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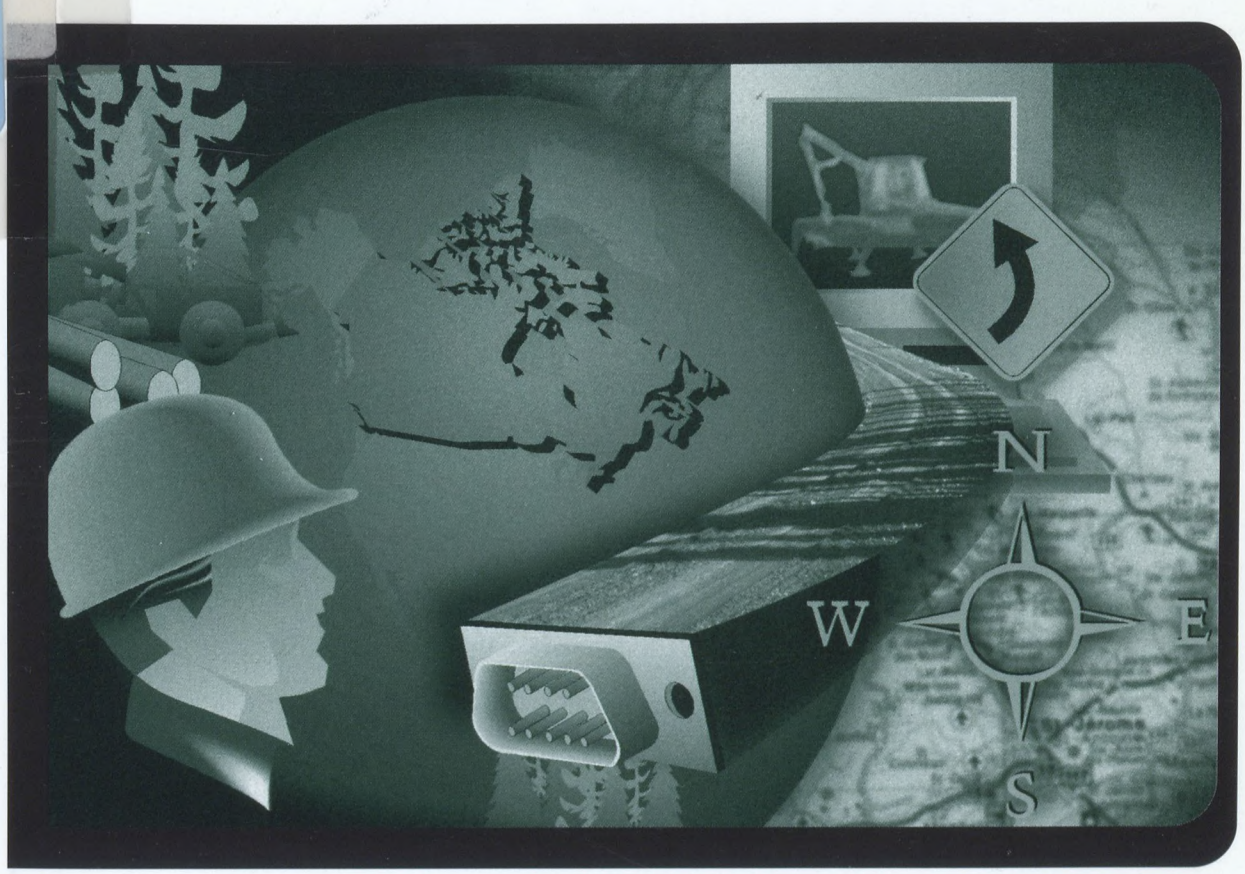
> TECHNOLOGY ROAD



>> Forest Operations in Canada

SPECIAL REPORT SR-117

Canada

TECHNOLOGY ROADMAP FOR FOREST OPERATIONS IN CANADA

Special Report No. SR-117

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Acknowledgments

This report was produced by FERIC in co-operation with the Industry Sector of Industry Canada and is based on a review of relevant literature, on FERIC's consultations with executives of Canadian forest product companies and equipment suppliers, and on the deliberations of focus groups and specialists within FERIC. The resultant information and recommendations were documented in two background reports produced by the Eastern and Western divisions of FERIC, which were integrated and summarized to produce the present report. Both full-length reports are available from FERIC upon request. FERIC retained the services of consultants to synthesize the various information inputs and produce the background and summary reports. Their able and dedicated contributions, as well as the guidance provided by Industry Canada officials, Mr. Subhash Juneja and Mr. John Hector are gratefully acknowledged. We would also thank executives from the forest industry and the equipment manufacturing sector, who gave up their valuable time to participate in brainstorming sessions during the development of the Roadmap.

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To obtain additional information about the *Technology Roadmap for Forest Operations in Canada*,
please call the Forest Industries and Building Products Branch of Industry Canada at (613) 954-3040, or
FERIC Head Office and Eastern Division, 580 boul. Saint-Jean, Pointe-Claire, Quebec, Canada H9R 3J9
Tel.: (514) 694-1140, Fax: (514) 694-4351, E-mail: admin@mtl.feric.ca
FERIC Western Division, 2601 East Mall, Vancouver, B.C., Canada V6T 1Z4
Tel.: (604) 228-1555, Fax: (604) 228-0999, E-mail: admin@vcr.feric.ca

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Foreword

This Technology Roadmap lays out a possible blue print for technological innovation in forest operations which is a very important component of Canada's forest industry. The ultimate objective is to achieve a highly prosperous forest sector in Canada over the next decade which is responsive to the growing demands for bio-diversity and sustainable development of the forest resource.

The contribution of the Canadian forest industry to the economic well-being of our nation is well recognized. It supports one million Canadian jobs. Over 300 communities in virtually every region of the country depend on it exclusively for their livelihood. In 1995, it sold close to $60 billion of product and most of that was exported. In fact this industry's net exports exceed the combined total of all of Canada's other exporting sectors.

Forest operations depend on advanced technologies to ensure international competitiveness of Canadian forest products and the sustainable development of our forests. The Roadmap presents a strategic plan for technological innovation, R&D and technology transfer in forest operations. It identifies the starting and destination points, discusses the driving forces, presents opportunities for technological improvement, and provides a series of recommendations for implementing the plan.

This strategic plan, the Technology Roadmap for Forest Operations, is realistic and achievable. It is an excellent example of government-industry co-operation. It was developed after extensive consultations with all stakeholders from the public and private sectors and is expected to attract their full co-operation in its implementation. As a result, we feel that this report is worthy of consideration and discussion; we urge you to give it your full attention.

In keeping with our objective, the promotion and use of leading edge technology, we are pleased to make this Technology Roadmap available on the Internet through Industry Canada's Site *Strategis*, at the following address: *http//strategis.ic.gc.ca/trm* for English; *http//strategis.ic.gc.ca/frt* for French.

Kevin G. Lynch
Deputy Minister
Industry Canada

Gilbert G. Paillé
President and CEO
FERIC

Abstract

The report presents a Roadmap for technological innovation, R&D, and technology transfer for forest operations in Canada over the next decade. The map identifies the starting and destination points, discusses the driving forces, presents opportunities for technological improvement, and provides recommendations on the best road to select for the future.

Executive Summary

A "forest operations technology roadmap" developed by FERIC in consultation with the forest industry, equipment manufacturers, and Industry Canada sets out targets for Canadian forest operations in 10 years: maintain delivered wood costs at current levels or lower them; meet regulations and public expectations on environmental sustainability; optimize fiber quality and supply; sustain a motivated, productive work force; sustain a viable, technologically based Canadian forest equipment sector; and effectively transfer technology and knowledge to all stakeholders. These are ambitious goals by historical standards. The Roadmap suggests that one avenue is to emphasize appropriate technological innovation.

The first option, improving existing technologies, builds on proven solutions and responds to rapidly changing requirements. The incremental benefits often justify the relatively low development costs. The Roadmap defines several priorities: greater mechanization in harvesting operations; new techniques for fiber and value recovery, thinning, waste disposal, and operating on steep terrain or with large trees; better transportation systems and equipment; improved road building; and alternatives to current silvicultural practices.

The second option is to invest in breakthrough technologies that promise quantum leaps in the competitiveness of forest operations. These technologies offer significant long-term payoffs, but the costs and risks are high. The Roadmap identifies several breakthrough technologies: machine automation and robotics, lightweight materials, global positioning systems, training simulators, artificial vision, environmentally friendly fluids, computerized decision-support tools, soft-footprint technologies, voice- and data-acquisition and transfer systems, operator/machine interface systems, and remote sensing.

The Roadmap also provides implementation recommendations based on a thorough assessment of trends and factors that affect forest operations, on existing technologies, and on consultations with executives and specialists in the forestry and equipment-supply sectors. Priorities focus on training, technology development and transfer, organizational linkages, and communications. Recommendations apply to and involve all stakeholders, including the forest industry, contractors, equipment suppliers, governments and research organizations.

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Introduction

This report presents a Roadmap for technological innovation, R&D, and technology transfer for forest operations in Canada over the next decade.

The Map itself depicts a mature and important sector of the Canadian economy, the forest industry. This industry sold $57 billion of products in 1995. Exports amounted to $41 billion, with *net* exports exceeding the total for other leading export sectors combined. The industry's activities supported close to a million jobs across the country. The forest industry is Canada's largest non-urban employer, and more than 300 communities depend on it exclusively for their livelihood. In short, it is Canada's leading manufacturing sector and the cornerstone of our economy.

On our Map, Canada's forest operations of 1996 and its existing technology base represent the starting point. These operations supply most of the wood fiber used in manufacturing products. Even recycled pulp and mill residues originate mainly from Canada's forest. Wood costs amounted to 60% of total sawmill costs in 1995 and were only slightly lower for pulp and newsprint. Thus, wood costs will determine our ability to compete in the world markets on which Canada depends so heavily. Wood costs associated with forest operations include not only the harvesting of trees and transporting the product to the mill but also silvicultural operations, forest management, and the planning and control inherent therein.

We have already travelled some way to reach our starting point. Forest operations have benefited extensively from R&D and innovation. Productivity per person-year has increased seven-fold during this century. Equipment is highly mechanized and often multifunctional, and cost reductions have been the prime focus in transportation as well as in harvesting. New requirements for forest renewal and management have been met, and environmental concerns are being addressed. Unlike in manufacturing plants and in the forests of many of our competitors, Canadian forest equipment operates in one of the most hostile environments in the world, with extreme variations in forest, weather, and ground conditions.

However, we cannot stay where we are indefinitely. Numerous forces propel us forward, often causing us to change direction and sometimes creating road blocks. Global competition requires more than ever that products be of high quality at competitive costs. Societal pressures and government regulations are imposing new environmental requirements. Trees are smaller and farther away, and softwood fiber is in short supply. The advent of contractors and their relationship with the forest industry adds yet another dimension. Manufacturers are looking at a range of new products that add value and that rely less on solid wood. And perhaps most important, people are increasingly being recognized for their contribution to change.

In response to these driving forces, technological innovation has the potential to revolutionize the full scope of traditional forest operations. We are on the leading edge of extensive structural change. Technology is the vehicle and R&D provides the power. We are in the driver's seat. But we must know where we are going and choose the best route to reach that destination.

The Roadmap takes us over the next decade to our destination in the year 2006. At that destination point, we would expect forest operations in Canada to achieve the following:

- maintain the cost of delivered wood at current levels or reduce costs;
- meet regulations and public expectations on environmental sustainability;
- optimize quality and inventory of fiber supply;
- sustain a motivated and productive work force;
- sustain a viable, technologically based Canadian forest equipment sector;
- transfer technology and knowledge effectively to all stakeholders.

In view of historical trends and reduced government spending, these are exceedingly ambitious goals. How do we achieve them? One answer lies in technological innovation. We must choose our route with care.

The next chapter reviews current and future driving forces in Canadian forest operations. These are factors and trends that will impact heavily on operations and related technologies. They are numerous, diverse and interrelated. We will encounter them throughout the trip. Most are on the Roadmap but we will also see some new territory, as conditions are dynamic and the Map will need updating.

The following chapter describes technological innovation in forest operations. It begins with the existing technology base, then moves forward into areas of

opportunity to improve these technologies in response to driving forces. The road then winds its way into regions which are less certain, but with the promise of technological breakthroughs and substantial payoff.

The last chapter sets out recommendations which address our objectives ten years hence. They will help us choose the fastest and surest route to reach our Roadmap destination. They apply to all stakeholders, including industry, government and research organizations, and are intended to benefit both the forest industry and Canadian equipment suppliers.

Just as travel guides are helpful in planning a journey, a number of sources were essential in providing the information and points of view expressed herein. These include many reports and presentations published over the last ten years, FERIC's consultations with the executives of Canadian forest products companies and equipment suppliers, and the deliberations of focus groups and specialists within FERIC.

Driving Forces

Driving forces clutter the Roadmap, like road signs pointing every which way. They are many and diverse. As the road on the Map moves towards the future, the driving forces become less clearly defined. But as we drive onward, we know that we must face them. Like the wind, they propel us forward or they slow us down. Like the hills and the curves, they are challenges that face technology as the vehicle and us as the driver. On occasion, they will seem to block the route.

Driving forces will impact heavily on the future of harvesting, transportation, silviculture, and planning. They will influence the extent and timing of requirements for technological change over the next decade in numerous ways.

It is clear that the effects of these various factors and trends are not mutually exclusive, but are interrelated to a considerable extent. Environmental concerns, for example, are manifested by both societal pressures and government policy. Declining fiber supply and the response to environmental concerns put upward pressure on delivered wood costs. Markets and product demand impact on fiber supply, while conversely, the species and quality of timber also affect markets.

Some of the issues are complex and not easily resolved. Objectives may even be contradictory, and decisions that favor one objective may be counterproductive to another. Clearcuts, for example, are being reduced in size for many reasons, but some ecologists are now saying that larger clearcuts favor biodiversity. Close utilization increases fiber recovery, but residue left on the site after harvesting is necessary for wildlife and soil enrichment.

Delivered Wood Costs

The need to control and lower wood costs is the most powerful force driving technological change. Cost competitiveness is the key to a viable and profitable forest industry, which is the mainstay of the Canadian economy. Moreover, lower wood costs increase the economic availability of timber.

The cost of delivered wood is the single largest component of total mill costs in the manufacture of lumber, plywood, pulp, and newsprint. In sawmills, for example, wood costs account for 60% of total mill costs. With the exception of Sweden, Finland, and Japan, our major international competitors have lower wood costs.

The major challenge facing forest operations is to improve cost performance through innovation. In some cases, this only requires implementing existing technology. In other cases, it will mean equipment that is faster, smarter and more productive, with more sophisticated mechanization and electronics.

The reduction of wood costs is made all the more important by cost escalations associated with other driving forces. The objective of reducing delivered wood costs therefore becomes twofold: (1) to reduce costs wherever possible through the application of new technology and improved practices, and (2) to minimize cost increases brought about by such developments as new environmental requirements, smaller piece size, and safety issues.

A major cost component that lies outside industry control is attributable to government: stumpage fees, forest policies, and regulations. These government costs cannot likely be reduced in the short term, but the money could possibly be better reinvested or redirected into the forest.

Environment

The list of environmental issues related to forest operations appears endless. They range from global warming to biodiversity to habitat destruction to fisheries protection. Environmental factors are, at present, forcing major changes in government regulations, thereby reducing fiber availability across Canada (notably in British Columbia) and impacting heavily on harvesting, transportation, and silvicultural practices.

Taken as a single issue, environmental concerns have rapidly become a predominant driving force that prevails at all levels throughout society. They are both contentious and intricate, and much of the science is incomplete. This issue is largely provincial in jurisdiction, but national in scope and international in terms of markets and special interests. Stakeholders are passionate in advocating their views.

Governments and industry have responded. British Columbia, the focus of considerable international attention, has enacted new legislation (including the Forest Practices Code) that sets very strict environmental rules for harvesting and transportation. The industry has initiated third-party certification of sustainable forest management that incorporates a range of environmental criteria and involves many stakeholders. This is a Canadian process, but it is gaining international recognition.

Environmental issues affecting forest operations are expected to be with us for some time to come. Technological innovation is a key vehicle on the road to deal with these issues. Equipment and systems that will be gentle on soils, water, biodiversity, and other aspects of the environment are required.

Fiber Supply

The ample supply of fiber in Canada has been a traditional strength of our forest industry. With access to 10% of the world's wood resources, Canada's forest product manufacturing has had readily available raw material, often close to production facilities.

The situation is evolving rapidly. Inexorable increases in product demand have caused harvesting to reach the limits of the softwood allowable cut of acceptable quality and costs in many regions of the country, despite considerable advances in manufacturing yield, recycling, and harvest utilization. In some regions, annual allowable cuts and the commercial forest land base itself are shrinking to accommodate environmental and preservation interests, leaving insufficient softwood resources to meet production and market requirements.

Hardwood resources are still underutilized in most regions, in some cases even impeding softwood harvests. This, however, will change over the next decade. For example, aspen, which is a dominant species in the Canadian hardwood inventory has come to be used extensively for board, lumber, and paper products.

In addition to volume-based calculations of allowable cut, the reality of harvesting economics will also reduce timber availability. This may be particularly onerous in regions already faced with shortages, as in the case of parts of British Columbia. New technologies to reduce costs could change that situation, thereby increasing the supply of fiber.

Log quality is declining, but higher prices for specialty products and increased competition for fiber are forcing the industry to maximize value recovery from each log.

Fiber supply is already a significant driving force, perhaps the most significant in many parts of the country. It will become even more critical as continuing growth in demand exceeds the amount of available wood fiber. Within a decade, its significance may cause a major shift in technological priorities applied to forest operations. Plantation forestry and agricultural sources of fiber are not expected to significantly increase fiber supply over the next decade.

In the meantime, technology will focus on dealing with shortages. Volumes per unit area and tree sizes will be smaller, requiring equipment modifications to retain productivity. Wood (on average) will be farther from the mill, and reducing transport costs will become more important. As the resource becomes less suitable for construction-grade products and more appropriate for pulp and reconstituted wood, technology such as cost-effective in-woods chipping may become more significant.

Market and Product Demands

Significant trends in markets and product demands include: the shift to value-added products, reconstituted

and engineered wood products, and wood-fiber composites; product differentiation and specialization; and the use of pin chips, sawdust, and hardwood species in pulp and paper products.

In light of declining timber availability, governments are encouraging value-added industries and companies are seeking new opportunities for growth in revenues and profit. Value-added products are aimed at both domestic and export markets.

The move to value-added and reconstituted wood products will mean more opportunity to obtain optimal value from logs that might otherwise be underutilized or even discarded in the slash pile. This material must be sorted by species, grade, and size to separate it from the regular commodity product flow. Without planning and appropriate technology, sorting is incompatible with present mass-production, low-cost commodity approaches.

In addition, more fiber will be obtained from forest biomass and site residues. There will be a greater proportion of the total harvest in the form of usable fiber for chips and other small pieces, and more mill waste will be reconstituted. At the same time, large, clear, quality timber will realize even higher premium prices and may require special care in the woods to avoid damage. Market demand for diversified, specialized products will place greater premiums on certain species and fiber characteristics.

Within a decade, new product markets and the trend towards value-added products could become increasingly significant as driving forces that will affect forest operations.

Sociopolitical Issues

A number of issues that might be termed sociopolitical tend to dominate the discussion relating to forest operations in Canada at present. This is a rather fluid group of issues that tend to spill over into other areas such as the environment and sustainable development, fiber supply, trade, land tenure, land use, and wood costs.

Two major issues of the past decade, and of continuing interest as industry restructuring continues, are employment and its Siamese twin, forest dependency. There is an increasing tendency for governments to link Crown timber availability and job creation. This is particularly true in British Columbia.

The question of consumptive vs. non-consumptive use of forests is a major issue in determining timber supply. For instance, a survey conducted in British Columbia found that 49% of respondents felt that timber harvesting is never acceptable in wild areas.

"Green labeling" represents a non-tariff trade barrier that may be of major importance to the Canadian forest industry. This essentially requires the certification that wood products are produced from trees harvested in sustainably managed forests.

Generally, the public expects substantially improved forest management policies and practices in government and industry, and insists on being involved in the decision-making processes that affect forest operations and planning.

Worker and Contractor Needs

Workers and contractors are separate but linked institutions. Both are increasingly recognized as critical to the success of forest operations and the application of new technologies.

Workers whose requirements have been addressed are more apt to be productive. Important considerations include performance, safety, training, ergonomics, and worker satisfaction. Studies show that machine operators are generally positive about the application of technology to woods operations. They believe that technology can improve the industry's image, motivation, productivity, and safety.

Contractors now harvest 90% of the eastern Canadian volume and a significant portion of the western harvest. These companies are smaller than the larger forest industry corporations, with smaller financial resources and less of a supporting organizational structure to plan operations and provide services such as maintenance. This requires equipment that is less costly to purchase and more robust. Over the next decade, contractors are expected to retain their dominance, but possibly become larger and more multipurpose entities with more resources and the ability to purchase larger and more specialized equipment.

Technology

Technology is the mode of travel that will move forest operations to its destination ten years hence, but there are many vehicles to choose among. A great number offer good value and a sure trip, but may not get us to our destination for some time. There are others, fewer in number, that have more power but that are unproven and more apt to break down along the way. However, they provide us with a good chance to reach our destination before anyone else.

The Roadmap sets out three levels of technology. It starts with the technology base that applies to existing forest operations and moves forward into areas of opportunity to improve these technologies. In the final section, a special area of the Map describes eleven higher performance vehicles that offer good prospects for technological breakthroughs.

Existing Technology Base

Technology has come a long way in forest operations. Over the last few decades, numerous harvesting systems have replaced more primitive methods in response to the driving forces prevalent at the time. Equipment is highly mechanized and often multifunctional. Reducing costs has been the prime focus in transportation as well as in harvesting.

In the harvesting operations of eastern and central Canada, full-tree harvesting systems are on the decline and will eventually represent less than 50% of the total harvest. However, in the interior of British Columbia and in the prairie provinces, full-tree harvesting will continue to dominate for some time. These harvesting systems typically involve the use of tracked feller-bunchers with sawheads, followed by grapple, clam-bunk or cable skidding, depending on site conditions. Delimbing and sorting are usually conducted at roadside. The main weaknesses usually associated with full-tree systems are site disturbance, nutrient export from the growing site, fiber breakage, and value losses.

The shortwood method, also called cut-to-length, usually involves single-grip harvesters, at-the-stump processors, and shortwood forwarders. It offers many advantages under appropriate conditions, including low environmental impact and suitability for use in partial cutting, which is increasingly important. Cut-to-length is gaining increasing acceptance and, within a few short years, should account for fully one-third of the total harvest. Problems associated with existing cut-to-length machines include high capital and operating costs and long learning curves for operators.

With the tree-length system, trees are felled and delimbed at the stump, often manually, then are brought to roadside, usually by cable skidding. This system accounts for 15% of the harvest, and is used mostly for small-scale operations and special situations. The main problems associated with this system are the physical demands of manual felling and low skidding productivity.

Seventy percent of the harvest in coastal British Columbia, with its mountainous terrain, is by cable yarding. Ground-based systems, primarily excavator forwarding of logs to roadside, account for 20% of the total, and aerial logging (mostly by helicopters) for between 5 and 10%. Helicopters, used for reaching timber inaccessible by other means, and cable yarding are used selectively and to a much lesser extent in interior British Columbia and Alberta. All these systems are very expensive to operate and require either large or valuable timber to be cost-effective.

Logs and chips are predominantly transported by road, using trucks. Chips account for more than 50% of the fiber volume hauled in Canada, and are carried by vans in bulk; logs are carried by trailers that typically weigh around 10 tonnes. Trailers, for the most part, are built with minimal engineering sophistication, which results in higher operating costs. Oversize off-highway trucks are used mostly in Quebec, Alberta, and British Columbia, where much of the roundwood is hauled on private roads. On the coast of B.C., the majority of operations that produce logs, chips and hog fuel have a marine link in their transportation phase. The major problems associated with transportation are high costs related to long haul distances and non-optimized payloads.

Most silvicultural equipment is used after clearcutting. Powered-disc trenchers, patch scarifiers and a variety of other implements mounted on tractors and skidders are used for site preparation. Planting is done manually, whereas direct seeding is done primarily from aircraft. Tending of young stands and precommercial thinning are on the increase. There are some attempts at mechanization. The main problems associated with silvicultural equipment are high costs because of limited machine markets and the difficulty of mechanizing some operations (e.g., planting, precommercial thinning).

Improvements to Existing Technologies

There remains a fundamental need to apply existing harvesting, silviculture, transportation, and road-building technologies at a local level. Innovation is also required to address some of the problems identified with current technologies, whether they be specific machines, attachments or other equipment. Such technological development is ongoing and is absolutely necessary to adapt to changing requirements and conditions, often in response to the immediate needs of operators.

Such R&D can build on proven operations by providing incremental benefits that greatly outweigh the costs involved. It can provide the flexibility and quick response needed to deal with the many dynamics associated with forest operations and the forces that drive change. These forces include the need to reduce costs, improve environmental performance and increase fiber supply. Such innovation fits squarely with a client-oriented philosophy and is of considerable interest to equipment manufacturers. It can contribute significantly to reaching the Roadmap's target destination, and its importance should not be minimized.

Numerous examples of innovation could improve existing technologies. A number of these are presented here; each potentially represents a significant area of opportunity.

Wood Harvesting

Lower-cost Commercial Thinning Equipment

A FERIC study revealed that 25% of its member companies in the east are now involved in commercial thinning. This figure will exceed 50% by the year 2000 because thinning provides immediate fiber and improves growing stock, yet costs remain high because of the inherently small tree size and the need to minimize damage to residual stems. Moreover, appropriate thinning techniques and equipment are still being refined, with most thinnings now conducted using motor-manual operations or small, imported wheeled harvesters.

There is an opportunity to develop and adapt equipment suitable to the requirements of thinning under Canadian conditions. The options include small, robust, affordable harvester carriers and small, narrow forwarders with high payloads and low ground pressure.

Mechanized Equipment for Harvesting Tolerant Hardwoods

Uneven-aged hardwood stands are now harvested with motor-manual felling and simple extraction techniques that use farm tractors, cable skidding, and horses. However, qualified crews are now less available for this type of operation. Mechanization is seen as the only solution, but the large tree size and the shape of hardwoods are obstacles that have yet to be overcome. Technological solutions include modified feller-bunchers and specialized feller-processors.

Mechanized Equipment for Tree-length Harvesting

Full-tree harvesting creates delimbing slash at roadside, and this is no longer acceptable in many areas of the country; however, cut-to-length technology is not always a viable option because some sawmills require tree-length material, and many harvesting operations have an efficient infrastructure in place for hauling and handling tree-length material. However, few options are available for producing tree-length material at the stump. There is a need to improve current alternatives for delimbing at the stump and for tree-length skidding or forwarding technologies.

Multi-stem Harvesting Heads

Existing cut-to-length harvesters process one stem at a time. This penalizes productivity when small trees are harvested and makes cut-to-length less attractive in northern boreal forests. The resultant need is to develop a harvester head capable of felling and processing multiple stems for small-diameter trees.

Harvesting Systems for Better Fiber Recovery and Value

Studies show that substantial volumes of wood fiber are lost or broken between the stump and the mill. New harvesting systems and work methods are required to reduce the incidence of stem breakage and fiber loss. There is also a need to develop improved roadside sorting and merchandizing techniques, especially for western Canada.

Waste Disposal at Sort Yards and Satellite Merchandizing Yards

Under certain conditions, the chipping or merchandizing of stems at satellite locations (away from centers of manufacture) offers significant economic advantages and better fiber recovery. The problem is how to dispose of the waste material generated by sorting and debarking. Dryland sort yards in western Canada also generate large quantities of debris. Innovation is required to use this material on-site or to find markets for the debris.

Mechanized Systems for Steep Terrain

Ground-based systems are most often not environmentally acceptable on steep terrain, and existing cable systems are expensive and thus only effective with larger timber. Cable systems designed to operate efficiently with small timber would reduce costs and soil damage on steep terrain. In addition, such systems could extend the operating season on wet or otherwise sensitive sites. Several modifications to existing technology are required.

Processing Heads for Large Trees

There are few processing heads on the market that can handle the large trees from second-growth stands that will be harvested over the next 20 years in coastal British Columbia. The development of such units would reduce breakage and waste, promote safety, increase productivity, and reduce costs.

Transportation

Improved Traction and Mobility for B-trains

B-trains are two-section trailers connected by a fifth-wheel mechanism. This configuration distributes the load more evenly across a greater number of axles and therefore causes less damage to roads than a conventional semi-trailer. As a result, provincial regulations allow B-trains to carry a heavier load, thus reducing haul costs. Traction on steep slopes, however, remains a problem that is hindering the acceptance of B-trains, and turn-arounds are also problematic. There is a need to develop traction-improvement devices and more flexible configurations for this equipment.

Combined Road and Rail System

The traditional transport of wood by rail is no longer cost-competitive. A hybrid road and rail system may in fact improve both cost and environmental performance for long hauls. It relies on specially designed bogeys that can be used to connect road trailers to form a rail convoy. Technological development of the necessary infrastructure is required.

Multi-purpose Trailers

Trials suggest that there are significant opportunities to reduce transport costs for wood in various regions of Canada by using the same trailer to haul chips in one direction and logs in the other. Other product mixes could also be considered. Until recently, there were no trailers specifically designed for this type of transport. A new unit was introduced into the market in 1994 and offers considerable savings to the operator. There are further opportunities for technological improvement.

Mobile Rock Crushers for Surfacing Roads

Road surfaces wear out and hauling gravel is costly in many areas. Mobile rock crushers recycle material pushed to the side of the road by repeated grading. One model has just been introduced commercially in Canada, and two others are at the prototype stage. Again, there are opportunities for improvement.

Road Development and Deactivation Equipment

The British Columbia Forest Practices Code has singled out roads for severe regulation. This has greatly increased delivered wood costs. Innovation is required to develop new techniques for road construction, temporary surfacing, and subsequent deactivation of the roads. The design of environmentally acceptable, reusable bridges, culverts, and other water crossings would reduce installation and deactivation costs and minimize siltation. Longer booms and special attachments on excavators would also be needed to retrieve and move material.

Silvicultural Operations

Site Preparation Equipment for Heavy Debris Accumulations

Increased use of delimbing-at-the-stump harvesting systems means higher concentrations of debris on the cutover area. As well, new environmental regulations will reduce cut-block sizes and restrict piling and burning of debris. These changes limit

the effectiveness of current scarification equipment. Site preparation equipment that is lighter, more mobile, effective, and transportable must be developed to deal with these conditions.

Site Preparation for Partial Cutting

Increased partial cutting requires new approaches to ensure regeneration. Planting sites must be prepared, but the areas are small, and site preparation has the potential to damage the roots and stems of residual trees. New equipment must be sensitive to ecological requirements and be highly mobile to be effective.

Enhanced Herbicide/biocide Application

Public pressures and government regulations are requiring more judicious use of herbicides. As an alternative to herbicides, biocides are currently under development in Canada, but viable application methods are lacking. Technologies must be developed to apply herbicide to single stems and to perfect ground sprayers as an alternative to aerial spraying.

Alternatives to Herbicides

These include the use of large seedlings, better site preparation, and mixing equipment that will reduce competition from other vegetation. Mixing attachments have not yet been designed specifically for this purpose. Large seedlings will require proper site preparation techniques, and suitable manual planting tools must be developed. Another alternative is the use of mechanical tending equipment, which requires further refinement to be effective on the more difficult sites.

Equipment for Seeding and Precommercial Thinning

In some regions of Canada, direct seeding results in successful regeneration and can reduce the costs of establishing new stands. Existing equipment is not well-developed, and is often unreliable and wasteful of seed, which is becoming more expensive. Purpose-built equipment for precommercial thinning is still required because of rising labor costs.

Treatment of Roadside Slash

In those regions where full-tree harvesting will predominate, the problem of treating roadside delimbing debris remains. These residue accumulations make successful regeneration of roadside and landing areas problematic. Slash burning is now unacceptable in most parts of the country, so that efficient mechanized means of treatment must be developed and implemented.

Breakthrough Technologies

There are exciting areas of innovation now on the horizon that offer opportunities for "quantum leap" technological breakthroughs in forest operations. These particular technologies will carry us more quickly towards our destination.

The Roadmap sets out eleven such areas. In most cases, these areas cut across the various operational phases of harvesting, transportation, and silviculture. They apply to all stakeholders and, of necessity, involve all stakeholders. These technologies present opportunities for significant long-term payoffs in terms of responding to the key driving forces identified earlier in the Roadmap. At the same time, the costs and the risk of failure may be high. To achieve results will require commitment from the forest sector in the form of a sustained effort over the longer term and a clear statement on R&D priorities.

Machine Automation and Robotics

Operators now focus on the routine and repetitive actions necessary to control machines. Automation of these repetitive functions will provide time to focus on strategic operating decisions. This will greatly enhance work quality and productivity, while reducing fatigue. It will also benefit the environment, contribute to value-added production, and increase the quality of fiber.

R&D initiatives are already underway. These include: coordinated motion control for single-joystick operation, self-learning machines that automate repetitive actions, sensors to monitor external conditions and adjust machine operation in response, and walking machines for steep slopes.

This area represents a good opportunity for Canadian equipment suppliers, some of whom are involved at the research stage. There is, however, a general lack of knowledge and the costs and benefits are uncertain. In some cases, the small market size may be limiting research.

Lightweight Materials

Traditionally, forest machines have been heavy, often with overdesigned steel structures to achieve the necessary robustness. However, times are changing and there are pressing needs to maximize payloads to obtain cost reductions and to minimize ground pressure to meet environmental standards. One solution lies in the development and use of light but strong materials for forest equipment.

Though some prototypes are under trial in niche areas of opportunity, other industrial sectors such as aeronautics are further advanced. Cooperation and sharing of information is a possibility with organizations such as the Canadian Space Agency. Specific opportunities exist for the following equipment: booms and attachments for longer-reach harvesting, air suspensions, trucks and trailers, forwarders, prefabricated water crossings, and prestressed wooden decks. Canadian equipment suppliers could thereby increase their competitiveness; however, some applications have limited markets, and development and material costs could be high.

Global Positioning Systems (GPS)

GPS uses a network of 24 satellites to locate precise coordinates on the earth's surface. This greatly facilitates the abilities to survey and navigate, which are very important in forest management and forest operations. For example, the use of GPS technology mounted on forest machines opens up opportunities for updating maps continuously, navigating machines along boundary lines, monitoring trucks and equipment, and assessing silvicultural performance.

The overall industrial market for GPS is extremely large. Forest operations technology can benefit from tapping into this large knowledge base. There are already commercial applications for GPS mapping and data surveying. GPS-based navigation is nearly at a commercial stage. There are, however, some constraints to implementation, including the poor quality of existing base maps, high development costs, and a lack of suitable software. On balance, the applications of GPS to forestry are highly promising and may give Canadian software suppliers a competitive advantage in world markets.

Training Simulators

The Roadmap has identified training as perhaps the most essential ingredient of technological success. Training paves the road forward and propels us more quickly toward our destination. It allows us to expand beyond the commercialization stage and realize the full potential of innovation. It fits well with all driving forces, most particularly cost reduction, regulatory compliance, and worker needs.

Training helps us deal with the growing complexity of forest equipment. Much of this is expensive to buy and operate, and training *in situ* can be costly when considering downtime and lower productivity. One solution is the use of advanced training simulators such as those developed for the aeronautical industry. This may significantly reduce the cost impact of training, making it more accessible to those in remote regions and broadening the scope of the training program. Operators would learn more quickly and make more effective use of their equipment.

Simulators are used in other industries, but are at the early developmental stages in forest operations. Specific opportunities include the development of low-cost (less than $100 000) graphic simulators for harvesting machines and the use of CD-ROMs for training. More complex simulations will cost more and will require a more sophisticated software and training infrastructure.

Artificial Vision

Artificial vision allows the machine to respond directly to critical parameters that affect its operation. It may eliminate operator bias and accelerate tasks now done manually. The Biris laser-imaging camera developed by NRCC is an example of the use of artificial vision in advanced automation systems. Specific opportunities in forest operations include optical measurement of logs, log grading, and the automated analysis of chips to determine sizes and levels of contaminants. Recognition and guidance systems for forest equipment represent a further opportunity.

Artificial vision is used in agriculture, and its application in forest operations will benefit cost reduction and fiber quality. Constraints to implementation include difficult and variable environmental conditions.

Environmentally Friendly Fluids

Forestry machines use hydraulic oils, chain oils, anti-freeze, and other petroleum-based fuels and lubricants. Environmental concerns and regulations are forcing the introduction of biodegradable alternatives.

Europe is further along in introducing legislation, but there are also pressures in Canada. Many applications are still unproven, and there are potentially higher costs and disruptive effects on equipment from the use of inferior products, particularly under harsh Canadian operating conditions. Innovation is needed.

Computerized Decision-support Tools

In the new age, computers are revolutionizing our approach to almost everything. Forestry and forest operations are no exception, and the opportunities appear unlimited. For example, foresters must handle tremendous volumes of numerical and spatial information. The planning, controlling, and reporting phases of forest operations now span so many parameters, including those that are ecological, technical, regulatory, and worker-related. Computerized tools will manage this data and will help managers to make better decisions.

Extensive computing power is available, but there is limited software development and relatively few programs. GIS is one example where Canadian companies are taking the lead. FERIC is developing an integrated computerized costing model for harvesting and silviculture. However, there are other specific opportunities related to managing the resource and landscapes, managing truck fleets, and designing, constructing, and rehabilitating roads. In fact, computerized planning tools will help integrate all forest management and operational objectives and values. There is a good opportunity here for Canadian software development.

Soft-footprint Technologies

Ground disturbance is an important component of environmental concerns. Government regulation is focusing on soil compaction and rutting, and on sedimentation in water. Limitations are being placed on the areas of disturbance, the depth of rutting, and the period of operation. This will increase operational costs and reduce the quality of fiber unless appropriate technologies are commercialized. The best solution may lie in equipment that leaves a softer imprint on the forest floor. This encompasses a wide range of technological options, such as high-flotation equipment, variable tire pressures, walking technology, pendulum wheel arms, and anti-slip systems.

Many of these technologies are not yet widely applied and others are in early stages of development. Innovation in this latter category may be costly given Canadian terrain and soil conditions and technical constraints still at the research level.

Voice- and Data-acquisition and Transfer Systems

Managing and monitoring forest operations are becoming increasingly complex in response to such driving forces as cost reduction, fiber quality, markets, and product and environmental demands. To meet these requirements, information must be exchanged in ever more detail and frequency between operations, central offices, and manufacturing facilities. Our Nordic competitors are beginning to use cellular phone technology for this purpose. Satellite communication technology may offer better results under Canadian conditions.

Much of this technology is available but not yet operational. This provides a good opportunity for Canadian manufacturers within the software and electronics sectors. Applications include communication in remote locations, on-board scaling during harvesting, weigh scales on haul trucks, and diagnostic equipment for roads.

Operator/machine Interface Systems

The skill and attitude of the operator have long been at the core of machine productivity. Technologies are being introduced that will give operators a better understanding of their machines' performance capabilities and allow them to adjust machine behavior to suit their preferences. Such systems will feature user-friendly graphical interfaces and will assist in monitoring and controlling operations, fine-tuning performance, and trouble-shooting.

There has been some development of these technologies for agriculture and in the Nordic forest sector, and there is an opportunity for the Canadian equipment sector to improve the ergonomic features of forest equipment.

Remote Sensing

Satellite-based imagery services are commercially available, although forestry makes little use of them. Further innovation will benefit the tracking of regeneration, insect-infested and diseased areas, and fires, as well as taking inventory and monitoring harvesting activity. Remote sensing could tie in with forest harvest planning, sustainable forest management certification, and decision-support systems. There is active development work in the universities and in some Canadian companies that specialize in this area.

Recommended Action Plan

We are in the driver's seat and the Roadmap is before us. Alternative routes lead toward our destination, but we have to make the choices. We would be wise to share information and ideas, and to make plans together so that we can move faster than our competitors. As with any journey, we must be prepared to make the commitment of time and resources required to see our plans through to the end.

The following recommendations are based on more than just the driving forces and technologies set out earlier in the Roadmap. They are based as well on a review of the literature and on extensive consultations with executives and specialists in the forestry and equipment-supply sectors. Many of these observations go beyond the largely technical aspects of R&D and into implementation, commercialization, and even subsequent phases.

Clearly, technical success alone is not enough. Other means and mechanisms must be considered to ensure that the full potential benefits of technological innovation are realized. Some of the observations that fall into this category are the need for training and technology transfer, the absence of a clear vision on the future of forestry operations innovation, low R&D spending levels in the Canadian forest sector (by international standards), an aversion to high-risk R&D, and a lack of communication between stakeholders.

The following recommendations, like the highways on a roadmap, cover a wide area. If acted upon, they will let us move into the fast lane and reach our destination sooner.

Technology Development

1. ***Establish Research and Development Priorities***

   Research and development priorities for the organizations that conduct the work, define the future directions or support the research through various funding mechanisms, should be parallel to the development opportunities outlined in the Roadmap. For example, applied-research organizations and equipment manufacturers should consider the improvements to existing technologies as priority work areas.

   Of the eleven breakthrough technologies identified in the previous section, early development and funding efforts should go toward the following areas, which hold the greatest potential impact on forest operations in the long term:

   - development of lightweight materials and structures;
   - GPS-based navigation and monitoring systems;
   - robotic controls and automation;
   - artificial-vision initiatives; and
   - training software and training simulators.

2. ***Establish "Centers of Focused Development" on Specific Breakthrough Technologies***

   This would bring forest companies, equipment manufacturers, associations, research institutes, and universities together under one "roof", with a wide range of experience and expertise in specific technologies. The objective is to get the best expertise focused on the development and commercialization of quantum leap technologies that would benefit all sectors. These centers could be established either on a sustained or an *ad hoc* basis, depending on the nature and scope of the innovation under development.

3. ***Work Closely with Industry Canada under the Technology Partnership Canada (TPC) Program to Support Initiatives that Correspond to the Priorities Set out in the Roadmap, Especially Breakthrough Technologies.***

   The breakthrough-technology priorities presented in the Roadmap are a result of intensive consultation with experts in forestry operations and R&D. They merit full consideration under the TPC Program.

4. ***Learn from Countries that have been Successful in Technological Innovation and Commercialization***

While institutional and market factors may be different in non-North American countries, there are undoubtedly aspects of their systems that are worth assessing and perhaps emulating.

A reconnaissance mission to northern Europe by representatives of equipment suppliers, the forest industry, and governments would be a good first step. The objective would be to analyze the factors behind the commercial success of Finnish and Swedish cut-to-length machines in the North American market. A subsequent activity could involve posting an expert on forest equipment in those countries for a longer period, perhaps six months, to gain further insight on Nordic technological developments and marketing strategies.

Technology Transfer

5. ***Establish Networks with Links to Sectors Other than Forestry for Facilitating Technology Flow and Transfer***

Development of highly promising technology often occurs within a particular sector unbeknownst to those in other sectors. Networking with other sectors would promote cross-fertilization of ideas and the opening up of potentially larger markets for specific areas of technology. Networking would lead to opportunities for interaction and co-operation on specific projects. For example, access to the National Research Council's broad research program and established networks would help launch this initiative.

6. ***Implement a Broad Technology Watch Into Research Organizations***

The objective would be to obtain relevant information on innovation and technology development in other sectors and countries. This would include scanning, reviewing, and assessing a broad range of literature; monitoring the Internet and technical exchanges are two other possibilities.

7. ***Expand and Promote Forestry Extension Services***

The backbone of continuing technical education and technical transfer in the U.S. is the forestry extension service, funded by government but operated through the university system. In Canada, a similar approach could complement the extension work already delivered by the provincial governments. There is a need to promote awareness of the importance of forestry in the daily lives of Canadians, thus facilitating the acceptance of the importance of technology.

Training

8. ***Enhance Training and Education in the Area of Forest Operations***

Training in the skills to use more technically sophisticated equipment closely relates to both productivity improvement and environmental performance. All stakeholders agree that enhanced training is essential to achieve the full benefits of innovation.

Five issues were identified. Training is required specifically for:

- advanced technology;
- knowledge of the purpose associated with various tasks;
- safety;
- team-building skills; and
- business skills for contractors.

Training should be addressed at the following levels:

- expanded training activities and course material;
- regional programs on operating heavy equipment;
- basic high school courses in harvesting technology;
- development and use of low-cost training simulators; and
- operator training as a requirement for accreditation.

Industry-led accreditation programs in Maine and Montana have proven highly successful in improving productivity and morale and in reducing accidents. Accreditation is considered important in such programs because it ensures that all employees reach minimum standards. It also instills a pride of occupation.

Some machine-operation training programs are now available in certain provinces, but no formal linkages with contractors and forest companies have been established.

University forestry programs should retain a technological and engineering component to insure that foresters are trained to recognize the importance of technology in the field of forest operations.

Organizational Linkages and Communication

9. Establish a Formal Advisory and Consultation Link Between the Forest Industry, Equipment Manufacturers, Research Organizations, and Funding Agencies

Closer links would benefit both the forest industry and equipment suppliers by contributing to a better definition of research priorities, operating requirements, and opportunities, and to more effective communication and shorter response times in bringing innovations to market. The Roadmap would set the agenda. Cooperative ventures would be encouraged.

10. Encourage Linkages Between Advisory Bodies on the Environment, Research Organizations, and Equipment Manufacturers

Such a mechanism could provide current and accurate information on such issues as biodiversity, forest ecology, and new regulations, and would facilitate an appropriate technical response. It would provide sufficient lead time for preparation instead of hasty reactions, which often prove costly. Misleading environmental information would be put in perspective.

Partners could include researchers, equipment users and suppliers, the Issues Group of the Canadian Pulp and Paper Association, provinces, the federal government, and universities.

11. Have the Canadian Council of Forest Ministers Prepare, Publicize and Implement a Vision Statement on the Technological Future of Forest Operations

The dual process of preparing a vision statement and publishing it would help to unify the sector and encourage longer-term commitments. The Roadmap is a helpful starting point. Breakthrough technologies would be addressed, and all stakeholders would collaborate. Interested parties, even the Canadian public, would then better appreciate the contribution of technological innovation to forest operations.

Forest Industry and Contractors

12. Revise the Traditional Structure of Contractual Relationships Between Contractors and Forest Companies

Contractors need a payback for using new technology and taking risks. They also require longer-term contracts to assure ongoing viability. The current system guarantees neither of these. Restructuring of contracts would, in the long term, encourage innovation and reduce wood costs.

Currently, successful innovation by enterprising contractors to reduce operating costs may mean reduced pay rates to the contractor. As well, innovation that provides secondary benefits, such as improved environmental performance, may not benefit the contractor at all. In these cases there is little incentive for the contractor to take the risk of implementing new technology.

Adequate and sustained financial returns would also allow the contractor to build long-term arrangements with equipment suppliers, thereby benefiting from price rebates and extended warranties.

13. Improve Information Flow and Technology Transfer to Forest Contractors

The competitiveness of the Canadian forest industry is inherently linked to the performance of its forest contractors. The need for knowledgeable and informed contractors is vital because equipment is becoming more sophisticated and expensive and the working environment is growing more complex and regulated. There is a need to promote technology transfer and education.

To achieve this goal, one possibility would be to work through existing associations such as the TLA in British Columbia and the APMF in Quebec. These associations could help link contractors, the forest industry, equipment suppliers, and governments, and would assist the sector in putting forth a unified position on technical matters. A revision of the mandate of the newly established Canadian Woodland Forum could be considered to facilitate the implementation of this recommendation.

14. Encourage Longer-term Relationships Between Equipment Purchasers and Domestic Equipment Manufacturers

Longer-term supply arrangements allow ongoing improvements in quality of products and better service. The establishment of good working relationships and effective communication between user and supplier contribute to a team approach that is effective in resolving technical difficulties. Moreover, Canadian equipment suppliers would then be able to obtain a scale of manufacture and a longer period for technological improvement that would benefit both that sector and forest operations.

15. Conduct a Review of the Comparative Costs of the Main Elements of Harvesting, Transportation, and Silviculture

As noted earlier in the Roadmap, the need to reduce costs and maintain industry competitiveness is one of the most significant driving forces. The proposed initiative would serve as the basis for establishing potential cost-reduction opportunities and would identify those with the highest potential for payback. Cost/benefit analysis and risk assessments for each undertaking would be helpful in establishing future R&D priorities.

16. Establish Eastern and Western R&D Implementation Committees

Many good innovations never make it to the implementation stage. There may be many reasons. Perhaps no one but the researcher has a major stake in the success or failure of the project. The project may lack a champion in industry or an appropriate equipment manufacturer, or little might be known about the initiative and its potential costs and benefits.

Implementation committees, comprising potential users, equipment suppliers, and researchers at FERIC, would be tasked with reviewing research results, investigating their economic benefits and costs, and urging testing and adoption of the technology by potential users, where warranted.

Examples of high-impact technologies that have been proven and that are ready for implementation and commercialization include:

- GPS navigation for forestry machines;
- central tire-inflation systems for logging trucks (eastern Canada);
- combined road-rail systems; and
- machine/mill satellite communication linkages.

Equipment Suppliers and Manufacturers

17. Establish a Clearinghouse to Provide Support Services in Marketing, Sales, Legal, etc. to Canadian Forest Equipment Suppliers

The equipment-supply sector is small and disorganized. Companies lack access to important information, including the technological needs of the marketplace. Export opportunities, particularly in the U.S., are substantial. A user-oriented clearinghouse of information and services would help address constraints and opportunities in domestic and export markets. A stronger sector would be more apt to sustain innovation.

18. Establish an Association of Canadian Forest Equipment Suppliers

Such an association would be an important vehicle to aid in the transfer and diffusion of technological information. Terms of reference might include technological reconnaissance in world markets and world harvesting areas. The association could deal directly with research institutes and forest-industry associations on technical issues and cooperative ventures.

A possible alternative to a stand-alone association is the active participation of the equipment suppliers in a strengthened Sustaining Members Group within the Canadian Woodlands Forum. The recently formed Bureau d'Exportation des Équipements Forestiers for eastern Canada is an important first step in the implementation of this recommendation.

Government

19. Structuring Regulations to Unshackle Innovation

Regulations that apply to harvesting, transport, and silviculture often vary from province to province. In some cases, this situation can impede the effective application of new technology and affect its cost-effectiveness. Truck and trailer manufac-

turers, for example, may have to make substantial model changes to satisfy different jurisdictions. Such regulations should be harmonized between provinces as much as possible.

Another barrier identified during the Roadmap consultation process is the existence of forestry and other regulations that prescribe process rather than stipulate results. When processes are controlled in this way, the option of using alternative technologies is constrained.

20. Update Useful Federal Initiatives

As part of the literature survey supporting the Roadmap, numerous studies and reports undertaken or commissioned by the federal government were reviewed. These were useful in R&D planning, but are unfortunately out of date. Examples include the Forest Sector Advisory Council cost studies, sector profiles, and the Machinery Task Force Report. The federal government has also sponsored helpful symposia on innovation. These should be continued and the studies should be updated.

Background Documents

The present report is a summary of the following two background reports produced by the Eastern and Western divisions of FERIC; both are available from FERIC on request:

FERIC. 1996. Technology roadmap for forest operations: Eastern Canada background report. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Internal Report IR-1996-12-03.

FERIC. 1996. Technology roadmap for forest operations in Western Canada: background report. For. Eng. Res. Inst. Can. (FERIC), Vancouver, B.C. Internal Report IR-1996-12-06.

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