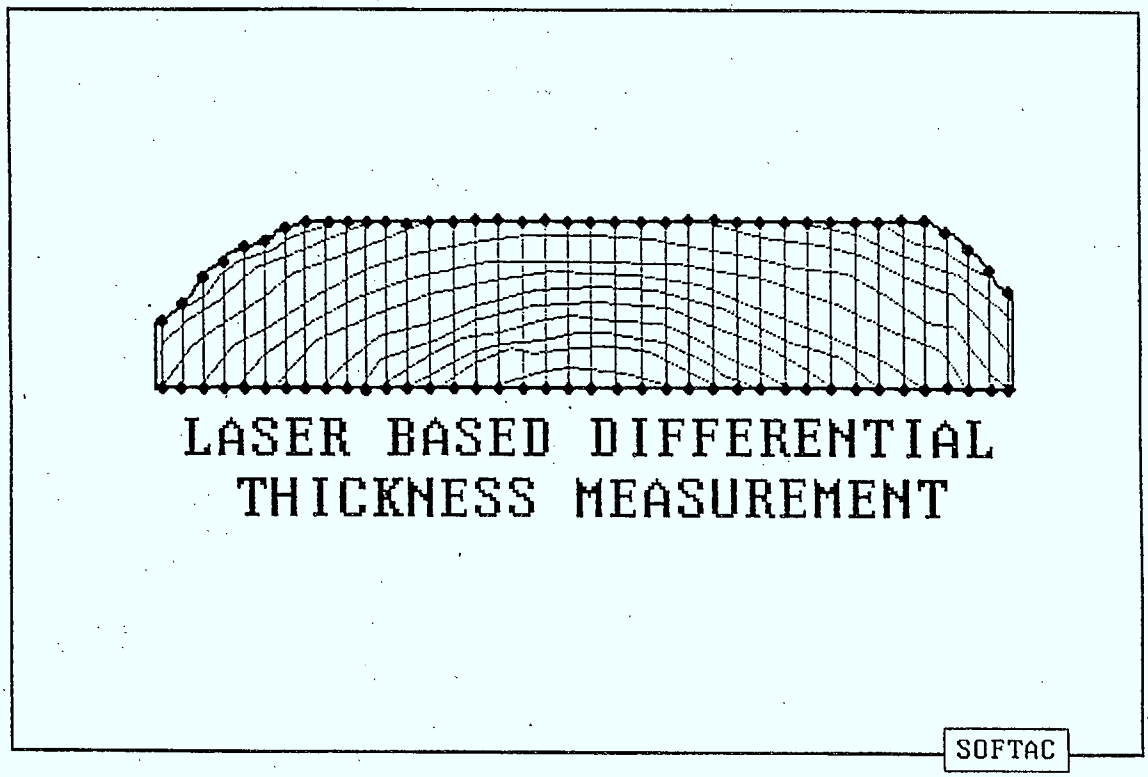


FIGURE 10

SOFTAC EDGER OPTIMIZER SYSTEM

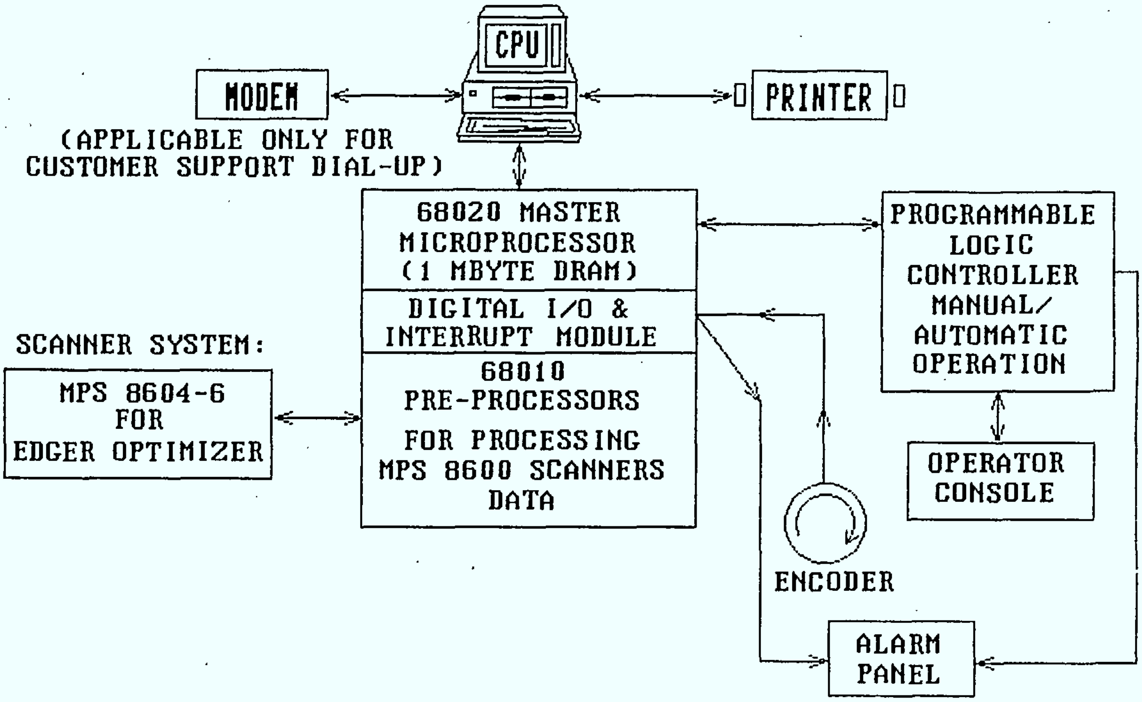


FIGURE 11

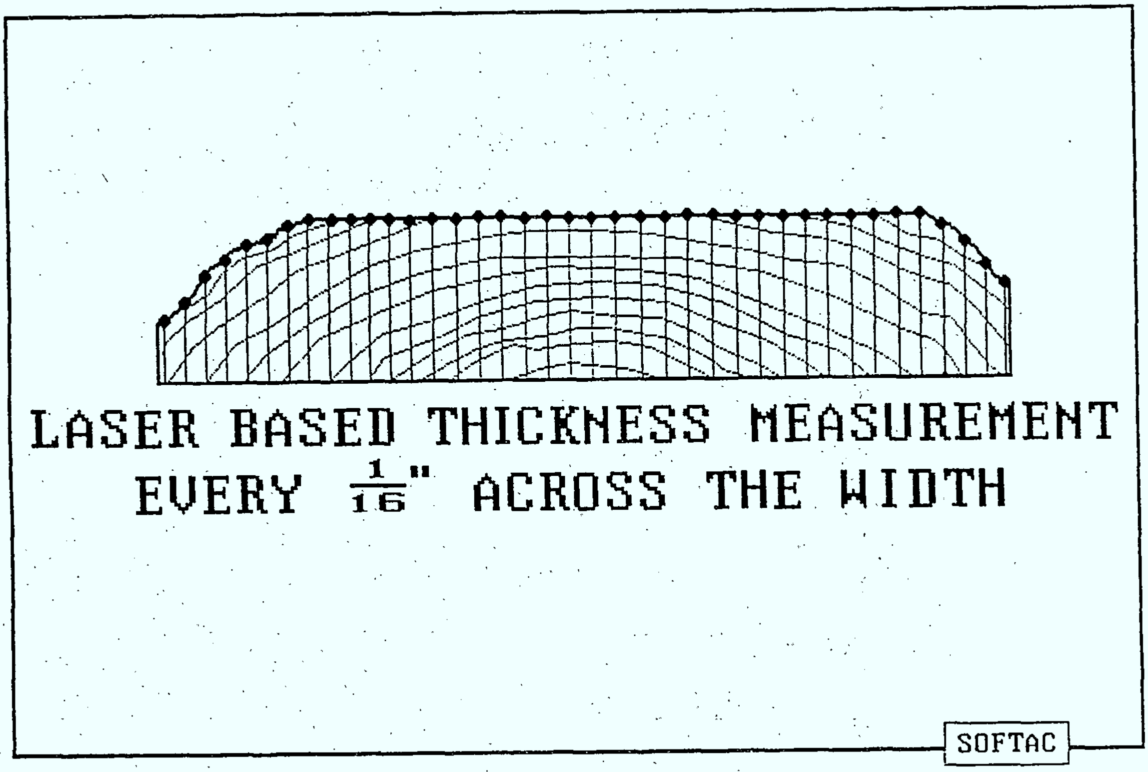

LASER BASED THICKNESS MEASUREMENT
EVERY $\frac{1}{16}$" ACROSS THE WIDTH
SOFTAC

FIGURE 12

Operator Grade Input Combines with Optimizer Scanner to Maximize Grade/Value Yield

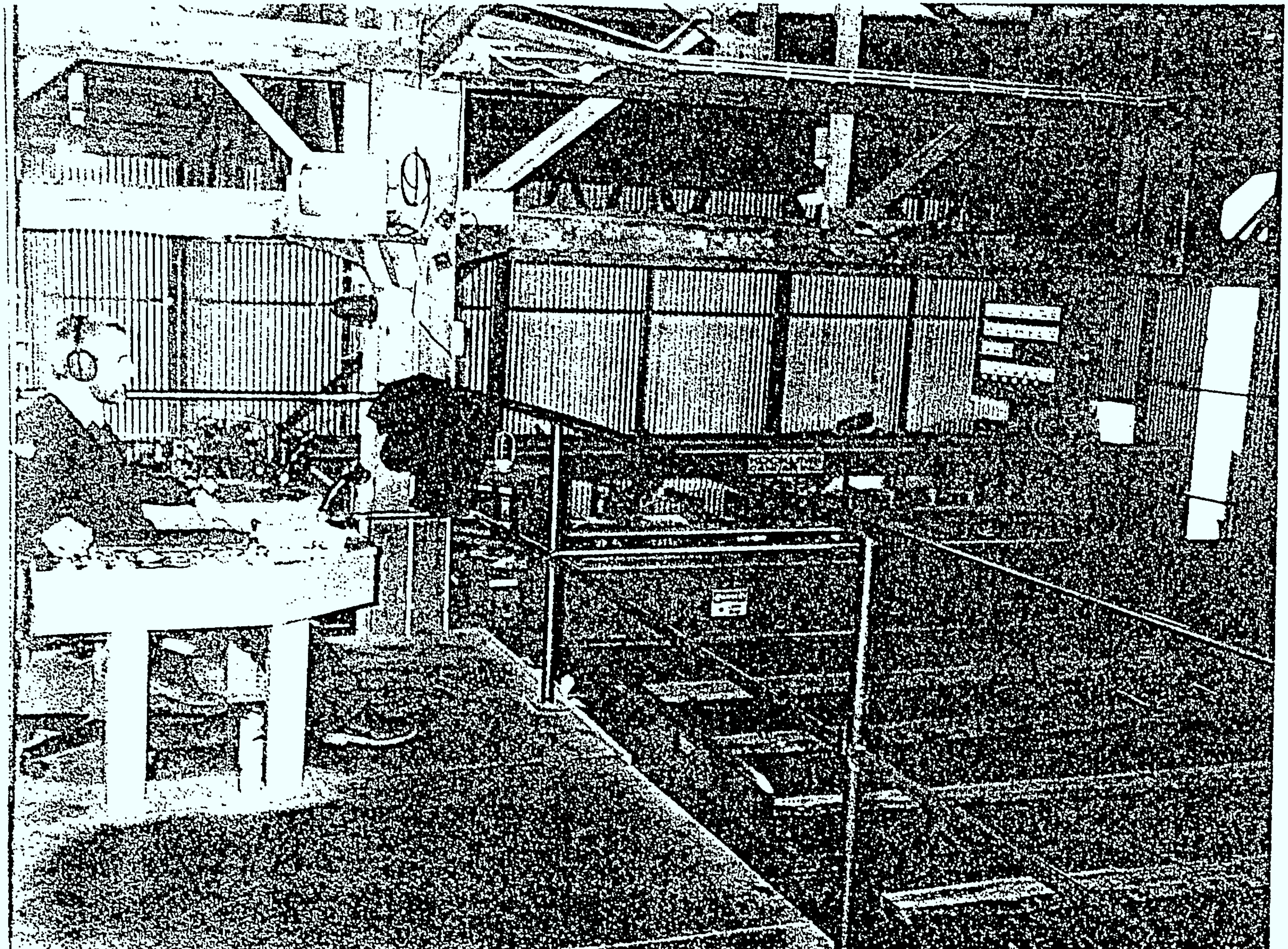


FIGURE 13

CALCULATIONS OF ESTIMATED ANNUAL SAVINGS WITH A HIGH SPEED TRIMMER OPTIMIZER SYSTEM.

42 MMBF/YEAR

REDUCTION IN OVERTRIM - from 7.75% to 0.75%

Diff of 7%
42,000 MBF x 7% x $200/MBF = $588,000

Less the value of green chips that would have been sellable

42,000 MBF x 7% x $40 MBF = $117,600

Net Diff $588,000 - 117,600 = $470,400

REDUCTION IN UNDERTRIM - From 6.75% to 0.75%

Diff of 6%
42,000 MBF x 6% x $20/MBF (Retrievable Value) = $50,400

IMPROVED THROUGHPUT - Estimated at 3% with additional profit increase of $22/MBF

42,000 MBF x 3% x $22/MBF = $27,720

IMPROVED LENGTH RECOVERY

Estimated at a 20% increase in prime length lumber.

Assuming 12,000 MBF of lumber could make prime length grade
12,000 MBF x 20% = 2,400 MBF

Resulting in an additional 2,400 MBF x $20/MBF* = $48,000

* Price based on additional value of prime length lumber

REDUCED LABOUR COSTS

Estimated at one man per shift = $25,000

TOTAL SAVINGS . . . $ 621,520.00/YEAR

FIGURE 14

THE ECONOMICS OF TRIMMING

The material used in this evaluation has been derived from actual sawmill shift report data, proprietary technical reports and information gathered from various papers issued on the subject.

In order to correctly evaluate the data, a few well recognized statements on the subject of green line trimming have been listed.

- Trimming is one of the largest sources of yield loss.
- Mistrim frequently occurs on 50% of the pieces being manually processed.
- The cost of mistrim is the change in value between the trimmed piece and the optimum piece.
- Undertrim is the volume of wood not removed during trimming which must be removed later.
- Typical Manual percent overtrim by volume

  Average 5% to 8%
  High 16%
  Low 2%

- Typical Manual percent undertrim by volume

  Average 5% to 8%
  High 10%
  Low 2%

- Typical mistrim reasons

  - 37% inaccurate cross section judgment
  - 29% incorrect positioning judgment
  - 7% decision entered early or late
  - 7% inaccurate length judgment
  - 6% wane turned down
  - 14% other

FIGURE 16

Automated Feed Speed Controls for Band Saws

Zarin Pirouz, Research Electrical Engineer
Dr. Eberhard Kirbach, Group Leader, Machining Research
Forintek Canada Corp.

1.0 BACKGROUND

Traditionally, the feed speed at which saw logs are fed into a bandsaw has been regulated manually. Recent attempts to control the feed speed have involved measuring power consumption or sawblade deflection, scanning logs for diameter, and relating the scanned diameter of the log to the position of the log on the carriage.

Measuring power consumption to control feed speed is based on the relationships between power consumption, cutting forces and sawblade deflection. When the cutting forces increase, the sawblade deflects and the power consumption increases. This is due to increasing cutting depth, increasing feed speed, increasing dullness, or a combination of these factors. Thus, power consumption indicates sawing accuracy, but only for the factors listed above. This method is not sensitive enough to indicate sawblade deflection when the deflection is caused by carriage mis-alignment, poor tooth fitting, excessive sawdust spillage, guide wear, cross line of the bandmill, or poor tensioning and levelling of the sawblade.

More success in tracing sawing accuracy to control feed speed is obtained with methods which measure the displacement of the sawblade during cutting. These methods use non-contact eddy current or laser beam transducers overcoming most of the shortcomings encountered in using power consumption. However, they have the serious shortcoming of not predicting sawblade deflection before the cut. They allow the regulation of the feed speed only when the saw is cutting.

Both these methods have limitations. To avoid overfeeding, the sawblade has to be entered into the cut cautiously. This leads to a production loss in most cuts. More seriously, these methods do not avoid overfeeding when the depth of cut changes suddenly due to irregularities along the log. Also, the methods do not properly correct the feed speed when blade deflection is due to underfeeding. Instead of increasing the feed speed they reduce it, which causes a more serious underfeeding situation. Underfeeding causes spillage which results in increased friction and beating of the edge of the sawblade, which in turn increases power consumption and sawblade deflection. The criticisms of these two methods apply primarily to band-sawing large logs. These methods are more suitable for smaller logs and cants which do not vary in height.

An advancement over these two methods scans the logs for diameter and uses this to control the feed speed. This is suitable for sawing small logs or cants where saw cuts are performed close to the centre line of the log. However, in sawing large logs, the cutting depth of most cuts is considerably smaller than the log diameter and this system, on average, feeds too slowly. This shortcoming can be overcome by more advanced scanning technology. For example, in addition to measuring the diameter of the log, the position of the saw line in relation to the centre line of the log is determined. This method works well if the log is round, straight and with little taper or butt flare, i.e. if it is without irregularities. This method is not appropriate for large first growth softwoods logs and almost all hardwood logs that have irregularities, i.e. sweep and butt flare.

The most accurate results can be obtained by determining the exact depth of cut. This can be achieved by obtaining a complete scan of the log and calculating the depth as the carriage position changes or by directly measuring the depth before the cut - much faster and at a much lower cost. The objective of this project was to develop a new feed speed control system for bandsaws that accurately measures the cutting depth ahead of the saw blade and regulates the feed speed according to the relationship between cutting depth, gullet loading and feed speed.

2.0 THE FEED SPEED CONTROL SYSTEM

The primary objective of the present development is to provide the bandsaw with a feed speed control system which avoids over or underfeeding of bandsaw blades and regulates the position of the upper guide for maximum blade support. As a result, lumber is more accurately cut which allows reduction in target size and planer allowance and, in the case of rough traded lumber, much improved product quality (dimensional accuracy).

Sawing Parameters

The feed control system is based on four sawing elements. The interaction of these variables determines the speed at which the workpiece is fed into the saw. Three of the variables are associated with the saw blade: saw velocity, gullet area and pitch, the distance between two adjacent teeth. The other variable is cutting depth as measured on the workpiece. The degree of loading of the gullet can be expressed as the gullet feed index. The gullet feed index relates these variables and the feed speed and is defined as:

$$\textit{Gullet feed index} = \frac{\textit{bite} \times \textit{cutting depth}}{\textit{gullet area}}$$

where

$$\textit{bite} = \frac{\textit{feed speed} \times \textit{pitch}}{\textit{saw velocity}}$$

Extensive research (Gronlund, and Karlsson, 1980; Allen, 1984) determined the maximum gullet feed index at which sawing accuracy is still acceptable. The feed speed at which this gullet loading occurs is considered the maximum feed speed. Mill tests were carried out to verify the published research results and close agreement was found between the published data and the results of these tests.

System Description

Two lasers are installed: one above, and the other below the cut. The beams are spread into lines with lenses and these lines are directed along the projected cut in alignment with the sawblade. The distance between the lines (which is the cutting depth) is measured with a camera. This information is processed with a microprocessor which then produces a signal for the variable speed carriage. The microprocessor uses a signal from through-beam photocells to detect the arrival of a log and activate the system. Figure 1 shows the system schematically.

The main advantage of the system is that the cutting depth is determined, and the feed speed set, prior to cutting. When the cutting depth changes due to sweep, burl, taper and butt flare, the feed speed is set for these cutting conditions before the saw reaches them. Furthermore, the system avoids underfeeding which other systems, such as measuring power consumption or sawblade deflection, do not.

The signal which controls the feed speed could also control the position of the upper guide arm. The guide arm should be positioned as close as possible to the work piece to obtain maximum support for the sawblade. In deep cuts the guide arm would be moved up to avoid being damaged by the work piece and in shallower cuts the guide arm would be moved down.

The system could incorporate a displacement probe as an auxiliary tool. This probe, attached to one of the guides, would record excessive sawblade deflection as a result of sawblade damage (due to metal or rocks) and excessive dulling of saw teeth (due to silt). The signal obtained from the probe would be used solely to stop feeding or through a signal (small red flashing bulb) to indicate to the sawyer that the sawblade is cutting inaccurately, and should be replaced.

This feed speed control system provides another feature: the laser lines on the log show the sawyer where the saw will cut and the sawyer can easily correct the orientation of the log for the best cutting position.

Hardware

Requirements for equipment chosen for this system included: sufficient processing speed to keep up with carriage speeds of 300-400 ft/min, robust design to withstand heavy vibration, dust and electrical noise, adaptability to be able to move and install the system in the saw mill, ability to assemble with commercially available parts, low cost and simplicity of the overall system. The following equipment was used:

Lasers, Lenses and Filters

Two five milliwatt Helium-Neon lasers were used as light sources. Cylindrical lenses on the lasers and optical filters for the cameras (matched to the frequency of the laser light) were used to improve the image detection.

Cameras and Camera Controller

An Opcon Inspector Series vision system consisting of two 256-pixel line cameras and a camera controller was used. Line cameras, rather than regular "full frame" cameras, were chosen to minimize image processing time. The camera controller is programable, supports multitasking, and has simple input/output capabilities. Acceptable resolution can only be obtained if the cameras are aimed at the correct range of vision, angle and distance. Figure 2 presents a schematic drawing of the geometrical parameters.

Microcomputer(PC) and Data Acquisition System

An IBM AT-compatible 386 microcomputer was used as the main processor to perform calculations, coordinate all activities, and store data for performance monitoring. A standard data acquisition system was used for parallel input and output (PIO), digital to analog and analog to digital conversion.

Programmable Logic Controller and Shaft Encoder

To measure carriage position, speed, and direction and to reduce the processing bottle neck in the microcomputer, a Programmable Logic Controller(PLC) was used. The PLC is expected to be of further use when the system is enhanced to measure saw deviation, handle the joystick interface and to control the saw guide. A shaft encoder was used to monitor the carriage drum movement. This shaft encoder generates 360 pulses per revolution. With the carriage used this pulse rate produced an accuracy of 0.105 inches per pulse.

A block diagram of the hardware arrangement is shown in Figure 3.

Bandmill

The bandmill used to test the system has a 30 foot carriage track and an 8 foot carriage. The overall experimental setup with bandmill, carriage, cameras, lasers and a log positioned on the carriage with the two laser lines can be seen in Figures 4 to 6. The carriage speed is variable, with a range of 0-650ft/-min. The carriage drive is powered by a 15 horse power hydraulic pump and is not equipped with a feedback control system. An industrial microcomputer controls this carriage. The operator sets the desired speed prior to starting. The computer implements the speed by applying the appropriate signals to special ramping circuitry. The hardware and software of the carriage were modified to allow for continuous regulation of the feed speed by the automatic feed speed control system without affecting the carriage operation in manual mode. Limit switches at the end of the track initiate a hardware override which smoothly stops the carriage.

Software

There were four basic software tasks: measurement of depth of cut, calculation of feed speed, implementation of feed speed and overall coordination.

Depth of Cut Measurement

When the system is initialized, the microcomputer calculates a table of relative elevations for each camera pixel and transfers it to the camera controller. During the cut, the controller obtains the picture frames and uses the table to determine the depth of cut by subtracting the relative elevation of the upper and lower laser lines. A second concurrent task transfers the depth of cut value for each picture to the microcomputer. Referring to the geometry in Figure 2, the following relationships were used to calculate the relative elevations (n is the pixel number best representing the image and n=0 and n=255 represent the top and bottom of the camera's field of view).

For the upper camera:

$$h_1 + d_1 - l_1 \times \tan\left[\alpha_1 - \frac{\varphi_1}{2} + \phi_1 \times \frac{n}{256}\right]$$

and for the lower camera:

$$l_2 \times \tan\left[\alpha_2 - \frac{\varphi_2}{2} + \phi_2 \times \frac{n}{256}\right]$$

Calculation of feed speed

The microcomputer receives the value of the depth of cut from the camera controller and uses the gullet feed index formula to calculate the theoretical desired feed speed.

Implementation of the feed speed

An algorithm for feed speed implementation was developed. It is designed to handle the normal operation of the feed speed control system as well as extreme cases. This algorithm utilizes the carriage response time, maximum possible acceleration and deceleration, maximum allowable feed speed and the calculated (theoretical) feed speed to implement the optimum feed speed.

Implementation of the feed speed on a carriage is entirely dependent on the carriage drive and control mechanism, as well as the operator interface. Typically, with a DC Drive carriage it would be a matter of applying an appropriately scaled voltage within a specified range to the drive.

The operator controls also need to be modified to implement the operator override. In most mills the operator uses a joystick to control the feed speed and the joystick signal has to be used in a speed matching mechanism to ensure a smooth operator override. These features were not implemented since the carriage used has a hydraulic drive and does not include a joystick for operator control.

Overall task coordination

The microcomputer coordinates and synchronizes the various activities of the system. It starts the picture-taking process when the log arrives in the vision field of the cameras. It then repeats the sequence of picture-taking, calculation and speed implementation steps in a loop. At the end of the cut the microcomputer stores the data calculated during the cut for further analysis, and slows down the carriage.

3.0 RESULTS AND DISCUSSION

The various tests carried out have successfully demonstrated the working ability of the feed speed control system. The functioning and effectiveness of the equipment was demonstrated without sawing. At this stage, there was no need to involve sawing since the primary objective of the tests was to determine how accurately the carriage speed changes with depth of cut. In the following sections, relevant performance parameters of the new feed speed control system will be discussed based on the observations made during the tests.

Resolution for depth measurement

Optical filters on the cameras eliminated any interference from ambient light and due to colour variations of the log surface. This was important since light conditions and the colour of debarked logs vary dramatically. Each of the upper and lower relative heights were calculated to the nearest centimetre, giving an expected depth resolution of one centimetre. However, this was only true while the cameras were set up as shown in Figure 2. With undesirable camera angles and distances, some camera pixels may represent much more than one centimetre. Thus, if in a mill, the cameras are not arranged with the appropriate geometry, the resolution may be compromised. With the arrangement shown in Figure 2, the range was 110 cm above the carriage bed. Depths of cuts up to 3.6 feet can be measured.

Figures 7 and 8 show the real profile of a set of rectangular objects as measured manually versus the profiles produced by the system, at the carriage speeds of 100ft/min and 400ft/min. These figures show that the system is, in general, successful in timely measurement of depth of cut even at 400 ft/min. It can be seen that the measured values are up to 1.5 cm less than actual values. The consistently lower values indicate that the cameras were not mounted exactly at the correct angles. Other tests indicated that even a slight discrepancy (one degree) between the real camera angles and the values used by the computer for computation would lead to inaccuracies as large as one to two centimetres. However, such deviations are minor for mill applications. Working with rectangular profiles with a flat surface resting on the carriage bed showed that the system can handle almost any shape of log.

System Response Time and Resolution Along the Log

The resolution of measurements along the log depends on how fast the log is moving and how often depth and position measurements are taken. Since these measurements were taken once per loop, it was important to make the loop time (the system response time) as low as possible. By distributing the various functions among the three processors as four separate tasks and running the tasks in parallel as much as possible, a system response time of less than 14.8 milliseconds was achieved. This included a 12 millisecond exposure time and was an improvement over the 20 milliseconds originally hoped for. Therefore, even at 400ft/min, the log was scanned every 1.2 inches. The total error in reading the log length, in the worst case, was less than 2.4 inches. Figures 7 and 8 show a horizontal shift which is larger than the expected error value. This is due to the fact that in each loop through the process, the camera controller passed the previously calculated depth of cut to the microcomputer, instead of the current one which was just being processed.

Lead Time Required Before the Cut

The lead time required before cutting starts was longer than the system response time. During this lead time, the system took a few pictures and started building a profile of the log. This allowed the system to pre-process the data before the cut and change the carriage speed from its initial travel speed to the appropriate cutting speed for the beginning of the cut. This change in speed may be large if the log is either very small or very large. After the cutting begins the required change in speed will be relatively gradual in comparison, even for butt flares. Nevertheless, this lead time kept the system one step ahead of the cut.

The longer the desired lead time, the further ahead of the saw the cameras, lasers, and photocells should be mounted. This distance also depends on the carriage response time. However, there is a limit to how far back the cameras can be moved without losing production time. Unless the log needs to be turned, the operator normally only needs to bring the carriage far enough back between the cuts to clear the saw blade.

For the tests on the bandmill, the cameras were mounted 12 inches ahead of the saw. This distance provided sufficient lead time, taking into consideration the 14.8 milliseconds processing time per loop and that in this time, even at the maximum speed of 400ft/min, the carriage travels only 1.2 inches.

To allow for experimentation with different lead distances, an additional parameter was used and set before the cutting begun to determine how far ahead of the saw the speed signal changed to produce the desired speed for each section of the cut. In future developments, this parameter could be recalculated during the cut. Despite being fixed during the cut, this parameter provided sufficient flexibility to obtain the feed speeds determined by the system from the carriage at the intended positions as shown in Figure 9. This plot shows the measured feed speed of the carriage, the feed speed determined by the system and the depth of cut versus the position on the log. The feed speed determined by the system is shown at the position at which a particular depth passes the saw.

Feed speed and carriage limitations

The response time of the carriage used was longer than typical systems in saw mills. Although acceptable performance was obtained for low accelerations by adjusting the lead distance, for sudden speed changes, the carriage speed lagged the input speed signal. Furthermore, lack of feedback control on the drive caused oscillating response to sudden changes in input speed signals. Both of these effects can be seen in Figure 9, where the measured carriage speed is shown to lag and oscillate around the speed determined by the system at the beginning of the cut. These equipment-related problems apply to this carriage only and were not focused on, because with a better drive they would not occur. Consequently, the only case chosen to represent the carriage speed performance involved steady rate of change in depth of cut and relatively low carriage speeds which did not aggravate the carriage shortcomings. Also to avoid large oscillations, the system was started with a reasonable speed depending on the log size. A commercial system mounted on a properly controlled carriage would be able to adjust to any log size within the accepted range automatically.

The resolution of the speed measurement was better than one percent for speeds as low as 50 ft/min. The speed was only updated every 120 milliseconds, which is slower than other measurement rates in the system. However, this did not pose any practical limitation for this stage of the development.

Equipment for Commercialization

Overall, the tests showed that the new system can use available technology and equipment and that with this technology or equipment the concept of measuring the depth of cut and calculating and implementing the feed speed before cutting can be accomplished. This has the advantage that a commercialized version can be readily built with already available equipment with the benefit that the cost of implementing the system will be substantially reduced.

Conclusions and Recommendations

A new automatic feed speed control system has been successfully developed. In spite of colour variations of the log surface and the frequently irregular shape of the log, the new system accurately measures the depth of cut. The accuracy in measuring the cutting depth is high when the log dimension changes up to a level of normal butt flare. In the case of sudden - stepwise- changes in log dimension, which occur very rarely, the accuracy deteriorates for a short distance (less than two inches) of carriage travel.

The processing speed of the control system also adequately handles the high feed speeds as employed in high production sawmills.

Further work is needed to allow overriding of the feed speed if the sawyer sees a need for it.

It will also be beneficial to incorporate a lateral sawblade deflection measuring device to adjust or indicate sawing problems related to excessive saw dullness, saw damage or extremely high wood density.

The use of commercially available equipment for developing the feed control system demonstrated that the system can be easily assembled and cost effectively manufactured.

Potential Economic Benefits

Since the new development automatically controls the feed speed and the position of the upper guide and also indicates to the sawyer where the saw is to perform its cut and when the performance of the saw is substandard, the benefits are two fold; higher grade recovery which may amount to at least $20 million annually and a 5-10% higher production rate. These benefits are primarily obtained in coastal mills.

Acknowledgements

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Gronlund, A. and L. Karlsson. 1980. Practiska rad vid bandsagning. STFI - meddelande Seri A666.

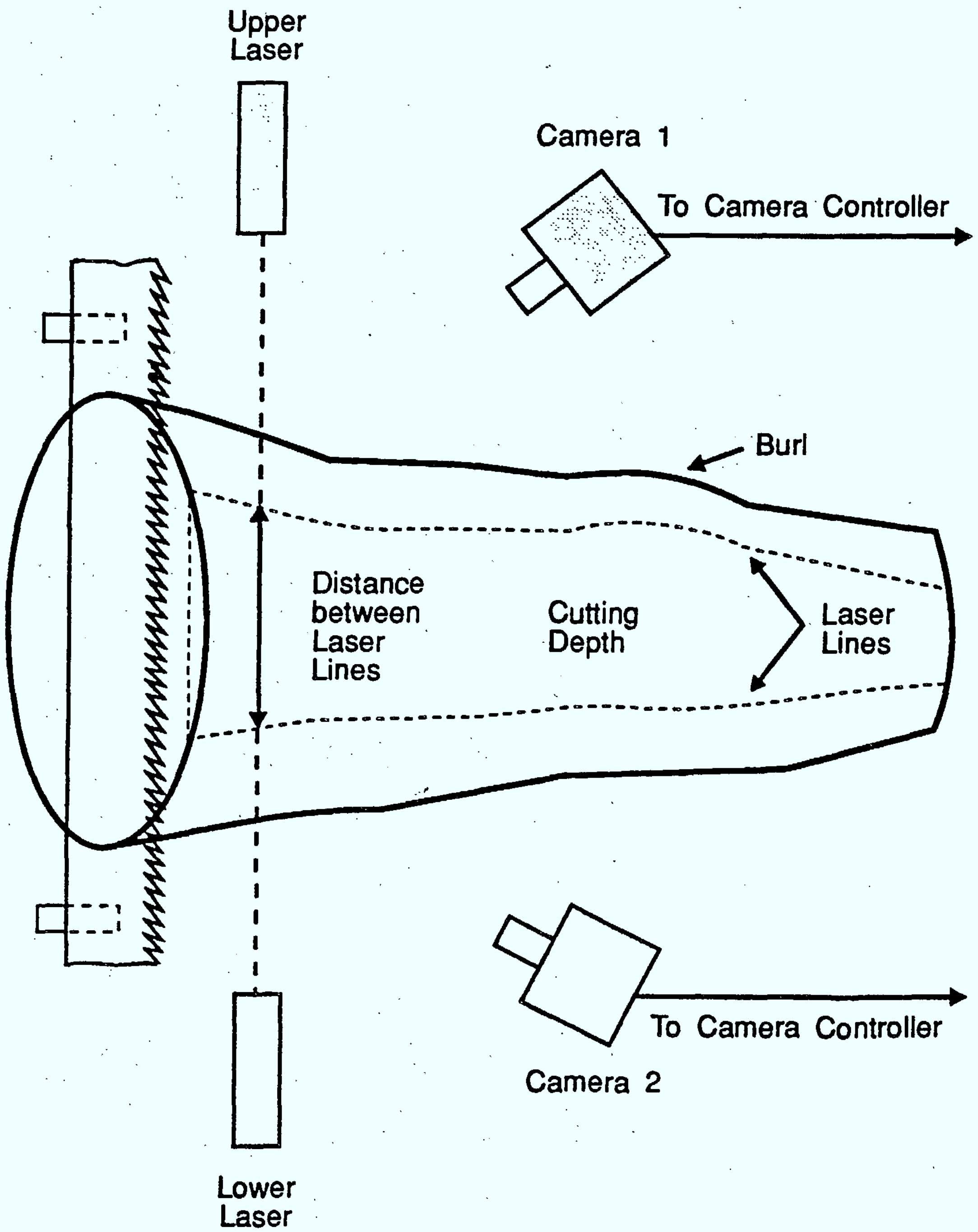
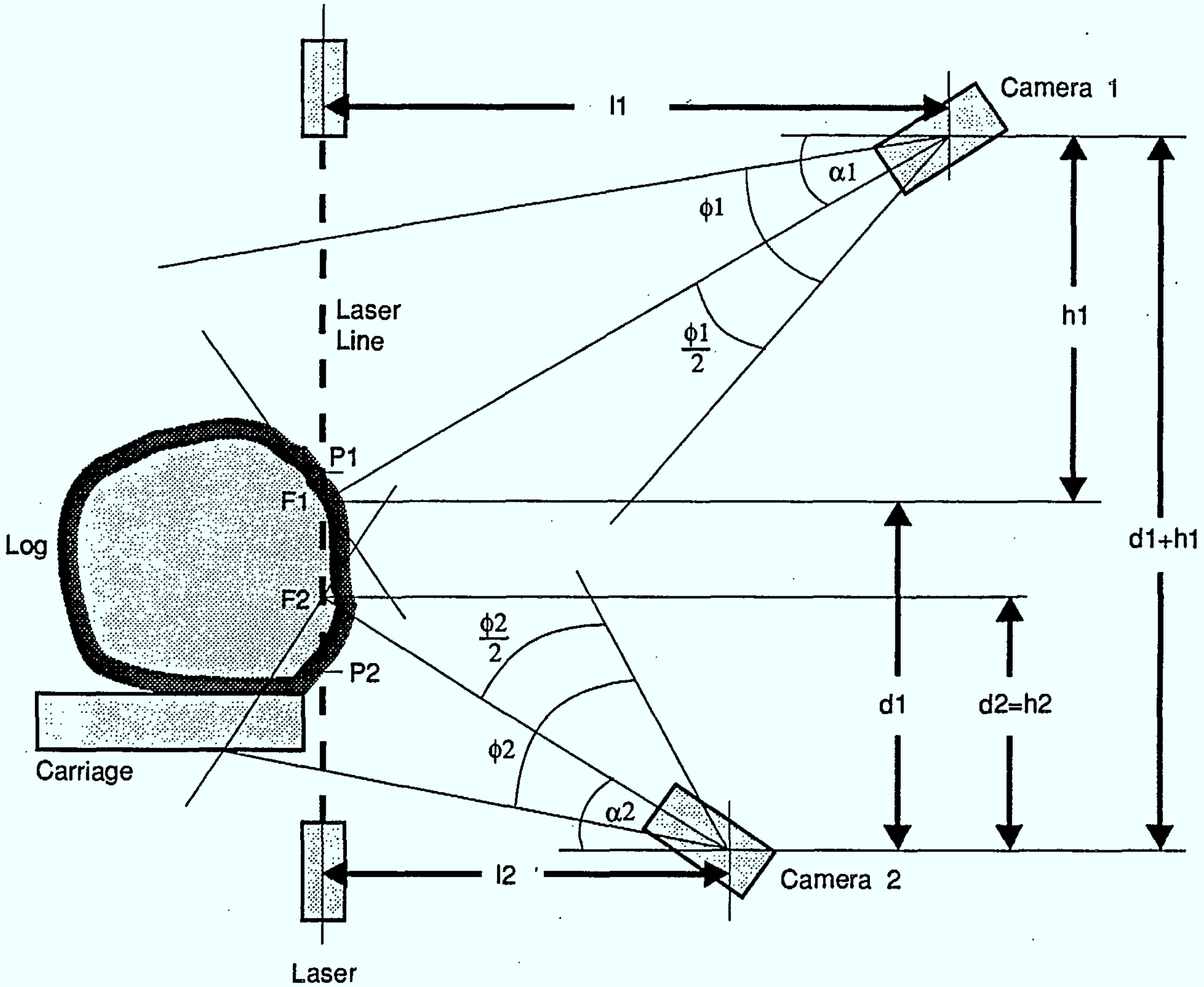


Figure 1. Schematic layout of the new feed speed control system.



P1 = The upper point of intersection of laser direction line and the log diameter
P2 = The lower point of intersection of laser direction line and the log diameter
P1 - P2 = Depth of Cut
F1 = Focal point of the upper camera on the laser direction line
F2 = Focal point of the lower camera on the laser direction line
l1 = Distance between upper camera lens and laser direction line (here: 129.0 cm)
l2 = Distance between lower camera lens and laser direction line (here: 65.0 cm)
h1 = Vertical distance between upper camera lens and F1 (here: 153.7 cm)
h2 = Vertical distance between lower camera lens and F2 (here: 77.5 cm)
d1 = Vertical distance between F1 and lower camera lens (here: 106.3 cm)
d2 = Vertical distance between F2 and lower camera lens (here: 77.5 cm)
α_1 = Tilt angle of the upper camera (here: 50 degrees)
α_2 = Tilt angle of the lower camera (here: 50 degrees)
ϕ_1 = Field of view of upper camera (here: 26 degrees)
ϕ_2 = Field of view of lower camera (here: 26 degrees)

Figure 2. Geometric arrangement of laser light generators, laser lines and the cameras in relation to the log.

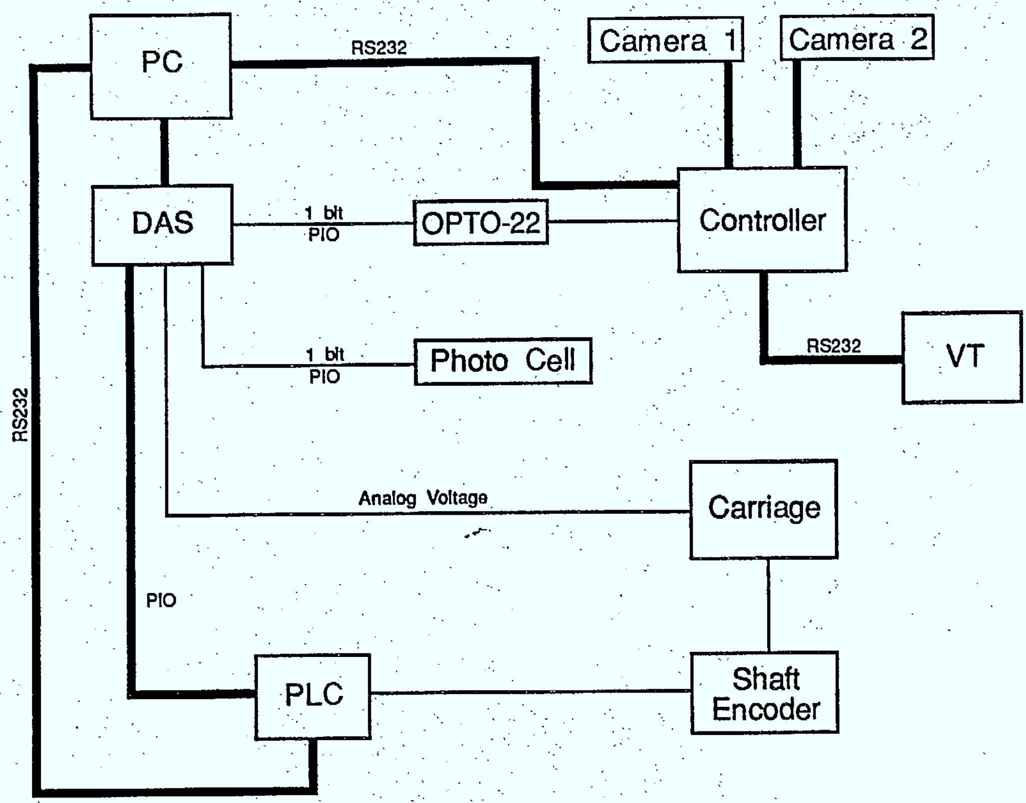


Figure 3. Hardware block diagram.

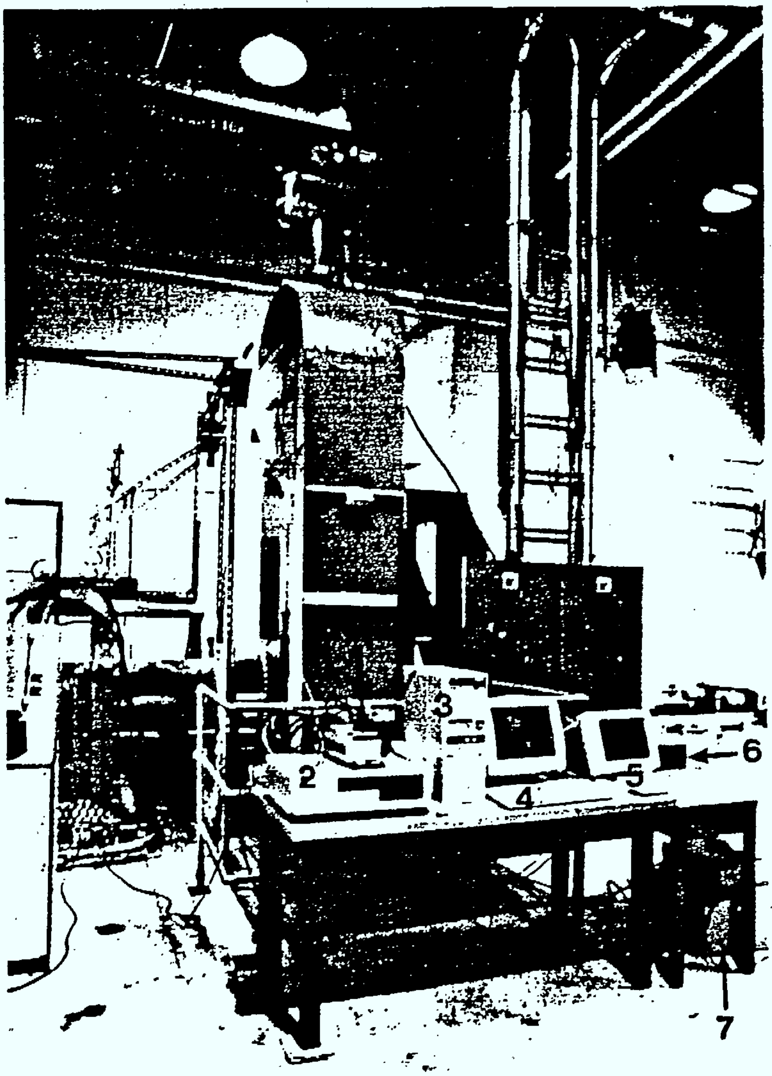


Figure 4. Electronic equipment used for developing the automatic feed speed control system. (1) Programmable logic controller, (2) data acquisition system, (3) microcomputer, (4) microcomputer monitor, (5) VT terminal connected to the camera controller, (6) camera controller, (7) printer.

Figure 5. Laser and camera set-up. (1) upper laser light generator, lower laser light generator in bandmill pit, therefore not visible, (2) upper camera, (3) lower camera, (4) upper laser line on log.

Figure 6. Upper (1) and lower (2) laser lines projected onto the log where the saw will cut.

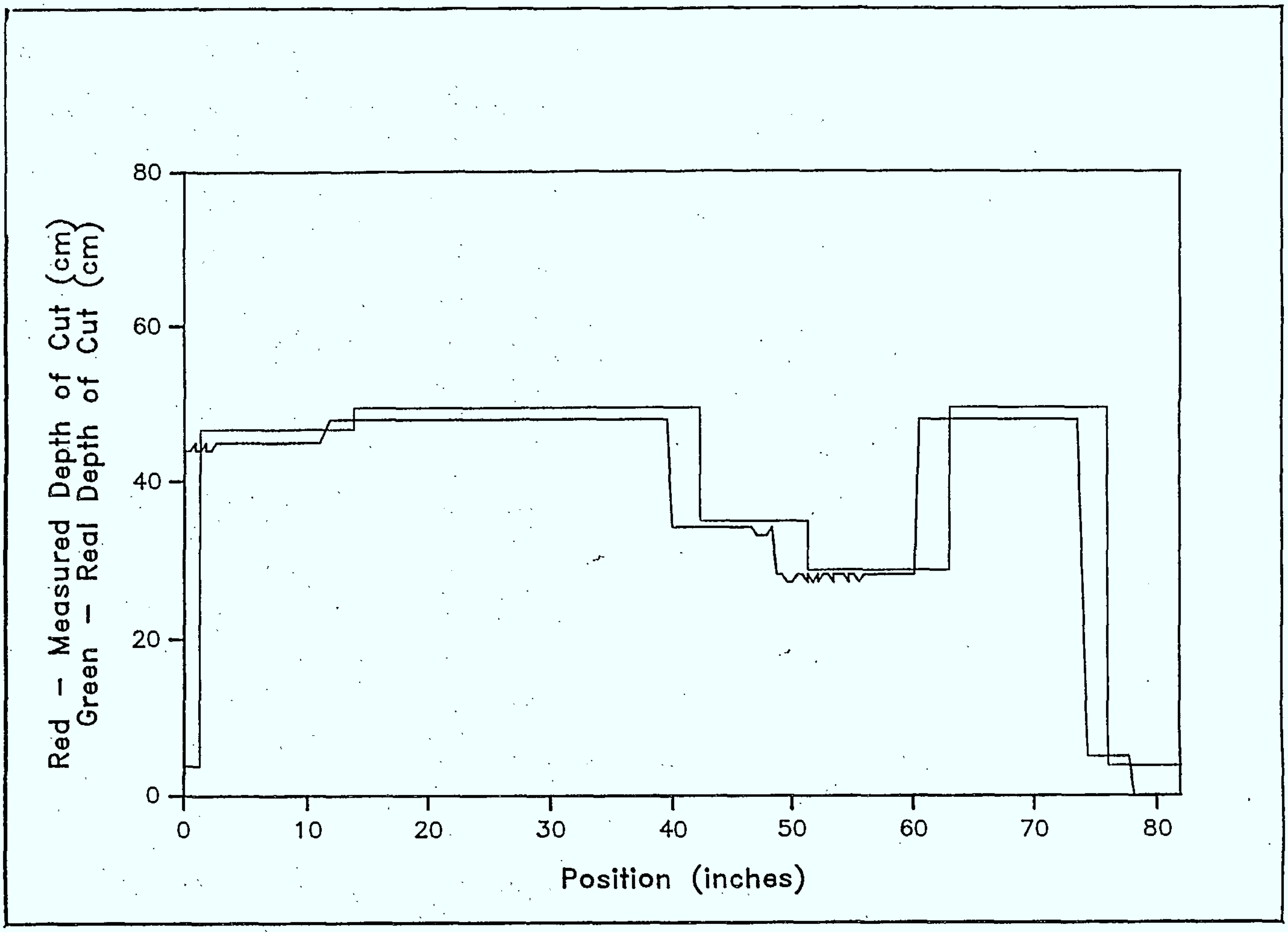


Figure 7. Real depth of cut and measured depth vs. position at 100 ft/min.

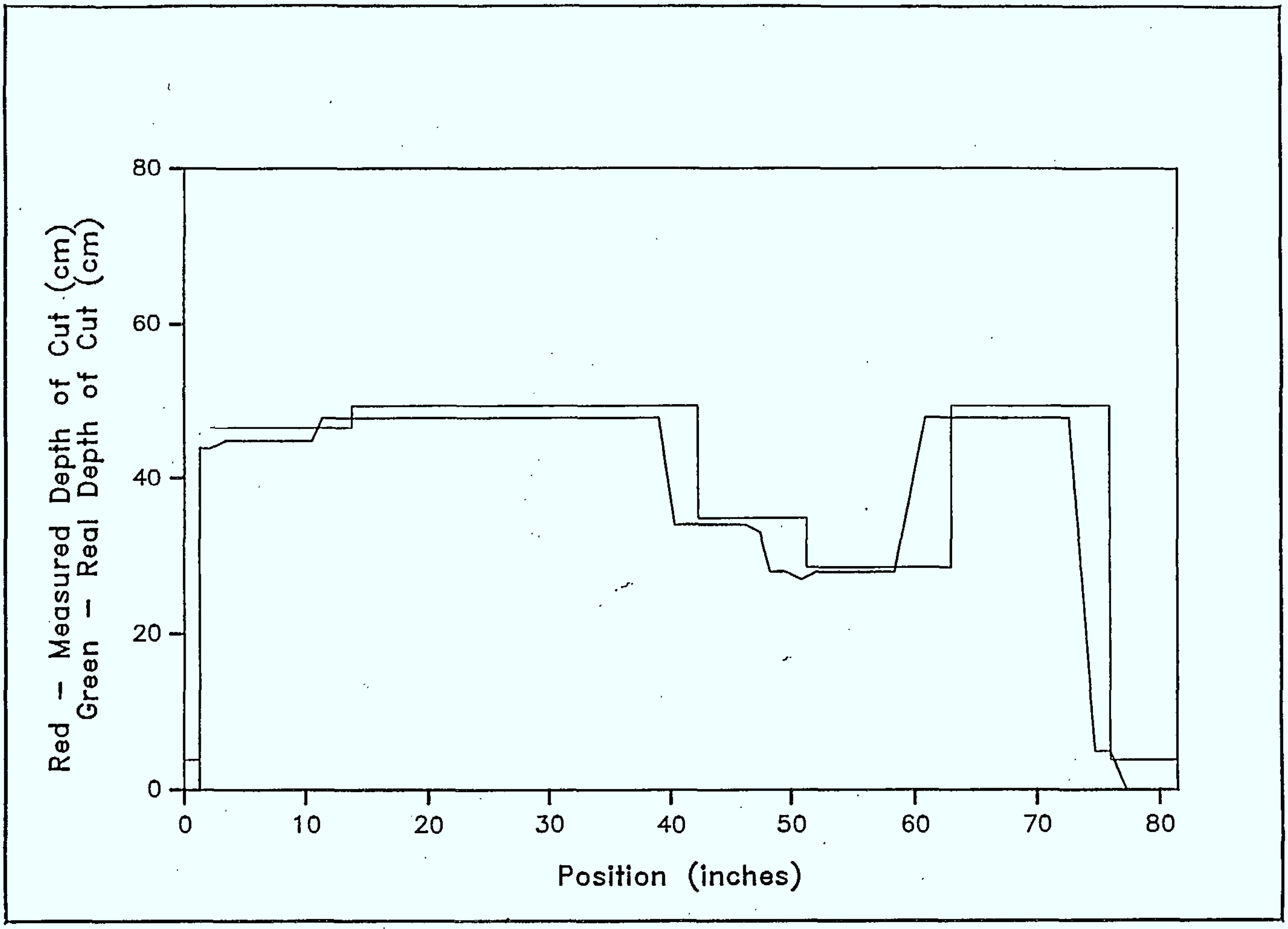


Figure 8. Real depth of cut and measured depth vs. position at 400 ft/min.

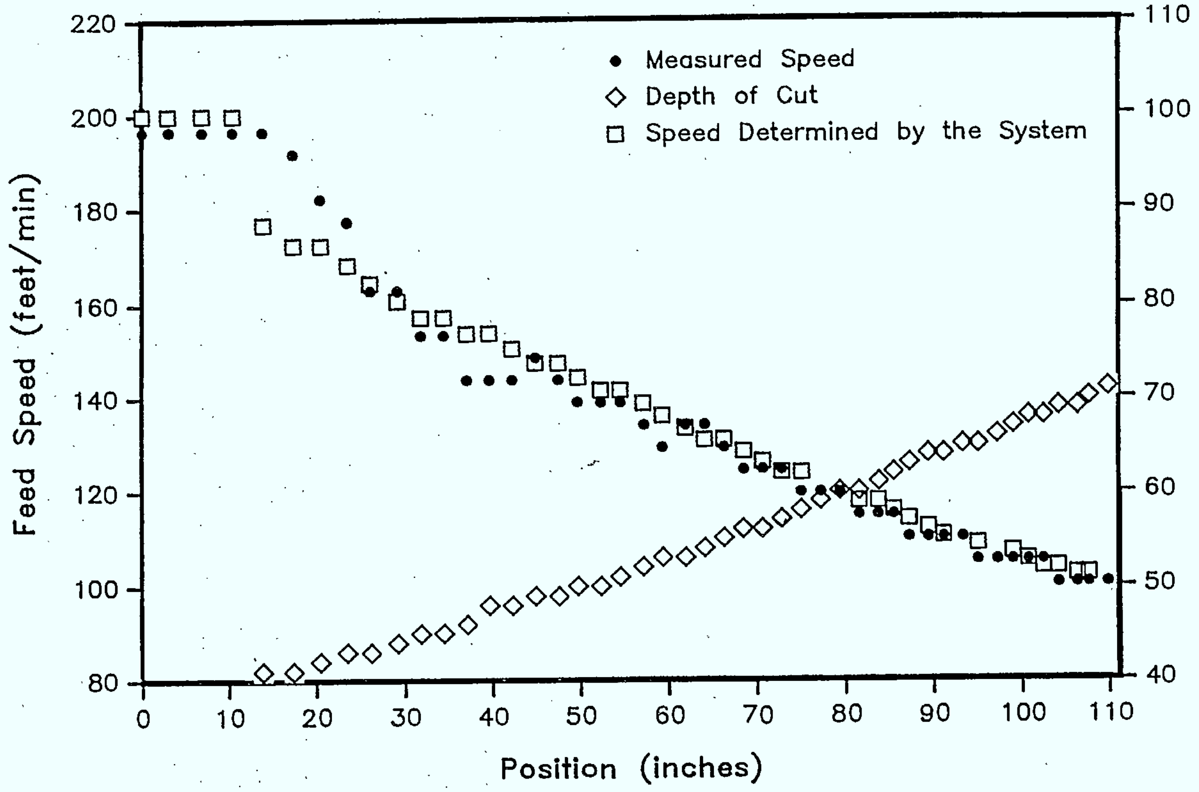


Figure 9. Depth of cut, measured feed speed and feed speed as determined by the system vs. position.

Technology Used To Reduce Lumber Costs and To Achieve Volume Optimization

Robert Czinner
President
Integrated Wood Research Inc.
Scarborough, Ontario

I am a lumberman.

My family has been in the wood industry since 1863 and I have been actively involved in the family business since 1971. As General Manager of Ziner Lumber in Toronto in the early 1980's, I was responsible for a $ 24 million a year operation that retailed, wholesaled and remanufactured softwood lumber to builder and industrial markets. During this period I came to learn that most of the lumber industry's marketing problems were being caused by it's outdated conventional wisdom, and I came to recognize that these problems were created by the industry's single-minded focus on reducing unit volume production costs combined with it's overlapping and confused distribution logistics.

It became obvious to me that there were 2 basic strategic changes needed to improve the economics of marketing softwood lumber. The industry must:

- increase the value of its overall cutting yields;
- lower its overall production costs.

We believe that the answer to achieving these two changes are the same for manufacturing wood products as they have proven to be in the manufacture of cars. These are:

- Use advances in computers & automation technology to improve manufacturing speed and efficiency;
- Determine the specific needs of your market and then focus on achieving them.

After performing our initial research we decided that the ideal solution would be to have a central computer capable of both analysing marketing data as well as directing the manufacturing process. The result would be an "Intelligent" manufacturing process that would redefine the economics of producing lumber, while better serving market needs.

In 1985 I founded Integrated Wood Research Incorporated (IWR) for the purpose of developing technology to create a practical "integrated" solution that could solve the problems of both the lumber market and the lumber producer. A method that would reduce lumber costs in order to capture market share. We reasoned that a fully automated sawmill would have to accomplish:

- high throughputs to lower unit volume production costs;
- flexible dimension & grade production in order to add the maximum value possible;
- intelligent production planned to accomplish open orders;
- consistently reliable quality control;
- intelligent production planned to accomplish fast inventory turnover.

We recognized early-on that our main objective had to go beyond automating the grading process, that without the ability to both plan and automatically direct the actual manufacturing process the critical goal of achieving flexible production could not be achieved.

In a preliminary study we commissioned to HA Simons, Consulting Engineers, we were advised that it would cost approximately $100 million to create and build such a Computer Integrated Sawmill.

We realized that to build a fully automated sawmill capable of integrating the production process with marketing data would involve very complex technical logistics that would inevitably define a very high risk financial proposition.

At this point we had to stop and ask ourselves: how could we fulfil our goal, that is, to reduce lumber costs in order to capture market share while reducing the risks associated with developing the necessary technology.

Our answer was to develop a completely automated, computer-driven, intelligent lumber remanufacturing process. The logistics of remanufacturing are much simplified to a sawmill, the production process is much less complex and much less expensive. Because input board widths can be restricted into the system one at a time, there are fewer potential output dimensions for the computer system to evaluate, which makes real-time optimization processing more easily achievable and less risky.

Because there are fewer material handling devices and actual machining centers to integrate and because the production process is by definition less complex, remanufacturing requires a much smaller facility and a considerably smaller investment in equipment and capital. In addition, the smaller scale of a remanufacturing operation allowed us the flexibility to engineer the plant so that it could function profitably as a failsafe in a partially automated mode, something we determined with H.A. Simons just wasn't achievable in a primary sawmill design.

The Opti-Stress System, our patented process, slashes production costs by 50% while increasing lumber value over 100%. At a total cost of $ 18 million it represents a substantially reduced risk compared to building an automatic sawmill, both technically as well as financially.

Now that I have explained why we developed Opti-Stress, I am going to spend the next 18 minutes explaining how it was developed, and how it was designed to completely redefine the critical distribution link between the production process and the broad needs of global lumber markets. I am going to present why we at Integrated Wood Research believe that the North American lumber industry is ripe for the introduction of our proprietary manufacturing system.

These days, forestry and lumber production are very often front page news. Today's growing industry concerns, including environmental, ecological and wildlife preservation, make it the right time to implement a solution which really addresses the problems faced by both lumber consumers and manufacturers. Without significant improvement, the North American softwood industry faces the prospect of a slow and agonizing death.

Because a large proportion of timber cutting costs are paid by the softwood operations of integrated forest companies, one cannot discount the vital importance of maintaining the viability of their lumber business. Without improving the economics of softwood processing, operating margins will fall due to restricted tree harvests and increasing costs. Prices will rise and the market will scramble to find new, substitute products.

I want to describe to you how we at Integrated Wood Research determined that combining advanced manufacturing technologies with in-depth market expertise would both redefine the economics of lumber remanufacturing as well as provide a vital technological stepping stone towards the creation of a completely automated sawmill.

Our innovative solution addresses how to satisfy the specific needs of global lumber markets, by significantly reducing production costs and improving production flexibility.

In the longterm, we are aiming to upgrade 25% of all the low grade softwood produced by North American sawmills using the Opti-Stress System. If that means forming joint ventures with large lumber producers, arranging royalty agreements or selling plants outright, we will pursue these options aggressively.

We are also aiming to provide the sawmilling industry with a proven systems architecture and integrated systems design that they employ to enhance their production flexibility and reduce their manufacturing costs.

We are taking a very labour intensive, slow, inflexible and high cost process and redefining it using the Opti-Stress System.

We believe that flexibility is the key to becoming preferred wood suppliers and capturing premium-priced markets.

We are introducing an entirely new opportunity to the lumber industry. While primary mills are geared to serve their own production needs, an Opti-Stress plant is geared to serve the needs of it's markets.

It was this distinction back in the early 1970's, only 20 years ago, that allowed the Japanese to penetrate the automobile industry. We believe that it will allow us to penetrate the wood industry.

To bring home the significance of this analogy, perhaps we must remember that the Japanese began their involvement in the car business by manufacturing motorcycles.

We believe that now is the time to improve the utilization of our forest resource. We believe that Opti-Stress is a critical link in the lumber business, a bridge between need and opportunity and the bridge between vision and accomplishment.

We are Integrated Wood Research.

A better way to better wood!

A Laser-Based Moisture Sensor

Dr. Wes Jamroz
Manager, Industrial Laser Systems
MPB Technologies Inc.
Pointe Claire, Quebec

1 INTRODUCTION

A novel optical technique for measurements of the moisture content in wood products has been developed[1]. This method has been designed in response to the urgent requirement from the industry for a non-contact, accurate and rapid sensor, which could be used in on-line applications. The requirement called for a sensor which could be used with wood products for moisture measurements over the fibre saturation point in wide range of moisture content classes.

The existing commercial moisture meters such as electrical detectors, drying chambers, balances etc. do not provide the required characteristics to be efficiently used in on-line green lumber sorting systems. These meters major shortcoming are: moisture content range limitations, limitation related to the lumber temperature, precision and speed.

The new method[2] is based on diagnosis of a laser beam, which is used to probe analyzed samples. This is non-contact, rapid and precise technique for moisture measurements. Implementation of this laser-based sensor ("LAMSOR") for on-line measurements will allow saw mills to sort the lumber into moisture content groups before the kiln. Thus, it will be possible to reduce kiln degrade, accelerate kiln throughput, and reduce subsequent planing machine down-time.

1 Technology development co-sponsored by "Forest Industries Program" - Industry Science and Technology Canada.

2 Patent pending

2 SYSTEM DESCRIPTION

A laser is a source of coherent and collimated light radiation. This radiant energy is very well defined and it can be precisely controlled. For example, duration of laser pulses can be controlled with the accuracy of fractions of millisecond. Therefore characteristics of laser-based systems in time-dependent measurements are superior to any other conventional method.

A response of an analyzed substance to a laser beam can be characterized by a set of parameters such as intensity, wavelength, direction, degree of collimation, mode structure, pulse duration. These parameters are primary ("immediate") responses to a laser beam as compared to secondary responses such as -for example- the temperature gradient caused by exposure to laser radiation. Therefore, a method which is based on analysis of the primary responses will provide much faster data analysis than methods where the secondary parameters are being measured .

The moisture content of a substance has been identified as one of these characteristics, which can be measured by using a set of laser beams.

A prototype of the laser-based moisture sensor ("LAMSOR 920") has been built and tested. The "LAMSOR 920" is the first commercial model of this new generation of fully automated moisture sensors to be used by the industry. This unit is capable of displaying:

- the moisture content of each board,
- the moisture content distribution of all the analyzed boards,
- the moisture distribution for custom selected ranges.

3 SPECIFICATIONS

A schematic illustration of the laser-based moisture sensor is shown on the Figure 1. A laser-head with a set of optics is positioned above analyzed sample. The probing beam is analyzed by a set of detectors attached to the sensor-head.

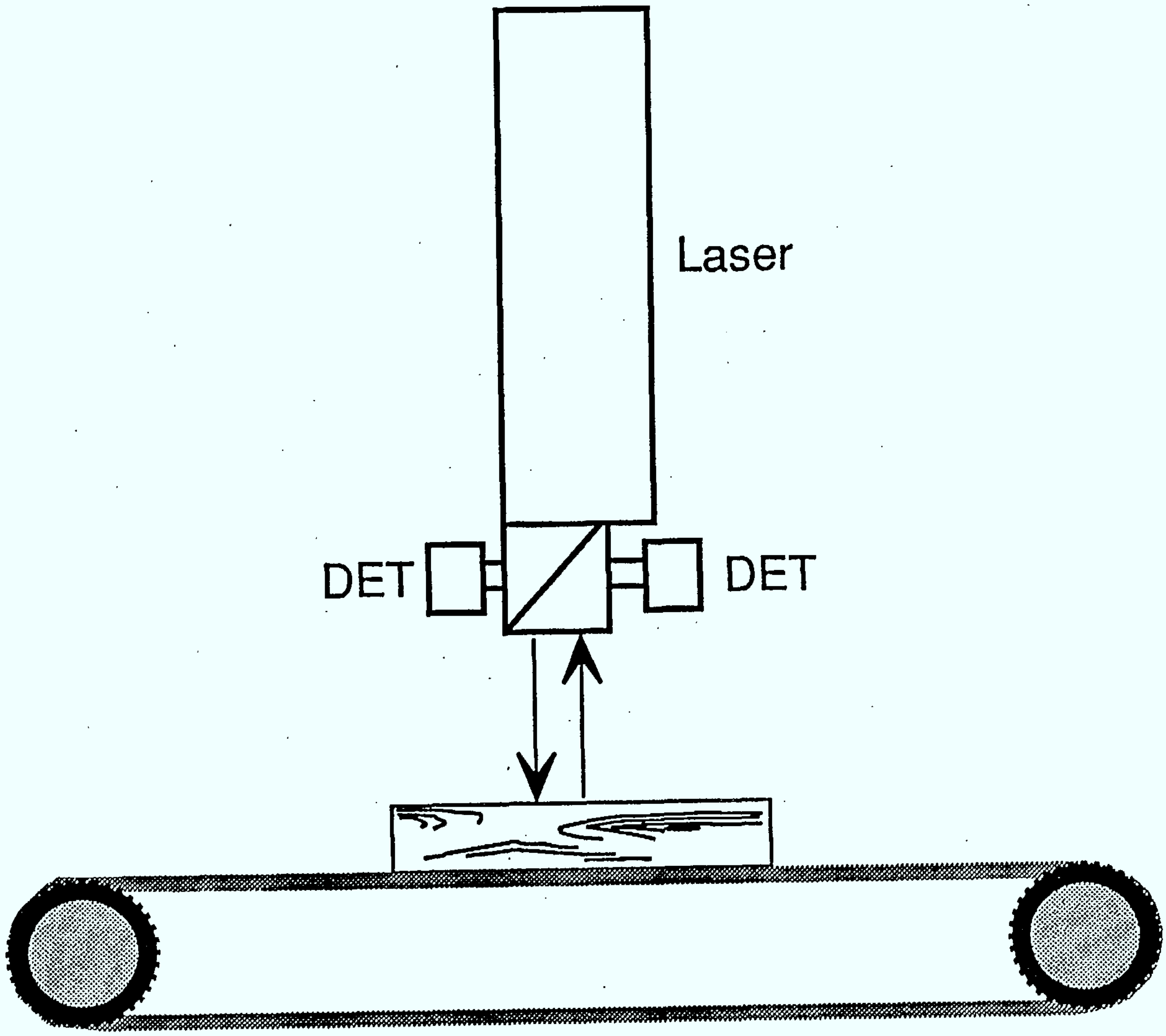
Figure 2 shows an example of experimental data obtained for lumber samples of Hemlock. Each experimental point marked on this diagram represents the mean value of 50 measurements.

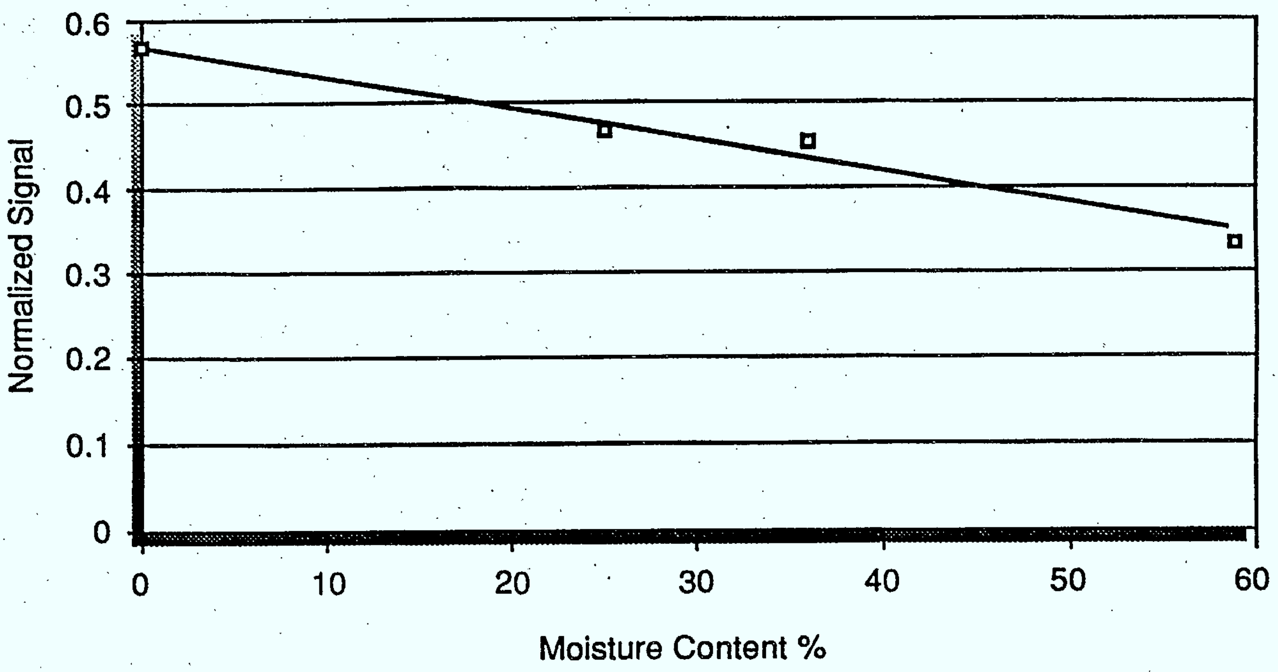
Some preliminary characteristics of the laser-based moisture sensor are summarized in TABLE I.

TABLE I. CHARACTERISTICS OF THE SENSOR ("LAMSOR"):

Power consumption:	< 1 kWatt
Moisture content range:	0 - 250 %
Overall size:	2 cubic ft
Warm-up time:	0.005 sec
Distance between sensor and a sample:	Adjustable (up to 0.5 meter)

The first unit has been scheduled for a mill trial during summer of this year.

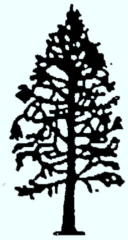

Laser
DET
DET



Normalized Signal
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
Moisture Content %

Measuring of Moisture Content of Green Lumber Using Infra-red Sensing

Tom de Scally,
President
Novax Industries Corporation,
New Westminster, B.C.



Who is NOVAX?

Canadian owned and operated company involved in the design and manufacture of microcomputer based industrial control systems for the forest and the traffic signal control industry.

Until 1981 NOVAX was a division of Durand Machine Company Ltd. of New Westminster, B.C. This company is known through North America and Europe for its line of automated machinery for the veneer and plywood industry.

Typical examples of projects NOVAX has been involved with are :

Rotary Veneer Clipper
Spindleless Veneer Lathe

As far as our traffic signal control activities are concerned, we have been involved in Central Traffic Management Systems in a.o. Vancouver, Ottawa, Metro-Toronto, Halifax, N.S. and Red Deer, Alberta.

History of the Moisture Meter

In 1985 Dr. Clark of Forintek perused declassified NASA documents related to the adhesion of heat resistant ceramic tiles to the space shuttle.

Higher moisture content, poor adhesion.

In 1986 and 1987 trials in-house and at Weldwood of Canada in Williams Lake, using radiant type heaters and hand held IR sensors.

Economic benefit studies by the mill concluded that if green lumber could be sorted 40% MC over and under, the increase in yield as a result of degrade prevention ranges, from \$6 to \$8 per thousand board feet. Energy savings were anticipated also however the magnitude was not known.

As a result of the preliminary tests, Forintek invited proposals for the development of an industrial model. Novax signed a licensing agreement in 1987.

First commercial units was installed in 1988 at Riverside Forest Products in B.C.

Further test runs performed by Forintek since the commerclaliza-tion of the Moisture Meter included frozen lumber (Northern Alberta) and lumber from small diameter logs in Eastern Canada.

UNITS IN OPERATION

A total of 12 units in B.C. and Alberta. Kept the first units close to home because of inherent teething problems with any new product. Also unit installed at Roseburg Lumber in Oregon, U.S. and an evaluation unit is presently being started up at Simpson Timber in Northern California to determine its potential use on red cedar or redwood. The system is in-line system and can handsomely handle 200ft/min (about 120 lugs/min at 20 inch spacing).

BENEFITS

The benefits of sorting green lumber before the kiln may be obvious, but will list anyway :

(A) Reduce the effects of overdrying, i.e. reduce degrade, a result of twist, warp, split ends, etc. This is the greatest single benefit of the M.M.

EXAMPLE: Apollo Forest Product. Falldowns reduced from 4-1/2% to 2-1/2%, a reduction of 2%. This translates in about $300,000 for a mill doing about 150 MM fbm per year. At the same time this mill reports decrease in degrade of another 2% of production, resulting in another $300,000 per year.

(B) Increase in planer mill production because of the problem with overdried boards has been eliminated.

(C) Energy savings -- Because of more efficient drying, significant energy savings can be obtained. Weldwood published some initial projected energy savings of about 20%. Even mills that product their own energy for drying will benefit from more efficient drying. E.G. E.B. Eddy in Ontario projected a total savings of about $250,000 as a result of electrical energy savings reduced operating cost at the boiler and freed-up capacity at the dry kiln. Also it is expected that carbon dioxide emissions will be reduced by 10%.

(D) More efficient use of dry kiln. Typical example -- A mill in Northern B.C. doing about $150 MM fbm per year, was able to cancel a dry kiln project estimated to cost $900,000.

PRINCIPAL OF OPERATION

The only Moisture Meter to operate above fibre saturation point. We heat the surface of a board at several points along the length of the board. We take a temperature reading, using infra-red remote sensing, before and after heating the board. This gives us a reading of delta T. This delta T is a function of the moisture content of the board.

When delta T is small, the board is wet. When delta T is larger the board is dry.

Typical delta T ranges, depending on the line speed, is 8 C for wet board and 20-35 C for dry boards.

Since the line speed determines the amount of time the board is subjected to the heat source, the Moisture Meter System incorporates a line speed tachometer.

ELEMENTS OF THE MOISTURE METER

(A) The heater element. Although the very first systems used radiant type heaters, the disadvantages associated with this type of heaters (e.g. large thermal mass) made us decide to go over to Quartz Halogen type heater tubes. The advantages of these type of heaters are many.

(1) Over 90% of the energy output is radiated energy with less than 10% being convection heat. This does largely away with the problem of draught in the mill, affecting the readings.

(2) The new halogen type heaters, because of the parabolic reflector, produce largely a collimated energy beam. Some of the energy is being divergent. We can now predict the amount of energy in the beam at different distances from the heater element. This in turn enables us to run the boards about 6 to 9 inches away from the heater elements.

Anybody familiar with a sawmill situation will appreciate the problems associated with boards on end and boards sitting on top of the lugs. With the heater elements being located too close to the chain, board will run into the heater, knocking the living daylight out of the heaters.

It also enables us to determine the moisture content of boards of varying thicknesses, which is becoming a must for mills getting involved in metric lumber sizes.

(3) The thermal mass of the quartz halogen type heaters is insignificant compared with the radiant type heaters, used during the initial test runs. Line stoppages in a sawmill are a fact of life. When a line stoppage occurs, the quartz halogen heater can be switched on and off as desired. The quartz halogen heater will obtain over 90% of its heat output with 3 seconds from turn-on, compared with 10 minutes for the radiant type heaters.

The reason for shutting off the heaters is to prevent discolouring the boards during extended line stoppages.

(4) Life Expectancy and degradation of heater output.

(B) Bolometers.
Novax has designed devices to monitor the heat output of each heater element. These are called BOLOMETERS. The bolo-meters will record any fluctuation in heat output from each heater as a result of heater degradation or supply voltage fluctuations. Small changes in heater output are compensated for in the MC readings. Large fluctuations will cause the system to shut down.

(C) The heat energy applied to a board surface increases with the square of the distance between the heat source and the board surface. Therefore, in order to determine the moisture content of boards of varying thicknesses, it is important that we monitor the distance between heat source and material. The smallest difference we have come across between boards of adjacent thickness is 3 mm, e.g. 19 mm and 22 mm.

Our board thickness measuring device therefore has to have a resolution better than 3 mm. At present we are using a laser-type range sensor which gives us board thickness resolution of one (1) mm.

(D) Width sensors.
In order to measure the temperature of the board travelling underneath the Infra-Red Sensor, we want to eliminate any readings of the background temperature.

In order to be able to accomplish this, we need to know the width of the board. Again we are using laser-type photo sensors with a resolution of one (1) mm.

(E) Infra-Red Sensors are used to determine the temperature of the wood before exposure to a heater source and after. Since we are sensing remotely, about 6-9 inches away from the material, there is no contact with the wood.

The response time of the infra-red optics limits line speed to about 200 - 220 ft min.

The placement of the IR sensors is critical in that the "cold", the "hot" sensor and the heater element must be perfectly aligned.

In order to compensate for changes in ambient temperature of the IR sensors, we are monitoring the temperature of the devices and compensate for any drift.

(F) Line tachometer.
Since the line speed varies from mill to mill, and since the line speed determines the amount of heat being Applied\ to a board surface, our system monitors the line speed and makes adjustments as necessary. A regular shaft encoder with 500 pulses per revolution is presently being used.

MANAGEMENT INFORMATION SYSTEM

MIS capability is included in the system, being able to produce histograms of moisture content by board thickness, board width and also board length.

This information is retrievable from a PC. Set up facility is also provided through the PC.

SOME QUESTIONS BOUND TO BE ASKED

Q. Does the system work on frozen lumber?

A. Yes it does. In the winter of 1990, Forintek did a demonstration project in Northern Alberta, trying to demonstrate the ability of the process to determine moisture content on frozen lumber.

The outside temperature had been about -40 C prior to and during the tests.

The results of the tests were positive and these results have been publicized.

Q. What about sorting capacity?

A. In order to do moisture sorting, additional sorting capacity or bins may be required.

The payback of the moisture sensing system alone may be 3 to 6 months, however if additional sorting capacity is required, the payback may be extended from one to two years.

Our advice to any prospective user of our moisture sensing equipment has been to look at the revenue created by the different sorts, such as thickness, width and length.

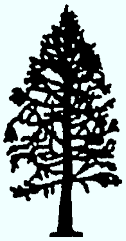
Determine the sort that creates the majority of the revenue, which in our experience has been mainly 4 inch and 6 inch, 16 feet long.

Try to separate these particular sorts by moisture content into 2 or 3 sorts, and double up in length on some of the lesser sorts.

In fact, of all the dimension mills that have installed our moisture sensing system, none have expanded on bin capacity.

Neurocomputers for Manufacturing

Paco Xander Nathan
Sr. Staff Engineer
Odin Corporation
Kansas, U.S.A.



SYSTEMIC ANALOGIES: A TREE, A NEURON...

Imagine a tree stretching out to the sky, with branch and leaf reaching for light, heat, air, and moisture. These nutrients collect from the farthest leafy reaches and flow down into stem, then branch, then trunk to provide life-giving energy all the way down into the edge of even the tiniest root. On one hand, a tree can be viewed as the sum of its parts: the functional divisions of leaf, trunk, root, etc. On the other hand, a tree can be viewed as a single system: a process for energy conversion, reproduction, etc. Broader perspectives would encompass similar systemic views at the level of a grouping of trees, an entire forest, an ecosystem...

Since the beginnings of computer science, mathematicians and engineers working in the field have striven to mimic biology's example of a computer: the brain. John Von Neumann, Norbert Weiner, Alan Turning, to name a few, all found inspiration from neurobiology. The basic philosophy was to find an electronic analog of the brain's cellular building block: the neuron. The field of neural networks has sprung from this quest.

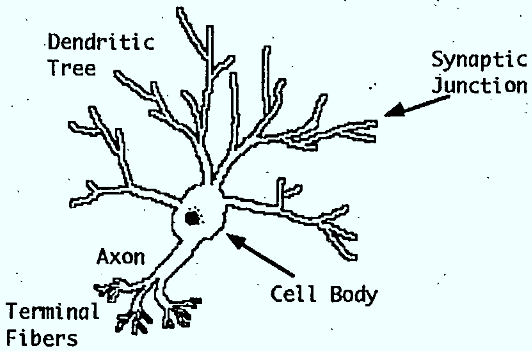


Figure 1 - Neuron form

Visualization of a tree illustrates several important points about neurons and neural networks. First off, a neuron is similar to a tree in both form and function. Photomicrographs of neuron cells resemble ordinary elms or oaks, with dendrites spanning out as branches and twigs, synaptic receptors much like leaves, neuron cell body like trunks, etc.

From a functional perspective, information in the form of electro-chemical messages collects on the neuron's dendritic tree structure, and accumulates in the neuron body. Processed information then fires out through the axon to connect with other neurons in a networked manner.

NEURAL NETS AND EVOLUTION

In terms of artificial neural networks, most research efforts have focused on specifying the behavioral characteristics of individual neurons, in the hope that many neurons could be grouped together to produce systemic behaviors. Typically, the electrical behavior of neurons is captured by using statistical models. *Backpropagation* (BP) is a classic example of this approach.

Another research direction, embodied by the *Quantum Neural Network* (QNN) design, takes a systemic view of neurons at several levels. Rather than statistically model the electrical behavior of neurons, QNN attempts to capture neuron information processing effects using fuzzy set mathematics.

Process effects are emulated at the synapse level, the neuron level and the neuron grouping level, with fuzzy sets providing a computationally efficient method for modeling.

Evolution provides an important distinction at this point. Phylogenetically, the most primitive neural system can be found in the *Reticular Brain Stem* (RBS). This structure is common to most all animals, including invertebrates, and handles sensory input processing for the most basic responses in an organism's central nervous system.

Many classic neural network paradigms, such as BP, have sought to model neurons found in the Neocortex, which phylogenetically represents one of the most advanced neural systems. Neocortical cells provide the long-term memory and associativity functions in higher-order mammals. A rationale for this approach would contend that high-order neurons might provide a key to more intelligent behavior. This has proven useful in the application of BP to such complex tasks as identifying an individual from photographs taken at different angles.

With this distinction in mind, the QNN approach has shifted focus to modeling the RBS first, and then branching out by grafting additional systems later. QNN currently subsumes the RBS and part of the *Thalamus*, to be precise. Accordingly, QNN provides a simpler function than neocortical models: associating waveform pattern input with symbol output. This is suitable for simpler machine tasks, such as process control and pen-input recognition.

FUZZY SETS AND COMPUTATION

Apart from neural networks, fuzzy set theory has increasingly attracted the attention of scientists and engineers in many fields. One of the compelling reasons for using fuzzy set theory is that it provides a computationally efficient methodology for mimicking human thought process and reasoning. This complements the neural network goal to emulate nervous system behavior. Fuzzy set theory, like the conventional set theory, is a branch of mathematics; it is a pure science and very theoretically oriented. Again, neural networks complement as an applied science intended to provide problem solving technique directly.

There are two main issues to address in employing fuzzy set theory within an application: the representations of the fuzzy subsets, and the definitions of the fuzzy subset operations. The former addresses whether a membership function should be linear, triangular, trapezoidal, or something else. The latter concerns questions such as the intersection of two fuzzy subsets should be governed by a simple minimization operation or something else.

Given an application, these representations and definitions need be stated in a very precise manner before fuzzy set theory can be exploited. In terms of computer software, this implies that membership functions and their related operations must be defined at compilation time as opposed to run time.

QNN provides a neural network framework for defining fuzzy set operations explicitly at compilation time. However, the adaptive nature of neural networks and synaptic behavior defines a methodology for defining and modifying fuzzy sets during run time. The resulting architecture benefits both from computational efficiency and adaptivity.

QUANTUM LEAPS AND NEURAL ARCHITECTURE

To understand the Quantum Neural Network architecture, first realize the three levels of systemic abstraction it employs. At the lowest level there are *synapses* that gather incoming information from the input buffer. These correspond to the synaptic junctions on the edge of a neuron's dendritic tree.

A collection of synapses feeds into a *neuron*, which defines some output symbol. Within the neuron, there may exist a plurality of *quantum levels*. The brain itself does not function according to a simple "stimulus-response" probabilistic model. Rather, new sensory input forces the thought processes into a temporary disarray of chaotic confusion. Eventually, the globally dispersed neural structures settle into some quantum level of understanding, as might be experienced in the familiar "A-ha!" sensation. In a different example, the concept of the word "star" may be inspired by a plurality of sensory input patterns: five-pointed polygon, stellar mass, popular cinema actress, etc. QNN provides a mechanism for associating many vastly different input patterns with the same output symbol.

Finally, the current topmost level of abstraction provides a *neuron group*, representing the aforementioned RBS structure. Within this group, several different symbols may be matched from any single input pattern. To illustrate this architecture from a computational perspective, QNN associates input waveform patterns with output symbols. Input arrives as a *waveform* that has been normalized in the *time* and *amplitude* dimensions to fit a specified sample buffer:

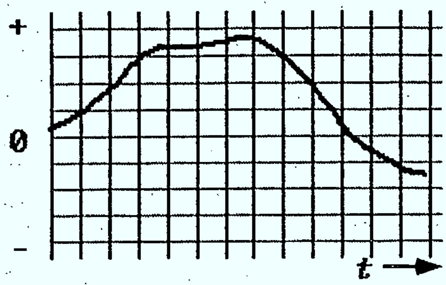


Figure 2 - Sample input waveform

QNN then takes each sample point as input into a synapse. Each synapse maintains a set of *fuzzy membership functions* to define its synaptic output as a function of input:

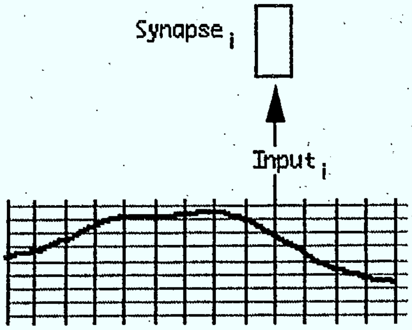


Figure 3 - Sample point as synapse input

A row of synaptic fuzzy membership functions, one for each sample point, comprises a quantum level. Therefore, the ensemble of synapses at a given quantum level learns and matches a particular perspective of a pattern. Each neuron associates an output symbol with a set of quantum levels:

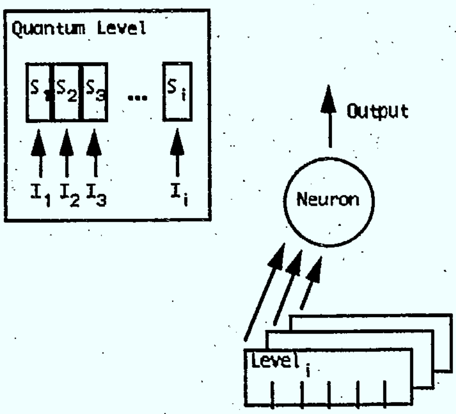


Figure 4 - Synaptic quantum levels

A collection of neurons, grouped with global match thresholds and learning parameters, in turn defines an RBS structure. This RBS structure implements a single neural network. Creation and modification of quantum levels within this architecture are governed by an RBS mechanism based on fuzzy set theory. Overall, this mechanism leads to several key features:

- New patterns can be adapted whenever they arrive, with no iterations or off-line processing time required. This provides a capability for real-time applications.
- The system adapts to gradual changes in the input patterns although it can be tuned to report abrupt deviations. This is important in "smart applications" for control systems.
- Fuzzy sets are automatically generated from input data. A major drawback to fuzzy systems is that the membership sets and rules need to be handcrafted; fuzzy membership functions in this architecture are both defined and modified automatically at run time.

Most importantly, QNN's "design rules" come from biological systems, which have inherent self-similarity. This results in an architecture that functions similarly at each level: synapse, neuron, neuron-group, sub-system, etc., and provides a rich upgrade path for development. Similarly, the QNN algorithm is scalable; its expected performance criteria and system requirements are well-understood for any configuration of pattern classification system. The reason for this stems from inherent parallelism.

The major tradeoff for using the QNN architecture is that input data needs to be represented as waveforms. An important caveat is that not all applications will find this form of input appropriate.

ALGORITHMS AND PARALLELISM

As mentioned, the QNN algorithm is based on the behavior of parallel biological structures. It can be explained best starting from the assumption of a parallel computing environment. Consider the following block level diagram:

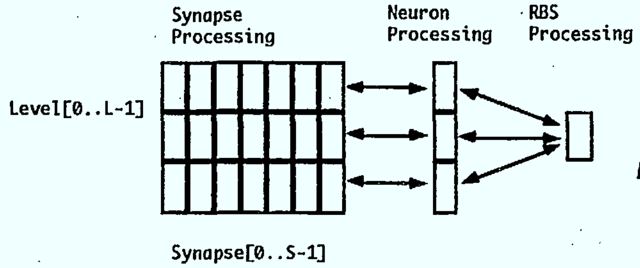


Figure 6 - Functional processing blocks

In a parallel implementation, the algorithm for QNN distinguishes three functional processing blocks: *synapse processing*, *neuron processing*, and *RBS processing*: Each of these three blocks requires its own set of subroutines and dataflow definitions. Parallelism in the QNN architecture provides a means of scaling: more synapses imply finer pattern granularity, more quantum levels imply greater pattern variability, and more neurons imply a larger set of possible symbol matches.

In software written for a standard CPU, these three parallel dimensions of synapse, level and neuron can be executed in three nested loops. A software implementation written in ANSI C requires about 3 Kbytes of object code on a 32-bit microprocessor. Therefore, the "serialized" software implementation can still be executed in tight loops. Consequently *the processing overhead in software scales linearly in each dimension*. This is in contrast with some other pattern matching algorithms which scale according to the square of the number of possible matches.

APPLICATION DEVELOPMENT PROCESS

A step-wise approach to fuzzy/neural applications makes their development concise. The following process codifies the steps a developer will need to use to produce a QNN application.

- Define the application in terms of associating waveform patterns with output symbols. The basic operations employed *match* and *learn*. For example, a handwriting recognition system concatenates x/t and y/t pen position samples to define characteristic waveforms for each letter.
- Estimate the network's architectural requirements. How many symbols are defined in the application (*required neurons*), how many sample points are needed for a characteristic waveform (*required synapses*) and how many pattern variations are expected (*required quantum levels*).
- Determine how fast the pattern classification operations must run. Does the application require a sample/response cycle every 3 milliseconds, or every 4 hours? Which operation will be the bottleneck, match or learn?
- Using answers from the previous steps, project the application's performance requirements. Network requirements can be entered into a spreadsheet to determine memory use and clock rate for a given processor, based on formulae from QNN benchmarks. Play "what if?" spreadsheet scenarios to find an economically feasible solution set.
- Use a software development environment for QNN to create a network configuration based on the derived solution set. These tools allow for rapid prototyping of fuzzy/neural applications.
- Evaluate sample data sets using this prototype to tune/refine RBS thresholds and network architecture for optimal accuracy and performance.
- Determine the pattern matching accuracy rates and confirm the projected performance estimates.

These steps posit a fundamental issue: the input waveforms must be characteristic and normalized to the number of synapses. One typical difficulty is that common waveform patterns are neither characteristic nor suitable for normalization. For instance, raw audio signals almost never contain characteristic waveforms for spoken words. The solution for this issue is to transform raw input into preprocessed waveforms. A wide array of signal processing tools and techniques can be employed for QNN preprocessing, but the computational costs of these techniques must be included in any performance analysis of a fuzzy/neural application.

FUZZY/NEURAL APPLICATIONS

To date, QNN has found application in three classes of computing: microcontrollers, desktop systems, and supercomputers. The architectural tradeoffs lending toward its capability for both real-time learning and scalable parallelism help create such a wide range of application.

Microcontrollers (MCU) typically get used in low-cost, low-power, embedded applications. Typical examples include handwriting recognition for portable computers, embedded control systems, etc. With this class, applications typically receive input as waveforms, so QNN provides a convenient algorithm. Also, MCU applications are generally very sensitive to cost projects. The fact that pattern matching performance can be scaled and tuned by adjusting RBS thresholds and network size positions QNN as a very flexible alternative.

Embedded products tend to be personalized for an individual user. For example, a handheld computer is generally only used by one person. Whereas many other pattern recognition systems draw off existing pattern databases, QNN can be used to build a pattern classification database itself. This becomes particularly important in applications that, for example, need to adapt to an individual's handwriting nuances but cannot afford to package a general handwriting database.

Desktop systems tend to use 32-bit microprocessors and have a much broader range of resources than MCU environments, for instance hard disk storage, co-processors, several megabytes of RAM. Typical examples of desktop QNN applications include medical analysis workstations, image recognition, process control, etc.

Since software simulations of QNN run in a tight code space, the algorithm can be run in cache on many of today's desktop systems. The fact that QNN performance scales linearly makes it suitable for desktop applications that draw on large databases. Since QNN generally can learn and match in real-time without hardware acceleration, it finds application in desktop computers used on the shop-floor for controlling production lines and quality assurance. Gradual adaptation is particularly important for process control where monitoring equipment must adjust over time to component wear.

Supercomputers in this case are defined as massively parallel arrays of fast processors. Here the parallel aspects of fuzzy/neural pattern recognition can be employed to help solve difficult data analysis problems such as seismic identification of oil field telemetry, weather prediction and financial forecasting.

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Implementing Advanced Technology in the Forest Industry

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This paper focuses on using advanced technology in the forest industry, specifically in the harvesting phase. The paper reviews the basic factors that have led to successful technology development, and mention what is required to ensure high technology development continues into the future. Finally, some examples of high technology developments in the forest harvesting sector are given.

As an introduction to the Canadian forest harvesting sector and the technology that it uses, I will briefly outline the harvesting operation. During harvesting, the trees are felled and dragged to a haul road where they are delimbed and transported either directly to the mill or to a central yard. If hauled to a central yard, the logs will be sorted by species and grade and then transported to mills. Depending on the size of the timber and the terrain, some of the phases are all manual, all mechanical, or a combination of both. In some cases, the logs can be directly converted to wood chips or hog fuel either directly at the harvesting site or at a central yard.

Before one can appreciate the potential for high technology in the harvesting sector, it is important to understand that current equipment and workers operate in a wide variety of conditions. The equipment and workers must operate in temperatures that can range from 35°+C in the summer to 40°C or lower in the winter; in environments where moisture or dust or both are usually present during most of the work day; on flat and steep terrain; and frequently more than 150 km from an urban community. The operators and owners of the equipment are often the only mechanics on site, and their training may be limited to hands-on experience. At some operations, skilled mechanics are available to service and repair equipment; at others, mechanics must be brought in when the equipment breaks down. The challenge to keep the existing equipment operating efficiently is great, and the challenge for maintaining and repairing new equipment with high technology components is even greater.

Today change is occurring faster, and operations must react even more quickly to these changes than ever before. The forest land base is decreasing in area, the quality of timber is decreasing, forest management responsibilities are increasing, and world competition in forest products and fibre dictates our harvesting and manufacturing costs. If the forest industry is to remain profitable, we must take advantage of technology to overcome some of these factors.

High technology can help the forest harvesting industry remain competitive. Technology can be used to allow workers to perform more tasks; make faster, more-accurate decisions; and to work more safely so that unit production costs can be reduced. Technology will allow more value to be recovered from the raw materials, and will create new products that will open up new markets. In turn, this will allow the industry to utilize more of its fibre, rather than leaving the fibre as residue at the harvest site.

Factors influencing High Technology Development in Canada and B.C.

The development of high technology is not simple, inexpensive, or risk free. New advanced technology, whether it is computer software, robots, artificial intelligence, new materials, innovative controls, super computers, or simply new equipment that utilizes a combination of these devices, can require a long time to develop especially if the basic research or materials are not in place. Easier to introduce, and sometimes faster, are developments based on technology that has been adapted from other applications. However, to develop and implement adapted technology may still require a substantial investment because the basic materials and components are not strong enough to withstand the rigors and isolation of harvesting operations.

Three other factors also inhibit the development of high technology in the forest harvesting sector. Firstly, the relatively small size of the forest industry market, and the variety of conditions in which each company operates generally prohibits the development of large numbers of similar equipment, instrumentation, or software. Secondly, the large companies have little capital available to spend on high technology development, and owner-operators -- who own a major portion of the forest harvesting equipment across Canada -- do not have long-term contracts for their services and therefore do not have an incentive to purchase new, advanced technology. Thirdly, people with both the technological expertise and a full understanding of the needs of the harvesting sector are lacking. We need more researchers with advanced technology expertise to work in harvesting.

Canada does, however, have a very innovative manufacturing sector that has adapted and developed most of the new equipment that is available today, Manufacturing companies vary from small machine shops that have developed attachments that fell, fell and process, or delimb trees, to large multinational companies that produce carriers and special-purpose equipment such as skidders, delimbers, feller-bunchers, and processors. Some of this equipment is marketed in the United States and overseas.

This innovative equipment -- and attachment -- manufacturing sector has developed largely because the regulatory agencies in Canada have not specified the specific equipment that is required to harvest a cutblock, but have rather set guidelines that determine areas where general types of equipment can operate (such as ground--based equipment, cable or aerial systems), or have established guidelines limiting the amount of site disturbance. It has then been up to the forest company to determine what type of equipment that can achieve the desired results. In addition, the competitive nature of the harvesting industry and the tough working conditions have provided incentives to develop technology. Manufacturers have worked with harvesting companies to develop equipment that is more productive, requires less maintenance, and will minimize site degradation.

The Swedish example is often used to demonstrate in which direction Canadian forest industry should head. To many people, the Swedes have a forest industry that has everything; sustainable development, a highly motivated labour force, and a high standard of living. The Swedish forest industry, including the extraction phase, is based on technology. They have done as much as possible to remove the worker from manual occupations, and have made the workers equipment operators. This high degree of technological achievement has occurred because there has been a high level of cooperation and understanding between machinery suppliers, forestry companies, and logging contractors. This cooperative approach has allowed a number of participants to share the risks, while also sharing the rewards. The cooperative approach also allowed the industry to take substantial risks during mechanization because the manufacturers had been able to trust the technology goals and develop experimental machines. The partnership arrangement encouraged rapid adoption of improvements in the efficiency of machines.

The Canadian forest industry has a similar framework to develop high technology, although it is not as widely perceived by the general public. In Canada, three research institutes are cooperatively funded by a large portion of the forest industry, as well as the federal government and some provincial governments. FERIC, the Forest Engineering Research Institute of Canada, undertakes applied research in harvesting, transportation, and operational silviculture. Forintek Canada Corp. undertakes research in the technological advancement of equipment for lumber, veneer, and composite manufacturing, building systems and fire research, and resource characterization. Paprican, the Pulp and Paper Research Institute of Canada, undertakes long-term or industry-wide research that will maintain the competitive nature of the Canadian pulp and paper industry.

A number of other organizations and research centres also have high technology laboratories that can assist the forest industry. Universities across Canada and the National Research Council have expertise; the Natural Sciences and Engineering Research Council, and industry, Science and Technology Canada are two of many funding agencies. In addition, in British Columbia, the Advanced Systems Institute, Western Economic Diversification, and the B.C. Science Council are available to assist with technical support and project funding.

Development of High Technology for the Harvesting Sector

Our experience to date in the development and advancement of high technology indicates it is important to ensure there are at least four and maybe five different representatives assembled at the time a project is initiated: users of the technology, technological experts, manufacturers, the appropriate research organization, and possibly the funding partners. To ensure success we have found that each partner must also have a vested financial interest in the project. With these partners in place, and working together, the technology developed should be useful to industry and marketable.

Each of the representatives has a specific responsibility. The user's define why the technology is needed, the operating conditions, and the characteristics of the product produced by the technology. The technology experts provide the knowledge (or the means to gather the knowledge) for designing and developing a prototype. The manufacturing representatives ensure the prototype is developed in a way that minimizes production that minimizes production costs, is practical to manufacture, and will withstand the rigors of the application. In Canada, we have a number of small-scale manufacturers that have developed technology independent of experts' input. Their innovative solutions and knowledge of the market are important contributions to any technology development project.

Research organizations working with the Canadian forest industry play a key role in the design and development of advanced technology by bringing their member companies together with the technological experts to develop the concept, manufacturing companies that have the abilities to develop the appropriate technology, and funding partners. In addition, the research organizations can undertake their own research, conduct market surveys, and evaluate the designs and prototypes developed.

It is important to have the funding agencies, if they are required, involved with the development. These organizations will maintain confidence in the project if they are aware of the full involvement and active participation of the other players. In addition, they can assist in suggesting other sources of funding if it is required.

Opportunities for High Technology in the Forest Harvesting Sector

In the harvesting sector, high technology is required in a number of areas. The following are just a few examples.

Devices and systems are required to monitor the locations of equipment and workers so they are not exposed to unnecessary hazards, or so that they can be quickly located in an emergency. Decision support tools are needed to improve the value of logs produced, to monitor inventory levels, to schedule equipment and manpower deployment, and to monitor and assess equipment heath. Controls and computers are required that can withstand the vibration shocks, and the moisture and dust conditions experienced by most harvesting equipment. With these controls in place on our equipment, the mechanical condition of components can be tracked and diagnostic tools developed to make repairs.

Advanced materials should be examined to determine their potential for reducing the weight of heavy objects (such as blocks and wire rope) that must be hand-carried into the logging setting, and to replace hazardous asbestos brake compounds. Instrumentation is needed to accurately predict the payload capability of cable-yarding machines and skidders, and complementary devices are needed to predict the weight of logs that are felled.

High Technology Examples

Before I finish my presentation, I want to review three examples of high technology either being developed or in use in the forest harvesting sector. While these examples show FERIC's involvement in high technology development, Forintek and Paprican have similar projects that move high technology from university and industrial laboratories to the Canadian forest industry.

In the 1970's, several organizations were examining concepts that might replace high-cost heavy-lift helicopters with alternate, less-costly vehicles. one concept that evolved was the hybrid flying vehicle that combined the aerostatic lift of an airship with the aerodynamic lift of an airplane. The first model developed was the Aerocrane. It consisted of four rotor wings with tip-mounted engines projecting from a rotating spherical balloon. The Aerocrane load designed to have 50% of the payload weight supported by aerostatic lift from the balloon and 50% by aerodynamic lift from the rotating wings. When tests showed the drag produced during forward flight would make it impractical for logging application, the inventors turned the Aerocrane 90 degrees and rotated it around a horizontal axis using the winglets for lift and the rotors for forward thrust. This was the Cyclo-Crane.

In 1979, construction began on a working model of a 1.8-tonne lift experimental Cyclo-Crane. The project was financed by five B.C. forest companies and FERIC coordinated the initial project. A windstorm in 1982 destroyed the first model before testing was finished. A second model was constructed and tested in 1984 under the sponsorship of the United States Forest Service. Unfortunately, the downturn in the forest industry in the mid 1980's prevented any further involvement by the B.C. forest industry. The Cyclo-Crane has been taken apart and work is progressing on a third concept. As the need to access our total forest resource draws closer, the hybrid flying vehicle concept will one day become a vehicle for extracting timber.

The second cooperative project involves the University of British Columbia's Telerobotics Laboratory. In the late 1980's, the Telerobotics Laboratory, in conjunction with MacMillan Bloedel Research and RSI Research and operating under an NSERC grant, had demonstrated that a hydraulic excavator could be telerobotically controlled with subsequent operator training, safety, and productivity benefits. Telerobotic controls differ from conventional controls where separate controls manipulate individual joints or rotation points to indirectly position the attachment. Resolved motion controls allow the operator to use one control to directly position the attachment, while an onboard computer position all the joints needed to place the attachment at the desired location.

The demonstration of the resolved motion controls on the hydraulic loader interested FERIC's member companies in the Interior of British Columbia. They saw the new controls as a way to increase productivity of fellerbunchers, and decrease operator training times. Consequently, a proposal was put forward to take this technology from the University of British Columbia's Electrical Engineering laboratory to the precommercial stage and demonstrate it to the industry through field testing. The organizations financially supporting this proposal are the B.C. Advanced Systems Institute; Finning Ltd.; Industry, Science and Technology Canada; University of B.C.; PSI Research Ltd.; Western Economic Diversification; and a consortium of FERIC's Interior members. The project proposal is currently being finalized. We expect to install a FB200 Feller-Buncher in our work area early this summer. We expect to demonstrate the telerobotic controlled feller-buncher during next winter's logging season.

My final example is the Saftety Link which is a safety tool, jointly developed by FERIC, Talkie Tooter and MacMillan Bloedel that is now available for fallers. The B.C. Science Council funded the initial development. The need for this device arose because fallers must work apart from each other, yet if they are injured, assistance must come quickly. The result is a belt-worn device carried by each faller, that monitors the signals from his partners' device. When inactivity is monitored for more than three minutes, or when one faller goes out of range of the other, the device will signal the partner through an audio signal. The Safety Link is now marketed and available to all fallers.

Conclusion

High technology is not new to the forest industry. However, the future profitability of the industry will demand continual investment in new technology. Successful development will be achieved with partnerships between users, technology experts, manufacturers, research institutes, academic institutes, and funding institutes.

A View From the Equipment Industry

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As my experience has been with a Vancouver based company which designs and manufactures machinery for the Sawmill and Panelboard Industries, my presentation will be from that point of view. Although some of the problems I will discuss are particular to British Columbia, generally what I see for the future will apply to most machinery suppliers in Canada.

For there to be a future for the manufacture of forestry machinery, companies will require two main ingredients. We will require "State-Of-The-Art" designs and will have to be competitively priced. Although these two ingredients are intermixed I intend to try to discuss them separately.

Firstly, why and how do we obtain "State-Of-The-Art" designs? The why is easy to answer. As logs become more precious and labour costs rise, as we have seen, mills will continue to need to be more efficient to survive. The demand locally in B.C. and the Pacific Northwest will continue to look for sophisticated products. This demand will continue to expand.

Due to high labour costs relative to the rest of the world, there will be little future for a supplier trying to sell a "me too" product which is not keeping up with the times.

As sawmill machinery becomes more sophisticated, both mechanically and control wise, it is becoming increasingly difficult to find qualified personnel to not only design products but to sell them with competence. For this reason, and others, as I will mention further into my presentation, it will be important to find a niche to specialize in, and develop the required expertise to support it. Any patenting of designs is advantageous as a protection from competitors.

The business of supplying machinery to the sawmill industry is extremely competitive. There is usually not a lot of capital available for Research & Development projects. Most companies, like CAE Machinery, spend most of our Research & Development capital on development work. I class development work as making changes to existing product lines, sometimes small changes and sometimes large, but always based on existing products. This work tends to be customer driven and generally results from feedback from our sales and marketing people. This type of R&D is relatively easy and readily accepted in the market place, as the changes are seen as having low risk. For this reason the payback is fairly quick, as long as enough of the product can be sold.

To keep on the leading edge of technology, more than this is required. There also needs to be the research required to develop some of the products we have heard about in the last few days; the products that would make the forestry sector more efficient, but are presently unavailable. Internal log sawing solutions and automated species sorting are good examples of such technology.

These projects usually take a long time and are too expensive for most equipment suppliers to develop on their own. So how can this be obtained? One method is for long term Government funding to equipment manufacturers for research on such projects. There are some funding programs currently available but they will have to be more extensive if this type of research is expected to be undertaken at the equipment supplier level. I am not convinced this is the best course of action. Possibly another option, through partnerships, would be more successful.

I will only mention this alternative briefly as we will hear later this afternoon from a speaker on this subject alone. From my experience in partnerships there needs to be three parties involved, the research organization, which does the long term work; the manufacturer, who develops and commercializes a product; and the user, who will test the prototype models. This process from concept to final product can be very expensive. There are dead ends on some projects and they will not proceed to completion, with none of the costs being recoverable. In this case, none of the three partners will gain much. On the other hand, if the project is successful the manufacturer has an opportunity to make some money in selling more of the product; the research organization will get some payback, usually through royalties on future sales of the product. The end user will have the opportunity to be the first to benefit and generally be a more efficient operator. If, however, the product developed is greatly superior, other mills will soon have purchased the new product and have it operating, no longer leaving the original test mill with an edge. So in other words, there is very little encouragement for an end user to get involved in such projects. From this perspective there appears to be little incentive for the end user to participate.

Funding must be available in some form to help support the end user. Sawmills are having tough times these days and, understandably, are not prepared to make major changes to their mill for testing, or to have extensive down time while working with prototype equipment. A suggestion has been made for government bonding. The partnership would pay a fee to the government for insurance on the value of the project. If the project were to fail, the partnership would be repaid the insured amount. This would help failed projects but does not help the end user with successful projects. And after all, when we begin these projects, we all believe they will be successful.

A Finnish company we have a cross licensing agreement with had their own sawmill where they were able to test their equipment. We have been jealous of this opportunity. Perhaps a government owned demonstration sawmill, which was designed for such a service, would be a viable option and it could be rented for a nominal fee.

Another aspect of "State-Of-The-Art" design which is becoming more and more difficult is the ability of engineers to keep up to date with new products and manufacturing processes. In the past we have tended to rely on component sales people, catalogues, seminars, subscriptions to different technical publications, and general "word of mouth" with acquaintances and mill personnel to keep up to date. The opportunity for self education is also somewhat limited. In B.C., where there is no large manufacturing sector, designers do not have many opportunities to attend manufacturing trade shows as they are not usually held in this part of the country. Today this method of collecting information is rather antiquated and will be more so in the future. A central agency which gathered such information and was accessible to Canadians could be a much more efficient way to transfer such information. I believe most designers would be prepared to pay for such a service. Forintek has developed their BAT system to access forestry related information. Perhaps this concept could be used as a basis for other information gathering systems.

Now, assuming we have come up with a "State-Of-The-Art" design, how do we ensure it will be competitively priced, or in other words, how do we ensure it will be of low cost so we will be able to sell the product profitably? To be competitively priced we must know who our competitors are and what their prices are. Presently, in Canada, we have strong competition from United States suppliers as well as Scandinavia, Japan, and Germany. There has been some criticism of Canadian sawmill equipment manufacturers not being competitive with European suppliers. Some of which come to mind are Linck, Ari and Uraken. I believe the prime reason for this is that in Europe, Scandinavia in particular, where the log supply is from plantation forests with very few species and which mature at relatively small diameters (30"), the mills all cut similar products and consequently equipment suppliers have had years to specialize in machinery for processing small logs. Equipment suppliers in Canada have been forced, due to the wide variation in tree size, species and different mill products, to supply a much larger variety of machinery. Small logs 15 years ago were processed on Chip-N-Saws, which were not of particularly high recovery. With the increase in log prices and the demand for increased recovery, these European systems have found a new market for their existing technology.

I believe Canadian manufacturers have the ability to design and manufacture such equipment, but up to this point, there has not been a large enough local market to make it viable.

Canadian manufacturers not only have to compete locally but have to compete on a larger scale, certainly this must include the U.S. and in many cases the world. Why can't we just compete in B.C.? Well, I believe the market area of B.C. is too small to support the R&D costs and expertise required to support the products in the future. By selling more of the same or similar products and increasing the volume for manufacture we will reduce costs on a per item basis and get better utilization of our expertise. Our technical and sales personnel become more competent as they are able to sell more of the same product and become experts.

As we move through the manufacturing process, there are savings in purchasing with the opportunity to purchase large quantities at discounted prices, there are also very large savings on the shop floor. In our fabrication area it takes the same time to burn five items as one with a multihead burning table which has five heads. In the machine shop, set-up time is reduced on a per item basis if more then one item is manufactured at one time. Shop personnel become more familiar with the product and their efficiency goes up. There are less errors and questions, which all result in higher efficiency.

Also, by focusing in on one type of product it enables the manufacturer to purchase dedicated machine tools to manufacture the parts efficiently. A few years ago we purchased a four axis machining centre, it presently operates 24 hours a day, five days a week manufacturing large quantities of two items for our flaker product. Previously we manufactured the parts on conventional machine tools. Table I shows the differences in the number of setups and time it took to manufacture one of the parts. As you can see, there was a 34% reduction in time which is a substantial savings. The parts are also manufactured more accurately and repeatability is excellent. CadCam also becomes much more viable if quantities and similarities of parts exist. This will also reduce engineering time and costs as well as the errors in re-entering drawing dimensions. This gives much more flexibility to the designer to include better designs if machining accurately will not be of additional cost. But again, he needs to be educated to know the capability of new machine tools so he can design efficiently.

Knowing that manufacturing larger volumes will help efficiency, how do we go about obtaining volume supply? As I have mentioned, enlarging market area is one way to obtain an increase in volume. But one must ensure a large market is available. Assuming there is a correlation between lumber production and a need for machinery, a look at lumber production will give an idea of available market. Table II shows the 1991 production of soft wood lumber for areas in the U.S. and Canada. But caution must be taken, as the same machinery is not always required in different areas. If the competition is not strong in the niche we have chosen, we may be able to increase our market share through increased sales effort. Partnership alliances with others in the same business, but not direct competitors, who are established in other areas could be another option. By reducing cost, demand for your spare parts also increases, reducing the attractiveness for "pirate shops" to take this business.

Another problem that B.C. manufacturers in particular are going to have in the future is our high labour rates. At CAE we are presently able to purchase fabricated and machined parts from a company in Oregon for approximately 30% less than our cost. We have an hourly rate for our machinist of $21.65 per hour. This is not attractive when compared with $16.00 - $18.00 in Quebec and $14.00 - $15.00 in Oregon. We, in Canada, need to be competitive outside our own country. I do not believe the quantities of equipment required in the forest industry will be large enough that we will need to be concerned with very low cost manufacturing areas such as Mexico and Brazil in the near future. When I am speaking of large quantity of supply, I am talking of machinery quantities in the 50 to 60 units per year for sawmills. As I mentioned, this equipment will be sophisticated and will require skilled personnel not presently available in these low cost areas to manufacture and assemble. But certainly, many of the United States and other industrialized nations will remain competitors as they have the required skilled tradesmen. As time progresses and free trade becomes a reality, we may find countries such as Mexico who are able to competitively supply the quality for mass produced components we require.

Also, the manufacturing industry needs to be taxed equitably. Presently, Canadian companies often have a portion of their cash being held by the federal government while awaiting GST rebates. This results in a loss or reduced profits. In B.C. there has been the reintroduction of a Corporation Capital Tax of .3% on paid-up capital over $1 Million, and also Provincial Income Tax will be increasing from 15% to 16% in July. Federal Income Tax is 24% for public manufacturing companies. These taxes all effect cost of goods produced and if our competitors do not have similar costs, as is presently the case in some of the neighbouring states in the U.S., it is difficult to compete.

In summary, for Canadian equipment suppliers to be successful as we move towards the year 2000 we:

1. Must become more competitive with manufacturing costs.

   Some ways to realize this are:

   - manufacture more quantities at one time.
   - dedicated machine tools.
   - labour and tax rates.

2. Must have "State-Of-The-Art" designs in niche areas. This will be accomplished through commitment to Research & Development. For this to be accomplished, there will have to be government support for projects from inception through to commercialization.

3. Must keep our work force educated so we can take advantage of the most up-to-date materials, processes and machine tools to allow us to be as efficient as possible in design and manufacture.

TABLE 1

FLAKER PART MACHINING COMPARISON

OPERATION	CONVENTIONAL MACHINE TOOLS	MACHINING CENTRE
Machining Operations (Set-ups)	13	5
Average Time Per Part	6.58	9.94
Repeatability	Fair	Good
Machining Finish	Fair	Good
Accuracy Control	Difficult	Easy

TABLE II

1991 NORTH AMERICAN SOFTWOOD LUMBER PRODUCTION

REGION	PRODUCTION (billion board feet)
British Columbia/Alberta	14
Eastern Canada	7
North Western United States	9
South Eastern United States	12
Inland United States	10

Ref: Markets 91: The Five-Year Outlook for North American Forest Products. Widman Management Ltd./Forest Industries.

The Changing Role of Information Technology in the Forest Industry

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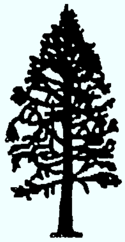

As we have seen in this conference, information technology affects all aspects of a modern enterprise. Some aspects of information technology are already well understood and widely applied, but others, which are just emerging, promise to be revolutionary in their impact. Computing resources were once isolated islands, separated from mainstream mill activity. MIS computer systems managed inventory, order-entry and scheduling; and limited-function computers controlled certain mill equipment. These islands of information technology have expanded and become interconnected. Mill equipment is now almost all computer-controlled; these computers share information with each other over industrial networks, and connect with the MIS systems for more effective monitoring and data analysis; computing is now mill-wide. The move today is to expand into enterprise-wide computing, with local and remote systems in complete and constant communication.

Information technology is the key to linking disparate but related functions in a contemporary business enterprise, whether forestry-related or not. Information technologies are also transforming and redefining how the functions of an enterprise are carried out. These transformations are affecting the large-scale organizing aspects of business as well as the day-to-day activities of individual technology users.

Some of the Major Roles of Information Technology:

1. Scientific/Engineering Analysis
2. Information Management
3. Communications

- Simulation of Processes and Structures
- Controlling Machinery and Industrial Processes

Scientific/Engineering Analysis

Apart from accounting functions, scientific analysis was once the predominant application of computer resources in industry and research. The demands of scientists and engineers were so rigorous that, until recently, only mainframe computers or minicomputers, were considered adequate for the task. Timesharing of precious and expensive computing resources was once a way of life. As a result, the software which was used for analysis was designed to use the minimum of computer resources, and therefore required considerable training and expertise from a user.

What was once mainframe capacity is now available on the desktop and the entire CPU is now at one individual's disposal. With the introduction of networking and data exchange standards, it is now possible for engineers and scientists to share data with other networked computers. Central computing facilities are thus no longer required to support a mainframe computer - they have often switched their function from being the keepers of the CPU to being the storehouses of data which is shared by everyone on the corporate information network.

Information Management (MIS)

Possibly the most traditional role for information technology in the business world is that of data management. This field has taken advantage of the dramatically increasing power and shrinking size and price tag of computers just as scientific and engineering users have. More, advanced, off-the-shelf software and better human interface design have increased the scope of MIS systems and permitted more wide-ranging analyses of data than previously. With plant-wide and enterprise-wide networks becoming more and more common, the breadth and availability of data is increasing. Up-to-the-minute information on inventory, shipping and mill activity can now be made available to all segments of a company, permitting rapid and accurate decision-making at all corporate levels.

The management of information is taking a new direction with the development of expert systems and reasoning technologies. In this field, the rules and relationships that make up expert knowledge of a subject become data to be analyzed, managed and put to use. With expert systems in place, complex decision-making can be made easier, with intelligent assistance founded on a database of the rules used by the appropriate "experts." The area of expert systems promises to have an impact on all computer users in the next few years. Just as changes in human interface design have affected every computer user, the innovations in computer reasoning technologies will be felt everywhere.

Communications

Communications technologies have significantly impacted even the smallest businesses. Inexpensive and affordable distributed computing environments are everywhere. There are local area networks in the office--sharing data, sending electronic mail and using common printers. In the plant, there are data highways logging information, transmitting alarms and permitting computer control of programmable control devices. Ever-simpler and more robust networks are allowing computer intelligence to be distributed to the sensor and actuator. Wireless data communications, already in limited use, will allow workers to interact even when moving around or while at remote sites.

We can only expect the progress in reliability and affordability to continue. Interconnectivity of systems will also increase. Forestry, with its dependence on transportation, will benefit tremendously from current trends in communications and easy data interchange.

Simulation of Processes and Structures

Computer simulation is the mimicking of structures, devices and processes. This technique is already a powerful tool for product design. If a design can be tested in the computer, before a physical model is produced, tremendous financial advantages can be gained: a design failure is far less costly if the failure is discovered at this early stage because modifications can be made within the computer simulation at little or no cost. As powerful visualization tools become readily and cheaply available, computer simulation will become commonplace for process control as well.

Controlling Machinery and Industrial Processes

Computerization has drastically changed the controls industry. "Soft" controls are much easier and less expensive to create and modify than hard-wired controls systems. Networking has provided intercommunication between devices and sensors and controllers. Applying computers to control will continue to become easier and more effective, as well as more reliable.

Human-Machine Interface

The area of human-machine interface affects all aspects of information technology. The power of technology can only be harnessed when ordinary people can understand and use it. The methods of communicating with a computer have come a long way from the punch cards and paper tape of not so many years ago. The empty screen with a DOS prompt is still fresh in many of our memories.

The use of graphical representations of information, which began with the desktop paradigm more than a decade ago, has expanded into on-screen control consoles, using abstract representations of real items like knobs, gauges and buttons. These developments have been widely accepted, and will improve as display and input technologies advance. Voice input and output is also gaining acceptance in specialized applications, such as voice mail and voice menuing, and applications for the handicapped. And user input, too, is moving away from keyboards, and towards input methods that require less dexterity and training: the mouse is already in common use and newer developments are specialized touch screens, voice input and pen-based computing.

The area of human interface design is still developing, and shows tremendous promise in making information available to the untrained and unskilled, as well as in increasing the productivity of the skilled professional.

The Forces of Change in information Technology

We are currently witnessing an enormous yearly increase in the power of microcomputers and a similarly large reduction in the size and cost of the memory they use. These cost reductions, plus market demand, are turning high performance personal computers into commodity items.

At the same time, a few operating systems environments have dominated the marketplace. And, due to the large marketplace that has been created, the very sophisticated software that has been created for these systems is being sold at commodity prices.

In addition, new software techniques such as object-oriented programming are changing the software development methodologies we use and allowing us to create more elaborate products, more quickly. Integrated programming and development environments are becoming commonplace. In the near future, new control technologies such as fuzzy logic, expert systems and neural nets will become practical and widely applied.

Many of these changes, which affect all of information technology, are being driven hard by the personal computing market. The low-cost, standard PC hardware and PC operating systems (DOS, OS/2, Windows NT), are creating a competitive market of stable, proven software and hardware, which benefits everyone from developers to users of the technologies.

Conclusion

Information technologies provide the potential for very significant increases in productivity in all industries, among them the forest industry. The rate of change over the past few years has been tremendous, and, rather than decreasing, is steadily increasing. For the users and providers of information technologies, there are many opportunities for tactical business advantage.

The National Research Council and Advanced Technologies of Interest to the Forest Products Sector

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Canada

Good morning, and thank you for inviting me to speak at Forest Sector 2000. This morning I will address the subject of research in advanced technologies at NRC and how it applies to your sector. I will also talk about how we use partnerships to transfer new technology to industry.

At the National Research Council, we are firmly committed to developing partnerships as the most efficient and effective way to transfer knowledge on new technologies and processes to Canadian industry. In fact, partnerships are at the heart of our long range plan called "the competitive edge". Partnership with industry is also central to NRC's Resource Technology Program and to a proposed new initiative in industrial machinery research. I will discuss these later.

NRC has been in the engineering research & development business for a long time. For example, at the Institute for Information Technology, we carry out research in information systems and software, helping Canadian companies achieve excellence in this area. Today I will show how, given this expertise, NRC contributes to the competitiveness of your industry.

Canada has a wealth of natural resources. Its resource sector generates a good portion of the country's export earnings, and will continue to be an engine of growth for many years to come. The Canadian forest products sector alone represented approximately four percent of the nation's gross domestic product, or $49.1 Billion, in 1989. In the same year, the forest products sector spent only $188 million on R&D, which amounted to four tenths of one percent of sales, well below the national average. The sector seems to have taken the benefits of science and technology for granted by putting very little back into research and development.

As noted by Michael Porter, Canada has an extraordinary opportunity to continue to build on its resource endowment. But this will not happen without a serious investment in R&D. I am encouraged by conferences such as these, because they signal a change of course in this regard, and a commitment to new technology development.

NRC is Canada's premier R&D organization. In partnership with industry, it helps Canadian firms increase their technical capabilities, improve productivity and develop new products. Whether working with individual companies or in groups, we bring our expertise to work on new materials, or in developing new processes and technologies. NRC accounts for about 10 percent of federal expenditures on science and technology. We currently have an annual budget of more than $400 million with over 3,000 employees working in sixteen research institutes across the country.

As a consequence of our long range plan, NRC recently restructured its operations to facilitate partnerships with industry. Six of our sixteen institutes are completely new, and all sixteen are now focused on specific fields of science and technology. A variety of structures have been put in place to stimulate interaction between our laboratories and the private sector. This includes business offices in most of our sixteen institutes, a corporate marketing service which is sector-oriented and special initiatives such as our resource technology program. NRC's Industrial Research Assistance Program, or IRAP, offers on-the-spot advice and financial support to companies who are introducing innovative products and processes. IRAP offers different types of assistance, depending on the company's size and on its needs.

Through the IRAP network, companies can expect direct delivery by technically qualified and experienced staff. NRC also provides firms with the services of CISTI, the Canada Institute for Scientific and Technical Information. CISTI is Canada's largest library of scientific and technical information, and is one of the most heavily-used collections in North America, handling about 450,000 requests for information each year. Through CISTI's on-line information service, firms can access information directly through their desktop computers.

NRC is committed to providing Canadian companies with the technological edge they need to compete and succeed in the 1990's and beyond. Our objectives are threefold:

- to strengthen our world class research in order to provide the crucial base of knowledge and expertise needed to support NRC's clients and partners,
- to build partnerships with industry, government and universities to ensure that our programs complement those of other performers, and contribute to industrial development, and
- to help sharpen Canada's competitive edge by emphasizing key areas of research where we can become world leaders.

Meeting these ambitious goals, particularly at a time when resources are difficult to come by, requires focusing our work on those areas where we can make the most impact. This commitment is at the heart of our current long range plan, entitled the Competitive Edge. This plan commits us to building partnerships with Canadian firms in all sectors of the economy. We involve Canadian companies at the front end of the decision-making process, to ensure that we conduct commercially-relevant R&D. Each of our institutes has industry-led advisory boards which make recommendations relevant to our strategic planning. We hope this symbiosis between industry and NRC will pay handsome dividends. Indeed, our objective is to double, by the year 2000, the private sector investment in R&D stimulated by our activities.

The Engineering Programs office, which I oversee, manages three sectoral programs: the Resource Technology Program, the Transportation Technology Program and the Public Security Program. I will explain the first program, as it appears to affect your sector the most.

In 1989, we established the Resource Technology Program to focus on the technological needs of the minerals, petroleum and forest products industries. This program is an important point of contact between your industry and NRC. Most of the work coordinated by the Resource Technology Program is carried out in collaboration with Forestry Canada, Paprican, FERIC, Forintek and other research organizations. The Resource Technology Program's current emphasis is on resource machinery, instrumentation and engineering consulting. I suspect this corresponds to the dominant interest of this audience. We believe your companies add value to the resource sector, particularly through application of "specialty" technologies. This is the area in which NRC specializes.

In many areas, NRC is at the cutting edge of emerging technologies that contribute to national competitiveness. To ensure that we can respond to competitive challenges, we have initiated a comprehensive assessment of Canadian needs for engineering R&D. This study will form the basis for future plans for the structure, focus and direction of NRC's engineering sector.

In conjunction with this engineering sector assessment, we are developing a proposal for a new NRC engineering institute with particular relevance to your sector - an institute dealing with machinery research.

The purchase and repair of machinery represents significant costs to Canadian industry -- roughly $73 billion in 1990. In your sector alone, nearly $8 billion dollars was spent on capital expenditures and machinery repair in 1990. Needless to say, improvements in machine design, operation, monitoring and maintenance would result in substantial savings to your industry and would contribute to national competitiveness. We already have some world class machinery expertise at NRC. The proposed institute would bring to the table further knowledge in newly emerging technologies such as mechatronics and computer prototyping. Within three years, it is proposed that the institute would comprise nuclei in most facets of machinery technology, from "specification to salvage".

The requirements of industry will largely dictate the R&D program of the new institute. Discussions with industry associations, as well as individual companies are being held to determine the current needs. The feedback we are receiving clearly points to research aimed at problems, such as:

- automation
- process control & scheduling
- monitoring for maintenance
- sensors

The word for describing this new technology is mechatronics.

The institute would encourage extensive interaction with industrial partners and other participants in the research community. For example, visiting researchers and industrial secondments would make up half the personnel at any one time, and the institute's activities would be guided by an industry-led advisory board reporting to me. Two thirds of the institute's resources would be directed to cost-shared, near-term, industrially-defined problems. This is the concept we are working on. As we are developing this idea, I would invite your reaction and guidance as to how such an institute could be made most relevant to your companies' needs.

It is widely accepted that information technology and automation -- or systems technology -- is crucial to the competitiveness of the forest products sector. Canada has one of the most innovative forestry-related software and instrumentation supply industries in the world. NRC has developed expertise in such areas as artificial intelligence, software engineering, systems integration, 3-d vision systems, photonics and opto-electronics.

In a speech last january, Janice Moyer, president of the Information Technology Association of Canada, described five benefits that can be derived from investing in information technology and automation. These benefits are especially relevant to the forest products industry because of the scale and complexity of most forestry operations. I would like to review them, because they illustrate the extent of NRC's capabilities and the diversity of our interactions with the Canadian forest sector and its high technology supply community.

The first benefit resulting from investment in information technology is the increased ability to perform tasks more quickly and accurately, resulting in reduced operating costs. NRC's Institute for Information Technology is working with several forestry companies on a number of R&D projects aimed at developing computerized decision-support technologies in pulp and paper mills. Projects under consideration include energy cost reduction in boiler operations, hydroelectric use, and the examination of steam and condensation problems. If the initiatives succeed, not only will the participating companies have access to systems developed to their needs, but automation companies will have a range of new technology products and services to sell.

Quality enhancement of existing products is a second benefit that can be derived from systems technology. In collaboration with Forintek, for example, our Institute for Research in Construction has been developing mathematical models to predict the fire resistance of wood-frame assemblies. A new three-year project has been created to develop computer models to assess the cost of fire safety features in larger wood frame commercial buildings.

In both projects, the purpose is to examine changes to the national building code which could lead to increased use of wood in multi-storey commercial buildings. The ability of systems technology to create entirely new products is a third benefit. This is an area -- new wealth creation -- where NRC can play an important role. For example, our Institute for Information Technology, in partnership with FERIC and a major forest company, is adapting NRC's patented 3-D laser vision technology to forest de-limbers and loaders for automated log scaling. Scaling is done by hand at present. Automating the procedure would contribute to the development of in-the-field electronic wood inventory control. Jacques Domay spoke of this 3-D vision application in forestry during the opening session yesterday morning. We are negotiating with a forest machine manufacturer to further develop this technology.

The road to the development of new systems technology products is not always as direct as in the case of the 3-D laser vision application. NRC's involvement in the development of the automated species sensing device that Ludo Daubner of Barringer will describe later today is a case in point. A few years ago, NRC was asked by New Brunswick forestry officials to develop a means of tracking the spray drift during their spruce bud worm spraying. Our development of a trace vapour detection technology was so successful that Transport Canada asked if it could be modified to detect bombs. This gave rise to our famous bomb "sniffer", which is now being produced and exported by a Canadian instrument manufacturer. Forintek recognized the potential of this technology for wood species identification in sawmills, and proposed a joint project to develop such an application. Forintek is now building a prototype with an industrial partner and NRC continues to serve as technical adviser.

NRC and the U.S. Department of Agriculture are now collaborating on a "sniffing" device that will identify at an early stage wood that has been attacked by bacteria. NRC and Swedish partners are working on a similar project to identify wood that has been damaged by fungi and other diseases. Thus our collaborative efforts may result in a variety of new sensors that could have a positive effect on your operating costs, and the spinoffs in terms of new Canadian products could be considerable.

The 4th benefit of information technology is the enhancement of strategic management. Some of you may have heard the term "management velocity", which describes the increasing rate at which managers must respond to new challenges. Systems technology has considerable potential for supporting rapid managerial decision-making. Our Institute for Information Technology has a strong track record for developing computerized decision-support technologies for the resource sector.

I have already mentioned the pulp mill decision support consortium in which the Institute for Information Technology is involved. Another ambitious project in which it is now involved is PROGERT (Projet de Recherche pour l'Observation et la Gestion des Ressources Terrestres). The purpose of this $30 million, five-year, Quebec-based R&D effort is to develop systems products and services for forestry in the area of remote sensing and geomatics. The eight-company consortium hopes to construct a visually-interactive computerized decision support system for the development of short and long-term forest harvest plans. Such a system would add "velocity" to the work of the forest engineer when it comes to preparing harvest plans and related environmental review documents. In this case, our institute for information technology and our Institute of Mechanical Engineering will contribute expertise in the areas of systems integration, object-oriented programming and symbiotic computing techniques.

Dilip Kotak of NRC will describe PROGERT and our other forest management initiatives later this morning.

Finding new ways of thinking about problems -- the 5th benefit outlined by Janice Moyer - is NRC's strong point. As I pointed out earlier in relation to wood "sniffing", the development of new technology often forces us to see problems from a totally new perspective. It is a long way from military jet engines to pulp and paper equipment, but one of our knowledge system engineers, Aurora Diaz, provided another example yesterday of how NRC can bridge the gap. Working with PAPRICAN, she and others at the Institute for Information Technology hope to transfer software expertise developed for military jet engine diagnostics to the pulp and paper sector.

I would not want to leave you with the impression that our contributions to the forest sector and its service industries stop at systems technologies. I am equally proud of NRC's contributions to the forest sector in the areas of mechanical and environmental engineering. FERIC and NRC's Institute for Mechanical Engineering have recently reached a tentative agreement on a project to enhance the stability and control characteristics of logging trucks. This project will produce benefits which will meet concerns for industrial safety.

The forest products sector generates enormous amounts of heat -- to dry newsprint, for example, -- at considerable cost. Little of this heat is recovered or re-cycled before being vented. Our Institute for Mechanical Engineering has developed technology to generate high quality steam using industrial heat pumps, with environmentally acceptable refrigerants. We calculate very high coefficients of productivity for this technology in paper mill applications.

The institute is currently negotiating with several industrial partners, including a pulp and paper machinery manufacturer, with the goal of building a full scale prototype. The resource sector is an enormous potential user of environmental technologies. Certainly, there is no lack of environmental challenges being faced by our forest products sector today. But these challenges are also an opportunity to develop new environmental products and services. NRC has considerable strength in this area. Through a number of our science institutes, and in partnership with your own research organizations, NRC hopes to make a significant contribution to resource-oriented environmental technologies. For example, we are now developing methods to treat pulp and paper effluent using membranes. NRC's Institute for Environmental Chemistry has recently concluded an agreement with a forest company, a major forestry consulting engineering firm and PAPRICAN. The institute is contributing its thirty years of experience.

NRC's Biotechnology Research Institute and our Institute for Biological Sciences share a history of industrial collaboration relating to the biological treatment of pulp and paper effluent. We are hoping to scale up our activities in this area in concert with PAPRICAN over the next few years. By this means, we hope to help the pulp and paper business meet the stringent regulations that have been developed in this area. We plan to develop strategies and treatments for recovery and re-use of de-inking rejects, and for the safe combustion of the remaining de-inking rejects. I should note that we are currently seeking industrial partners to commercialize the results of most of these initiatives in 1988, the Canadian Council of Forest Ministers (COFI) recommended that NRC make a greater commitment to forestry-related R&D.

I hope that my remarks today have convinced you of the strength of our commitment to your sector, and particularly to its related high technology supply industry. Unfortunately, time does not allow me to describe the full spectrum of forest-related projects at NRC. However, you should know that NRC technology relevant to your needs extends well beyond the domain of computers, engineering and the environment. These technologies can do much to improve the productivity, safety and new product development.

Working with our partners at PAPRICAN, FERIC, Forintek and Forestry Canada, NRC is willing to act as a research catalyst, but our resources like yours, are limited. Partnerships between NRC, the high technology supply community and you, the users of this technology, are absolutely essential, if Canada is to maintain its position as the world's most important forest products exporter. I want to assure you that, whatever form these partnerships will take, NRC is ready to play its part.

The Potential of Partnerships: Problems and Opportunities

G.M. MacNabb
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Mr. Chairman, Ladies and Gentlemen;

While I have undertaken many speaking engagements over the past 30 years this is the first time that I have found myself as the concluding speaker of a three-day conference and with a start time well after the last flights to the rest of Canada have left the Vancouver airport. However, while the potential audience may have eroded somewhat, speaking in this time slot has a few advantages. Perhaps the most fitting analogy is to someone riding in the caboose of a very long train (forgetting the fact that the caboose is now an endangered species). One has the advantage of being able to look ahead and to see the twists and turns and the challenges that others have already faced and how they have fared, and, of course, being able to look back down the track with perfect 20:20 hindsight, a position normally available only to auditors and evaluators.

However, that analogy begins to pale or even sting somewhat when you realize the limited power of a conductor riding the caboose. His, or her, options are in fact very limited. The course itself has already been set and cannot be altered; one can only influence the speed at which one achieves the inevitable destination. The other option is, of course, to stop the train and get off; a modest version of "stop the world I want to get off"; a philosophy that beckons with increasing attractiveness as my age creeps up and as the frustration levels of my particular voyage mount.

What in the world, you say, has this got to do with the announced subject matter of my talk today: "The Potential of Partnerships: Problems and Opportunities". Well it has a degree of relevance because during my efforts to produce partnerships of various types I have perhaps shared the same type of frustration felt by the conductor who sees the need to change direction, and advantages of such action, but is powerless to do so. In my case, of course, when I have failed to convince an individual or a company of the benefits of research partnerships, ours in particular, I have the luxury of being able to turn away and to try again on another day. That, however, has not lessened my level of frustration over our collective hesitancy to change both industrial practices and government structures so as to deal more effectively with a global business environment that, itself, is changing at a faster and faster rate. Needless to say I am an advocate of greater partnerships and it is within that context that I want to address, in particular, the last of the four objectives of this Conference: "explore the barriers and solutions to the application of the most sophisticated technologies to the industry". Over the past three days you have heard a great deal about such technologies from a wide range of experts in the relevant fields of science and engineering. Every area covered has related to intelligent systems of one form or another and their potential for improvements in all phases of the forest industry. It should not surprise you, therefore, that I have listened with particular interest in my capacity as President of an industrial consortium managing a $60 million research program in intelligent systems and robotics, a consortium with almost 40 industrial members, but with not one from the forest industry of Canada. Surely after these three days you don't need any more convincing about the relevance of these technologies to this industry. We seem to have an abundance of applications and solutions, but we also seem to have some major barriers to be overcome if the real potential of the technology is to be realized.

You will excuse me if I use PRECARN as an example of the type of partnership required to achieve that optimum potential. Needless to say, I have come equipped to talk about that particular experience, its problems and its potential. I acknowledge fully the joint activities underway in other technological fields, but, given the thrust of the presentations at this Conference, an assessment of an intelligent systems research partnership appears warranted.

I won't burden you with the background of PRECARN and what it was that motivated a group within the private sector to set up this collaborative research effort during the period 1986 and 1987. Suffice to say that we saw an excellent capacity for fundamental research in Canada in this particular field, but a major deficiency in our collective capacity to use the results of that research in Canada. Accordingly, we set out to bridge that gap between fundamental research and the much shorter term research efforts of industry. We focused therefore on a collaborative effort of university and industry personnel at the precompetitive stage of research.

I will skip over the barriers we faced during the start-up years and talk about where we now stand, the results and benefits being realized, and the residual problems we face. The membership of our particular partnership now stands at 38 (Figure 1). It is an interesting partnership to say the least. It is far from being sector-specific; it has more users of technology than it has producers; it involves provincial and federal government research agencies; and it involves government departments in an "associate", non-voting capacity. What is not shown here is that all of our projects must also have the active participation of university specialists. What we **don't** have, as I mentioned earlier, is any representation from the forestry industry per se.

What are the benefits of this particular partnership? (Figure 2) All of our members, whether they are active participants and investors in a project or not, get regular briefings on the whole of the research program; they all get royalty-free access to intellectual property developed from projects commenced after they have joined (there is a sliding scale of royalties for projects commenced before membership); and they get regular briefings on, and preferred access to, the research results of the Institute for Robotics and Intelligent Systems (a National Network of Excellence administered by PRECARN). The subset of our membership actually involved in our projects get the added benefits of designing the research program, being aware of the results well before other members, testing the results within their operating environment, and getting a share of any third-party royalties. In return, of course, they share the results of their research with other members. This willingness to share is a unique feature of PRECARN that most other consortia have been unable to accept. It is also a real test of the precompetitive nature of the research effort.

What should be stressed at this point is that all members get the advantage of a highly-leveraged research program given the distribution of the investment among the various participants and the significant level of government support. More about that in a minute.

Many partnerships have got hung up on the question of ownership of intellectual property. The Alvey program in Great Britain is a good example. PRECARN is not concerned about the ownership issue. (Figure 3) If provincial government funders wish the participating companies from their province to own the research results we are agreeable and two of three provinces have followed that route. What PRECARN does insist upon, however, is that in every case PRECARN has royalty-free rights to any and all intellectual property developed and the ability to pass that IP on to our membership in accordance with our policy on access to research results. The right to use, rather than the right to ownership, is the key factor, and, as a result, we have three provinces supporting our research and agreeing to have the results available royalty-free to companies across Canada. In this balkanized country of ours that is a major achievement!

Now let's look at the benefits of leverage. (Figure 4) PRECARN has four projects underway at the present time. The total investment over a five-year period is almost \$34 million. Thirty nine percent of that comes from the federal Department of Industry, Science and Technology, just under 7% from the National Research Council, 20% from provincial governments, and 34% from PRECARN itself and the participating members in the projects.

The leverage to an individual participant, however, is even greater. (Figure 5) For example, in our "APACS" Project the private sector participation of 37.1% is spread seven ways with the largest contributor donating just over 7% of total project costs. Such donations are usually in-kind contributions of the salaries of participating staff, overhead etc. We encourage that kind of real involvement rather than cash crossing the table to permit someone else to do the work.

This APACS project illustrates another benefit from the way we put project partnerships together. (Figure 6) APACS stands for Advanced Process Analysis and Control Systems and entails a five-year effort to develop a true state-of-the-art package for the analysis and control of continuous processes. In this case CAE is the probable candidate for the packaging of the resultant technology and they have four potential users of such a package already involved in, and influencing, the research program. The make-up of the team almost ensures effective transfer of the technology to the user community. We are not producing research results and then searching for user candidates.

Our IGI Project (Intelligent Graphic Interface) is another good example of this principle. (Figure 7) In this case MPR Teltech here on the West Coast is the most likely marketer of the resulting technology and they have possible customers working with them in the form of Shell Canada, TransAlta Utilities etc. In fact, this project is unique in many ways. For example, the first stage of the research program involved human factors research in the actual control rooms of TransAlta, Shell and Xerox Research and soon at Syncrude in Fort McMurray. With the approval of the control room operators and their unions, our research team analyzed their operating practices, the use of the existing graphic displays, and the real perceptions and wishes of the operators. Even before the research is done to produce more user-friendly and effective graphic interfaces, the project has produced benefits to the participants as well as a marketable service to other non-PRECARN companies. Again we see the benefits of a partnership involving users and producers of the technology.

I don't have time today other than to note that our other two projects now underway involve autonomous and telerobotic devices and that a fifth project now submitted for funding support is in the field of knowledge-aided design. In addition we have two feasibility studies underway, one led by INCO in mining automation and one in advanced robotics led by SPAR. At this point I should also note that in its first round of research proposals, PRECARN invested $100,000 in a feasibility study of research leading to a robotic platform for use on rugged and steep terrain. The leading university researcher involved was Peter Lawrence who spoke at the beginning of this Conference. The proposal was termed by one of the reviewers as the most advanced work in motion research underway anywhere and PRECARN was prepared to support it if sufficient private sector interest could be obtained, especially in the forestry sector. Unfortunately no such interest was forthcoming.

To complete this overview of one form of partnership in research I should mention once again the Institute for Robotics and Intelligent Systems or IRIS. (Figure 8) IRIS is the second largest of the National Networks in terms of funding and the largest by far in terms of the number of researchers involved from one end of Canada to the other. (Figure 9) It involves over 130 research faculty, 22 projects and 18 universities. Its projects (Figure 10) cover all aspects of computational perception, knowledge-based systems and intelligent robotics, but, in some ways its most important characteristic is its ties to PRECARN. PRECARN sponsored the IRIS proposal and continues to provide funding support as well as being responsible for the overall administration of the network. But even more important, we reviewed the research proposals before they went in, we are provided with regular briefings on their progress, and some of the research results are already feeding directly into PRECARN projects.

The PRECARN/IRIS alliance is a remarkable combination of efforts by industry, universities and governments and it is my view that we have only begun to tap its full potential. It is almost inexcusable that the forestry industry of this country is not involved in a direct manner and I must take some of the blame for that. Obviously my powers of persuasion have been inadequate in this particular case.

Just look, however, at what has been achieved. (Figure 11) Six years ago we had a network of 14 Fellows of the Canadian Institute of Advanced Research working in the field of intelligent systems in a coordinated manner. However, there was no effective or organized tie to Canadian industry. We now have closed that gap by adding the industry-driven projects of PRECARN and the much

expanded network of university researchers in the form of IRIS. We now have a truly national partnership in this important field of research.
So far I have talked only about the benefits of this partnership and have avoided referring to the problems. I have done so purposely because I don't want to close this Conference on a negative note. However, there have been major problems and barriers and many still exist. There always are when you try to do new things and run into the inertia that always impedes change. Let me just say that, with regards to industry, there are whole sectors of our economy that fail to see the merits of being involved in longer-term research no matter how highly leveraged it is. Many don't even acknowledge that the word precompetitive exists. Partnerships are something for legal and accounting firms, not industry! In the case of some large operations that undertake considerable research, I have encountered the "not invented here" syndrome. If they are not already doing it, it can't be worth doing. They seem blind to the research partnerships being developed by some of the world's giant's of industry. The fact is that few, if any, companies can now undertake, on their own, all of the research of importance to them. Partnerships and alliances are clearly the way of the future.

My other major problem has been the interface with governments, the government of this Province being the wonderful exception. Governments have been supportive, and for that I am truly thankful, but the delays that have been entailed in working something new through established bureaucratic systems has been awesome. Perhaps it is only fair that a former bureaucrat experience this trauma. I will spare you the detail. Just let me note that all four of our existing projects have had to start before all funding agreements were in place because otherwise the research would no longer be valid and the whole momentum of our program would have been lost. For one project the time between the initial funding request to a province until actual contract signing was 3 1/2 years. In another case it is almost three years and still counting. The hard reality is that the current highly structured forms of government, with few if any opportunity for initiatives by a single individual or even a single group, are not equipped to deal effectively with innovative proposals falling outside their finely defined programs. The same governments that call upon all others to be more innovative cannot themselves be innovative or perform with the speed demanded by innovation. Frankly, that is the major problem facing the effective working of any partnership having a significant tie to government and, unfortunately, few within government are prepared to recognize it.

However, if governments and industry have had difficulty responding to the relatively modest partnership program which I have described, I can only imagine the overall reaction to the form of industrial partnership this country must consider if we want to compete with highly effective corporate alliances in other countries. I speak here of alliances such as the "keiretsus" of Japan and their equivalents in Germany and northern Italy.

Alliances of companies that are mutually supportive and with cross ownership; alliances where the partnership companies share their collective financial, human resource and knowledge resources, and alliances where the strategic view is long-term and externally oriented and the rewards are shared. Yet these "integrated business enterprises", or "IBEs" as we are calling them, are not anti-competitive, the individual members do compete with one another, but not to the detriment of the IBE. Inter-company procurement is encouraged and the bottom line of the IBE is always to facilitate the growth of its members in an expanding global economy, not to manage them.

That's the competition of the future and some of us are looking at the potential for the development of IBEs in Canada. One of the major challenges is the reluctance of our financial institutions to play the same pivotal role as been done by banks in these other countries. (They want something more concrete and secure like Olympia and York!) But even in the financial circles there seems to be a degree of movement. Surely it is not beyond our capacity to develop such collective undertakings in the field of communications or even within the wood and building industries. Wood-based advanced materials and systems have been suggested as an IBE possibility where such value-added materials would be sold directly into world markets or included within advanced systems such as pre-packaged custom homes. We have the intellectual capacity to develop the required new materials for traditional or new markets and we have the advanced software and communications skills that would allow customers to select and design complete systems in distant locations for immediate manufacture, packaging and shipping from a network of Canadian plants.

There are many who will think that we are dreaming in technicolour when we consider such radical changes to our established ways of doing business. However, unless we pool our collective talents in partnerships such as IBE's, there will be less and less business for us to do. Events of the past year, especially in Ontario should have driven this message home to everyone.

So the bottom line is that the relatively modest partnerships that we see today have faced many problems in terms of industrial and government response, but they are now beginning to produce some of their significant potential. However, we all have a responsibility to think well beyond the present and to build far greater strengths through alliances that are still the antithesis of our conventional "go-it alone" North American philosophy, a philosophy which increasingly, will not carry the day.

I have little doubt about the success of this Conference and others like it. However, all too often it is the converted preaching to the converted. Our greatest and most important task is to influence our respective and collective decision makers and to get them to embrace the technologies that have been so ably presented and to do so in an ever-increasing partnership with others.

Thank you for your attention.

PRECARN MEMBERSHIP
(May 20, 1992)

Alberta Research Council
Alcan International Ltd
Asea-Brown Boveri Ltd.
Atomic Energy of Canada Limited
B.C. Advanced Systems Foundation
B.C. Hydro
Bell Northern Research
Bristol Aerospace Ltd.
CAE Electronics Ltd.
Canadian Space Agency
C.I.A.R.
Communications Canada *
C.R.I.M.
Energy, Mines and Resources
Ernst & Young
Falconbridge Limited
H.A. Simons Ltd.
Hatch Associates Ltd.
Hewlett-Packard (Canada) Ltd.
Husky Injection Molding Systems
Hydro-Québec
Inco Limited
MacDonald Dettwiler & Associates
Manalta Coal Ltd.
MPB Technologies Inc.
MPR Teltech Ltd.
National Defence *
National Research Council of Canada *
New Brunswick Power Commission
Ontario Hydro
Petro-Canada Resources
Shell Canada
Spar Aerospace Ltd
Syncrude Canada Ltd.
TransAlta Utilities Corporation
Vadeko International Incorporated
Virtual Prototypes Ltd.
Xerox Research Centre of Canada

* Associate Member

BENEFITS OF MEMBERSHIP

- REGULAR BRIEFINGS ON ALL RESEARCH PROGRAMS
- ROYALTY FREE ACCESS TO I.P. DEVELOPED IN PROJECTS
- ADVANCED BRIEFINGS ON IRIS RESULTS

ADDITIONAL BENEFITS OF PROJECT PARTICIPANTS

- DESIGN RESEARCH PROGRAM
- AWARE OF RESULTS FIRST
- ABILITY TO TEST RESULTS FIRST
- PRO-RATED SHARE OF THIRD PARTY ROYALTIES

PRECARN

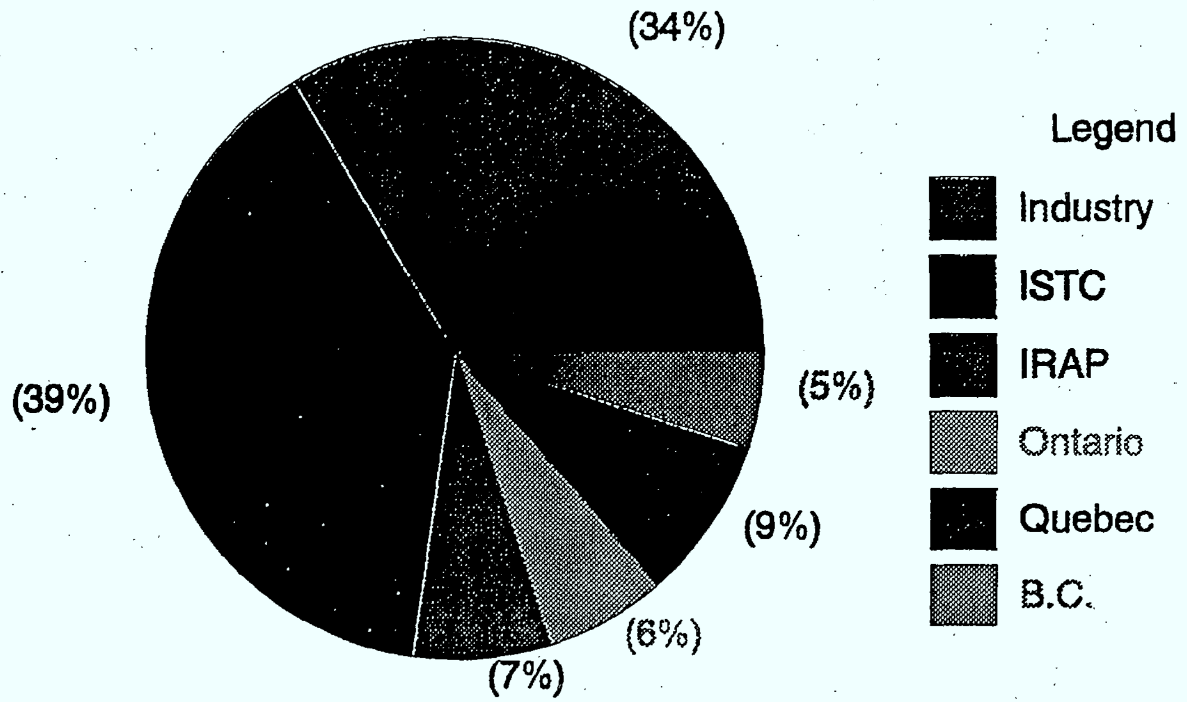
Intellectual Property

- PRECARN owns if possible
- Except where participants/province provide significant contributions
- All members have royalty free rights to use
- Third party royalties may be shared between owners and PRECARN

FIGURE 4

PRECARN Associates Inc.

Funding of Research Projects



Funding for the first four projects (APACS, IGI, ARK and TDS) from 1990 to 1995 for a total value of $33.6 million.

FIGURE 5

APACS PROJECT

* PRECARN / PARTICIPANTS

PRECARN	$ 418,900	4.5%
ONTARIO HYDRO	684,300	7.4%
CAE	674,100	7.2%
SHELL	576,300	6.2%
STELCO	407,100	4.4%
HATCH ASSOC.	540,000	5.8%
UNIV. OF TORONTO	146,600	1.6%
TOTAL	3,447,300	37.1%

* REQUESTED FROM IRAP[1]	2,356,200	25.3%
* INDUSTRY, SCIENCE & TECH.	3,497,600	37.6%
TOTAL	$9,301,100	100.0%

1 IRAP will initially commit to $1,000,000 over two years only.

"APACS"

ADVANCED PROCESS ANALYSIS AND CONTROL SYSTEMS

Member Participants

Ontario Hydro, CAE Electronics Ltd., Shell Canada, Stelco Ltd., Hatch Associates

Other Participant

University of Toronto

Status

Project underway as of July 1990

Research Phase

5 years at $9.3 million

Objective

To adapt state-of-the-art expert system development tools for production of expert systems used in the operation and control of a power plant.

"IGI"

INTELLIGENT GRAPHIC INTERFACE

Member Participants

MPR Teltech Ltd., Alberta Research Council, Shell Canada, TransAlta Utilities Corp., Xerox Research, H.A. Simons, Digital Equipment, Hewlett Packard, Virtual Prototype

Other Participant

Simon Fraser University

Status

Project underway as of February 1991

Research Phase

5 years at $6.9 Million

Objective

Develop an advanced intelligent graphic operator interface for complex real-time monitoring and control systems to respond to alarm information correctly and in a timely manner

FIGURE 9

I R I S

Institute for Robotics and Intelligent Systems

- Federal Network of Centres of Excellence
- Managed by PRECARN
- University-Based, involving 18 Universities
- Basic research, but aimed at industrial applications
- 22 projects in 3 research areas:
    - Computational Perception
    - Knowledge-Based Systems
    - Intelligent Robotics

IRIS RESEARCH PROGRAM

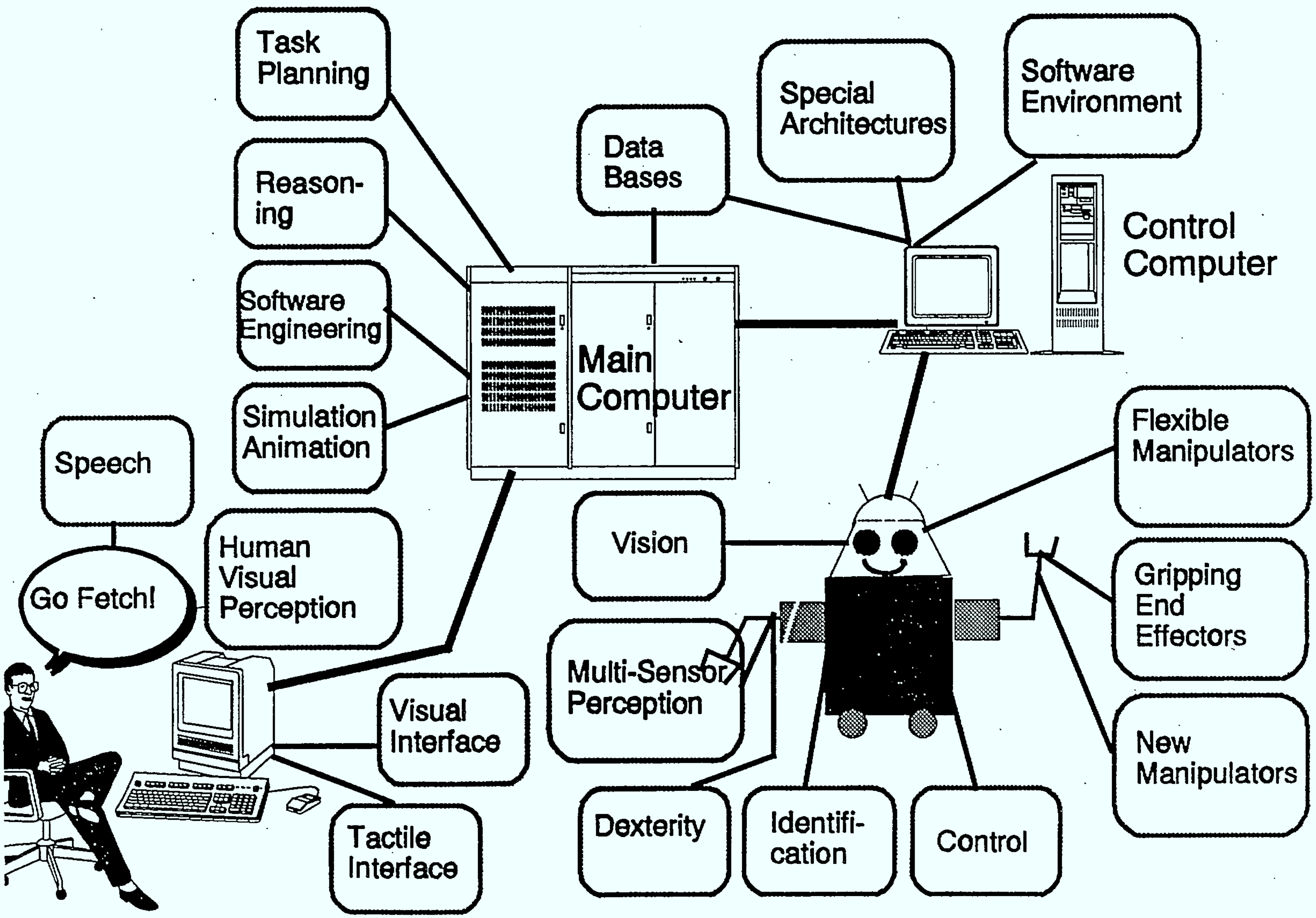


FIGURE 10 The Future: Forcing the Pace of Change

GEARED FOR PROGRESS

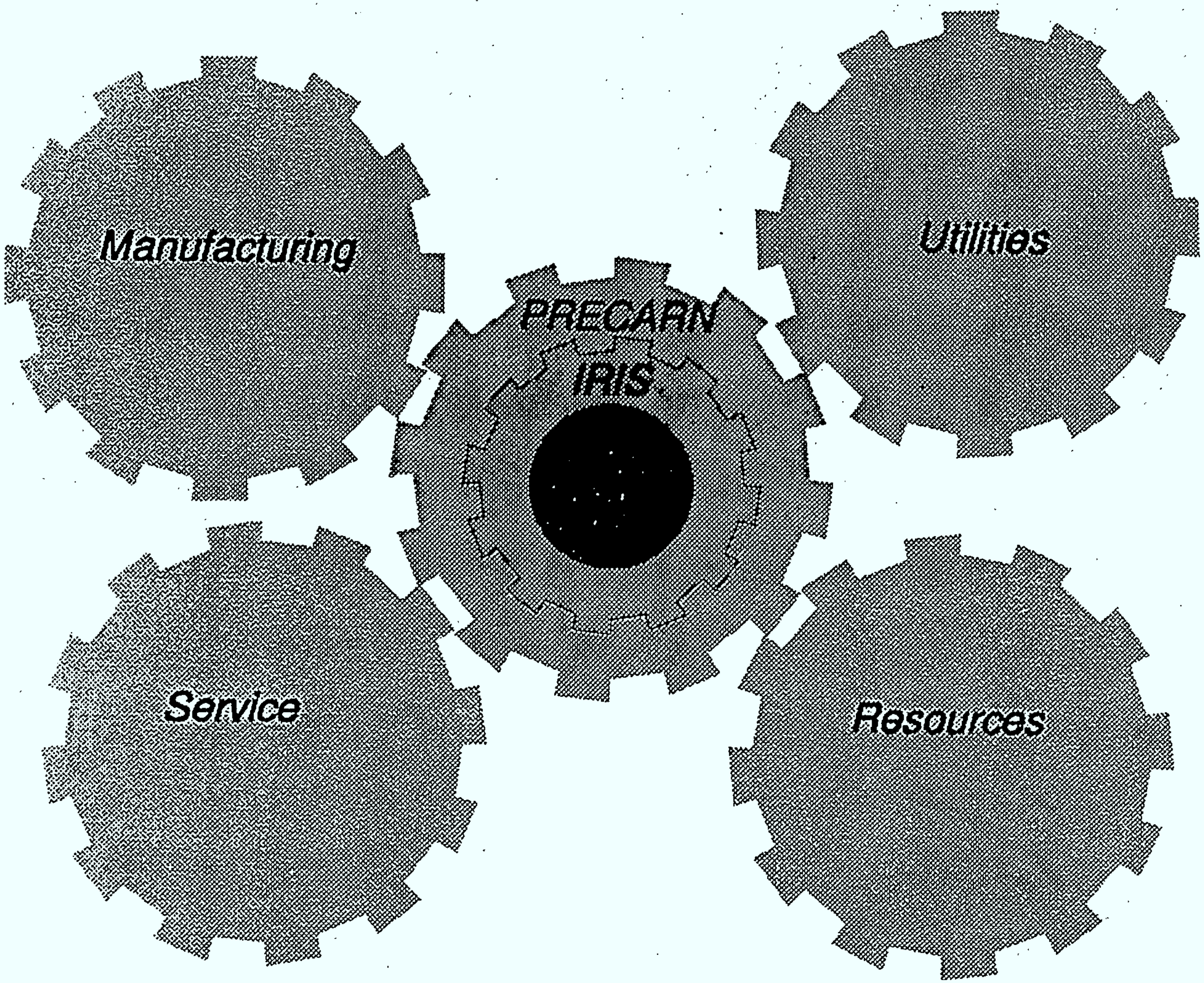


FIGURE 11 The Future: Forcing the Pace of Change

Competitiveness and Directions for the Future

Harry Rogers
Deputy Minister
Industry, Science and Technology
Ottawa, Canada

Thank you, Jocelyn, for that kind introduction and thank you, Ladies and Gentlemen, for giving me the opportunity to meet with you here, this afternoon.

I wish to thank Subhash Juneja, the FS 2000 organizer and his committee members -- Pierre Gautreau, Tony Jarvis, Joe Fox, Ian Efford and Veronica Gareau. As well, these sessions could not have happened without the diligence of our Regional office, and in this regard I wish to thank Wilf and Donna Torunski.

As many of you will know from experience, the final speaker at a conference such as this often finds him or herself in a somewhat unnerving position. After three full days, coming up with something new and fresh is not a simple matter. That is the down side. But it is a very real concern, particularly when conference presenters have been as high-quality as those who have preceded me to this podium. The good news is that, as the final speaker, I can say what I like without fear of contradiction. Now I know how Peter Mansbridge feels each night when he gives us the last word before tucking us in and bidding the nation adieu.

Some of what I have to say, this afternoon, could have been written a week or even a year ago but certainly not all of it. Not by a long shot. The thoughts with which I wish to leave you today, have very much been influenced by the things my officials have heard and seen during the past three days.

Last week or last year I very likely would have begun an address like this by putting the forestry sector's competitive position into perspective and encouraging its representatives to apply new technological solutions to the challenges of meeting market demands and ensuring future profitability. In essence, that remains my message, today. The major difference is that speaking to you, now, after three days of FS 2000 presentations, I have a notion that I am speaking to the converted.

I cannot imagine anyone in the forestry sector leaving this hotel without feeling far more optimistic than when he or she entered it on Monday morning. This conference has gone well beyond pious hope and wishing thinking. We have seen hard evidence that the forestry industry, arguably Canada's single most important revenue producer in the past, has the potential to be exactly that in the future.

The forestry industry in Canada is not in decline, it is in transition. We are not witnessing a sunset, in the 1990s; what we are seeing is a sunrise. They have a lot of the same characteristics, depending upon when and from what vantage point you see them, but sunsets and sunrises are very different things.

There has been a good deal written and said recently about the relative competitive advantages of different nations and of specific industrial clusters within different nations. The reigning guru, today, appears to be Professor Michael Porter of Harvard University. Most of you here, this afternoon, will have read either some of his work or, more likely, newspaper accounts that purport to summarize what he has written.

Porter has done first-class research but a good many misconceptions have somehow arisen from it. He has not written off such traditional industries as forestry. He has not offered as a fail-safe recipe for success the notion that competitive industrial strategies today and in the future lie only in pure high-tech industries such as aerospace. I have heard people characterize Porter's contribution in this way. These people are wrong.

What Porter and a good many other commentators are saying is that traditional industries such as forestry must adjust both attitudes and processes if they are to remain vibrant. Those, like Porter, who look to the world of high technology as a source of competitive advantage are not suggesting we abandon our historically proven industrial winners. They are simply suggesting, quite accurately in my view, that if our traditional industries are to remain competitive, they must make some dramatic changes and make them, now.

Surely, that is what each and every presenter at this conference has been saying, as well! Certainly, that is what we at ISTC have been saying for some time. As the very name of our still new department suggests, a marriage of Industry, Science and Technology is the only reasonable hope we have in this country of protecting and increasing market share profitably. It is no longer a theory. It is a fact of international of life.

What this conference has succeeded in doing, is to remove from this fact of life some of what I tend to call the "fear element". There is, in 1992, an understandable reluctance on the part of industry to invest in exotic technological experiments at a time when uncertainty is already running high and when, next to optimism, money is the rarest commodity around.

There is, undeniably, a serious downturn in parts of the forestry sector. Arthur Grunder's dramatic graphics drove that message home quite clearly when he gave us his "Business Perspective" on Monday after lunch. The economy, generally has been struggling and, in the midst of hard times, this sector has found itself particularly burdened by everything from off-shore trade restrictions to increased environmental regulation. It is not surprising that prudent executives and directors tend to take a rather jaundiced view of self-proclaimed miracle workers spouting scientific mumbo-jumbo and peddling intangible computer-borne cures.

This conference has gone a long way towards stripping away the mysteries of high-tech as an abstract notion. We have seen real-life applications, not listened to fanciful dream spinners. Speaker after speaker has been there, has "walked the talk", if I may borrow a somewhat hackneyed expression. I do not intend to attempt anything remotely resembling a complete summary, but, I cannot resist mentioning a few key examples.

Those of you who made the trip to Forintek's beautiful headquarters on Monday evening must have been impressed by what you saw. To pick just one of the new developments showcased there, I think it is safe to say that MPB Technologies' demonstration of its new Lamsor 920 Laser-based Moisture Sensor and species separator was nothing short of incredible.

The gurus and theorists talk endlessly of technology transfer. There it was, before your very eyes. The same laser technology being used to transmit long distance communications, to perform microscopic surgery or to bring distortion-free Mozart into your living room, is now available to save lumber mill operators millions of dollars.

MPB's laser sensor is not a dream in the early stages of development. It is an operational device, ready for a real-life trial. In August it will be installed in Frank Dottori's Tembec mill at LaSarre, Quebec. There seems little doubt that it will be effective and every reason to suggest that mill owners in Canada should be rushing out to put in an order.

I know for a fact that our American competitors will be monitoring its progress very closely. They are nervous and, when you consider projected cost savings, they're wise to be nervous. This technology will increase profitability and I very much doubt that our nemesis to the south, Senator Bacchus, will find it easy to convince his constituents that MPB's laser constitutes a basis for retaliatory trade measures.

On another table at Forintek, you may have notice a far more modest example of technology transfer. A British Columbia Institute of Technology student, as a project for academic credit, has combined a personal computer, a video camera and a simple robotic arm to create an automatic means of sorting and planting embryos for reforestation. Total cost, so far, has been under 30 thousand dollars. It is still in the developmental stage but, essentially, the thing works. It's viable. Once perfected it could save the industry substantial amounts of time and money.

The Canadians at this week's conference gave us hope. They demonstrated that theory can become reality, that Canadian space-age information technologies can be married to an industry like forestry that is almost as old as history itself. But not everyone we heard from at FS 2000 was a Canadian and in that simple fact lies a crucial message.

The world is not standing still while we make our minds about the benefits of information technologies. Our international competitors are forging ahead. They, too, have read Porter and the other experts. They have read, as well, the writing on the wall. They too are exploring the worlds of science and technology in search of that elusive competitive advantage.

Yesterday, Kevin Lyon took us on an enlightening tour through the workings of Australia's highly impressive Petrie Mills. He and his management team have adopted a bold approach to adding value and profitability through process control and continual experimentation with traditional methods. They have turned their backs on accepted "truisms" about warehousing and inventory control. They have set "impossible" goals and surpassed them through the use of information technologies. They are the competition. It would be imprudent to underestimate them.

On Monday, Tharald Frette, from Scotland's supermodern Caledonian Paper Mills treated us to a detailed demonstration of what his country can do with our trees. Some years ago, Scotland reforested vast tracts with Canadian sitka spruce. Caledonian is harvesting those trees now and effectively marketing the by-products, using a competitive strategy founded on the benefits of total automation.

Last evening at dinner and today at lunch we had rare opportunities to glimpse into the future. I did not bring my own crystal ball to Vancouver but I think that based on what we have all shared over the past three days of presentations it is safe to draw one or two conclusions.

First and foremost, I believe that even the most conservative among us must be convinced that there is no turning back. The world of forest products has changed forever and will continue to change. Biotechnology will bring us ever improved species, information technology will continue to exert pressure on accepted norms of quality and productivity and new materials like SL 3000 and Parralam will open new niche markets for enhanced wood products. There can be no return to yesterday.

The second startling reality is that no nation can control the agenda of change with which all nations must at least keep pace and that tomorrow's winners will outstrip. We have heard from the United States, Australia, Scotland and Finland. They are not waiting for us. If we make them an interesting and mutually attractive offer, they may be willing to joint venture or partner with us but they won't wait if we decide to dither and put off the inevitable.

Canadian industry must move and move, now. We cannot sit back, let the other fellows be the risk takers, and then, think we can swoop in and reap the rewards of their technological initiatives. It doesn't work that way. Not anymore. We have to commit, first to the adoption and adaptation of existing leading-edge technologies and, then, to the applications research and development required to bring new process innovations on stream. It's expensive and gut wrenching, especially in hard economic times. But, if we don't make the commitment we may not be in the game when we judge the economic time to be right.

And the commitment, when we make it, must be across the board. It is not simply a matter of pouring in the R&D dollars and siphoning off increased profits. Between those two poles stand a number of other vital concerns. More particularly, I am referring to people and the environment.

Janice Moyer said it during her presentation on Education and Enterprise and a number of other speakers referred to it as well. If industry is to succeed, the concept of value-added must be extended beyond saleable high quality products. It must be extended to include people as well. To improve our productivity and quality-enhancing capabilities we must commit resources and dollars to enhance the skills of both management and line-employees. Lip service to education and re-training will not do the job and if we refuse to make the commitment we can rest assured that the competition will take full advantage of our short-sightedness.

We hear so much these days about partnering, about new lines of communications between old competitors, about old enemies becoming new friends. But, there is a lot more to the concept of partnering than interaction between the board rooms of former competitors. The winners in the contest for world market share are discovering that all sorts of previously unheard of partnering can pay handsome dividends.

Let me take half a minute to expand on that notion. It is not inconceivable, for example, that the captains of industry and the champions of the environment could discover that they share a great many common goals. Equally, a marriage of labour and management for the purpose of smoothing the transition between the status-quo and the future is not necessarily a union of fire and water. And there are good examples of constructive management and union relations here on the West Coast that prove my point.

By way of a third example, let me suggest that, following what we are seeing as the Constitutional bargaining process continues in Toronto, aboriginal involvement in industrial planning is no longer unimaginable. Put simply, the concept of stakeholder is undergoing rapid change in Canada in 1992.

I recall a time, not so very long ago, when old style free enterprisers would bristle furiously at the very notion of private and public sector co-operation. Surely no one here, today, questions government's right to a place at the industrial policy-making table. Just as surely, no one here would attempt to down play government's contribution (through R&D support, policy advocacy, market analysis, trade promotion and technology development programs) to the enhancement of this industry's strategic advantages.

The reality, as we position ourselves for the competitive challenges of the next century is that no one stakeholder, no matter how powerful, can go it alone. The age of rugged individualism is gone and gone forever. This is a fact of modern life, not only in this industry but, as well, in every other industrial, academic, governmental and non-governmental sector and community in the world. The future will belong to those who learn this lesson and learn it well.

My reading of this FS 2000 Conference is that this lesson has not been lost on Canada's forest sector. The value of strategic alliances has been a constant theme over the past three days. Any number of presenters have utilized a marriage analogy to drive home the point that the bond between stakeholders and contributing partners must be absolute. Given the divorce rate in North American, perhaps we could find an even stronger example, though, I am certain that everyone gets the point.

In these final remarks, I have been able to touch on only a few highlights. It would take many hours to do justice to all that was said and demonstrated in formal sessions and at the showcases in the corridors. Before concluding, however, there is one final point that I believe must be reiterated. I am referring to the notion of spinoff benefits.

Almost every presenter made the point that unexpected side benefits inevitably flow from innovative strategic planning and applications. For example, it costs a good deal of money to train or re-train personnel but, once the job is done, once a work force is upgraded, the company suddenly finds it has a new and potentially very profitable resource on its hands. Skilled people are in demand. They can both save money by guiding a company through difficult situations and generate dollars by marketing their skills as a spin-off product for their company.

The same phenomena is likely to result from a corporate commitment to sustainable and environmentally friendly production. Dollars are needed up front to fulfil such goals but, once the new processes are up and running, once new control mechanisms are in place, the industry is likely to discover a market for its new knowledge, technology and equipment. The pressures on one company to conform are bound to be felt elsewhere. The first to comply may very well find itself in possession of easily marketable by-products.

In this aspect of free enterprise, of course, as in every other, there are no guarantees. But, the possibilities, the likelihoods are good. Just look at this conference. Speaker after speaker has come here representing leaders in one field or another. Whether industrial, academic or governmental, these are the people who took the risks and succeeded. Their experience and the guidance they can offer are very much saleable commodities.

It is never wise to speak in terms of watersheds or turning points but I hope that this conference has, at the very least, generated interest and enthusiasm. I hope that those who came here as sceptics will leave as experimenters and that those who came here as experimenters will leave as enthusiasts.

So much of the difference between success and failure comes down to attitude, to asking, as Senator Robert Kennedy said so many years ago, not "Why?" but "Why not?" I hope everyone leaves here inspired to ask, "Why not?" If we take that attitude and apply it to the responsible development of Canada's great riches, we simply cannot fail.

Thank you very much.

DATE DUE - DATE DE RETOUR

ISTC 1551 (2/90)