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> TECHNOLOGY ROAD

>> Canadian Aircraft Design, Manufacturing and Repair & Overhaul

(Ontario Pilot Project)

SUMMARY AND OVERVIEW

Canada

The Canadian Aircraft Design, Manufacturing and Repair & Overhaul Technology Road Map (Ontario Pilot Project) was jointly sponsored by the Ontario Aerospace Council (OAC) and the Aerospace and Defence Branch of Industry Canada, and was produced in two volumes. The Summary & Overview volume presents summary information compiled by Industry Canada based on the findings of the contributors to the Ontario pilot project. The Critical Technology Reports volume presents the critical enabling technology reports compiled and written by the participating Ontario aerospace firms.

Additional copies of the Canadian Aircraft Design, Manufacturing and Repair & Overhaul Technology Road Map (Ontario Pilot Project) – Summary & Overview are available from:

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The Summary and Overview volume is also available electronically on the World Wide Web at: http://strategis.ic.gc.ca/tr

Copies of the individual Critical Technology Reports are available to manufacturing firms, universities and other educational institutions, research organizations and government agencies in Canada in either electronic or printed format. Please contact the Aerospace and Defence Branch at Industry Canada,
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Canadian Aircraft Design, Manufacturing and Repair & Overhaul Technology Road Map (Ontario Pilot Project)

Summary & Overview

Prepared by:
Aerospace and Defence Branch
Industry Canada

ONTARIO AEROSPACE COUNCIL

November 1, 1996

The Ontario Aerospace Council's Strategic Directions report of 1994 called for a stronger "home base" of world class aerospace capabilities for Ontario. It also recognized the close linkage between target market demands and new technology requirements. Therefore, the Industry Canada initiative on technology road maps was very timely and OAC was pleased to co-sponsor the Aircraft Manufacturing and Repair & Overhaul Technology Road Map pilot project. The resultant document provides a wealth of information essential for Ontario companies to meet market expectations and position themselves for growth. I encourage all Ontario aerospace companies to consider the findings of this report in their strategic technology planning.

In my experience, the partnership established between industry, researchers and government to produce this road map is unique. As well, it has established closer relationships and ne networks amongst the participants. This new team approach is critical to the future of our industry.

This project required a lot of effort. I am proud of the way industry and the participating Ontario- based research organizations responded to the challenge. I would particularly like to acknowledge the contributions of the National Research Council, National Defence, and Industry Canada.

It is important to recognize that this road map is the first step in an iterative process. Since technology is evolving at an ever increasing rate, the road map must be revisited periodically. As well, it is my hope that the rest of Canada's aerospace community will participate in a follow-on road map that will verify and expand the findings of this pilot project.

Yours truly,

ONTARIO AEROSPACE COUNCIL

Kenneth G. Laver
Chairman

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November 1, 1996

The world aerospace market has entered a growth cycle that promises prosperity to those companies who can correctly position themselves to produce the right products. The Canadian aerospace industry is now the sixth largest in the world, and could be fourth by the turn of the century. Success depends on the ability to finance, to establish appropriate relationships with other firms, to market, and to use the right technologies. By virtue of its rapid growth and diversity, technology is the most complex of these factors.

Industry Canada is focused on improving the competitiveness of Canadian industry through trade, investment and technology initiatives. Technology road maps are our business plan for the latter, identifying the enabling technologies critical to future success. Therefore we were very pleased when the Ontario Aerospace Council agreed to co-sponsor a pilot project. The resultant Aircraft Manufacturing and Repair & Overhaul Technology Road Map represents the first time a group of Canadian aerospace companies, in partnership with the government and academia, have addressed their future technology needs.

This report, and its successors, will be a factor in setting the government's policy and strategic planning priorities. More importantly, it will provide guidance to all Canadian aerospace companies, as well as other stakeholders, in their strategic technology planning.

The significant resources provided by the Ontario companies and the scientific community, including the National Research Council and the Department of National Defence, indicates the importance they place on this initiative. On behalf of Industry Canada, I thank all participants for their dedication in producing this excellent report.

John M. Banigan
Assistant Deputy Minister
Industry Sector

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FOREWORD

The Canadian aircraft industry consists of some 200 plants employing about 40 000 workers. Industry shipments are $5–6 billion annually. With only a small domestic market, foreign trade is of critical importance, representing over 70 percent of sales. Canada ranks fifth among world exporters of aircraft and aircraft parts, and is one of the few nations that achieves a surplus in aircraft industry trade.

To sustain competitiveness beyond the cyclical upturn of the late 1990s, the Canadian aircraft manufacturing industry faces new challenges. The world aircraft industry is rapidly moving away from its historical cost-plus military-oriented culture focussed on product technologies and performance, towards an industry that operates along more conventional business lines with equal emphasis on manufacturing efficiencies. Changing customer requirements, the restructuring of the international industry as a result of overcapacity in some market segments and the emergence of new competitors are forcing established manufacturers to focus more than ever before on the processes by which its products are designed and manufactured. Cost has become the major competitive factor in the aircraft industry today.[1]

This new environment requires that firms continuously reduce their product development and manufacturing cycle times through improvements in design and manufacturing processes as well as in management techniques in order to be able to bring new products to market earlier and at a lower cost.

The ability to overcome the challenges and exploit the opportunities in the new global environment will vary by the nature of the activities in which each firm is engaged. Canadian companies with a simple build-to-print capability and easy-to-acquire manufacturing technologies are vulnerable, as are those with a cost-plus military focus. Those companies with a long-term commitment to cost reduction and innovation are in a better position to compete in the changing global environment.

Technology Road Maps identify the critical enabling technologies required by the industry to meet future market demands. They provide a strategic planning tool to industry, academia and governments. Other nations have already made extensive use of this tool in their industry development programs. Industry Canada, to help ensure that Canadian companies continue to prosper, has initiated Technology Road Maps in a number of industry sectors, including the aircraft industry.

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1 Industry Canada, Aerospace and Defence Branch, *Aircraft and Aircraft Parts: Part 1 — Overview and Prospects,* Sector Competitiveness Framework (Ottawa: Public Works and Government Services, 1996).

EXECUTIVE SUMMARY

Current and future customer demands for higher performance from their suppliers at lower cost require that Canadian aerospace firms select and implement the right technologies to remain competitive. Technology Road Maps are used internationally to identify and reach consensus on future technology requirements. This is a report of the first Technology Road Map for the Canadian aerospace industry. It was initiated as a pilot project by Industry Canada, specifically for the aircraft design, manufacturing and repair & overhaul sector.

This project was undertaken during the period May through October 1996 by Ontario aircraft companies and research organizations in partnership with the National Research Council as well as the departments of National Defence and Industry Canada. It was co-sponsored by the Ontario Aerospace Council. This Technology Road Map identifies critical enabling technologies the sector will require to design, build and maintain aircraft, aircraft systems and components to meet customer requirements in the period 2001–05.

Technologies are selected on the basis of their potential contribution to marketplace competitiveness and their strategic applicability across the industry sector. The Technology Road Map describes 50 enabling technologies in eight technology areas (Design, Environment, Maintenance and Repair & Overhaul, Management, Manufacturing, Materials and Structures, Systems, and Visualization), published in two volumes. The first volume is a summary of the process and technologies, and the second contains the technology reports.

This Technology Road Map represents the first time that these participants have collaborated to define the technological future of this industry. The process itself provided unique networking opportunities as well as improved communication and supply chain relationships.

The Technology Road Map will benefit all participants. For companies, it is a strategic planning tool to identify the gaps between their current technological capabilities and future requirements, and to make technology investment decisions to close this gap. For research organizations and educational institutions, it provides guidance for structuring future programs. For governments, it provides a strategic direction for industrial development activities.

1. INTRODUCTION

1.1 Vision

To help make the Canadian aeronautics sector the world's preferred source of supply for its products at all levels.

1.2 Purpose

To identify those critical, enabling technologies that the Ontario aerospace industry will require to design, build and maintain aircraft, aircraft systems and components in order to meet customer demands in the period 2001–05.

1.3 Goal

To provide private and public sector decision makers with an industry consensus on future, market-driven technology needs and to guide investment, training and policy decisions.

1.4 Background

In mid-1995, Industry Canada investigated the feasibility of a Technology Road Map (TRM) for the Canadian aerospace industry. Recognized by the Ontario Aerospace Council (OAC) as an important follow-on to their earlier work on Strategic Directions, Industry Canada and the OAC formed a partnership in early 1996 to undertake a pilot TRM with the Ontario aerospace industry. An industry champion was found in Ken Laver, President of Messier-Dowty Inc. The Industry Canada Aerospace and Defence Branch TRM team then gave presentations to chief executive officers (CEOs) and senior executives of selected aerospace firms to explain the concept and solicit participation. 66 CEOs and technologists from 22 firms,[2] the OAC, the Aerospace Industries Association of Canada, the Ontario Centre of Materials Research, the University of Toronto Institute for Aerospace Studies, the National

[2] AlliedSignal Aerospace Canada
Bombardier deHavilland
Cametoid Ltd.
Canadian Airlines International Ltd.
Canadian Marconi Company
Ceramics Kingston Ceramiques Inc.
Comtek Advanced Structures Ltd.
Deloro Stellite Inc.
Derlan Aerospace Canada
Diamond Aircraft
Eurocopter Canada Ltd.
Fleet Industries
GE Aircraft Engines Canada
Haley Industries Ltd.
Litton Systems Canada Limited
MBM Tool & Machine Co. Ltd.
Menasco Aerospace
Messier-Dowty Inc.
Orenda Aerospace Corporation
Pratt & Whitney Canada Inc.
Sensor Technology Limited
Vac Aero International Inc.

Research Council (NRC), the Department of National Defence (DND), the Ontario Ministry of Economic Development, Trade and Tourism (MEDTT) and Industry Canada attended a launch meeting in Toronto on May 17, 1996. This meeting established the marketplace requirements basis for the Technology Road Map, and resulted in a firm commitment to proceed with the pilot project. At a subsequent Toronto meeting on June 26, 1996, senior technology experts from these firms, the NRC and the DND formed eight Technology Working Groups (TWGs). Each TWG selected and prioritized the critical enabling technologies they would study, and elected one of its industry members as group leader. A scribe was appointed from Industry Canada or the NRC. The TWGs developed papers on each technology over the following three months. Final agreement on content, presentation and method of dissemination of the TRM documents was reached at two meetings: on October 29, 1996, by all TWG participants; and on November 27, 1996, by the chief executive officers and senior executives of the participating firms.

2. METHODOLOGY

The Technology Road Map process consisted of the three steps shown in Figure 1.

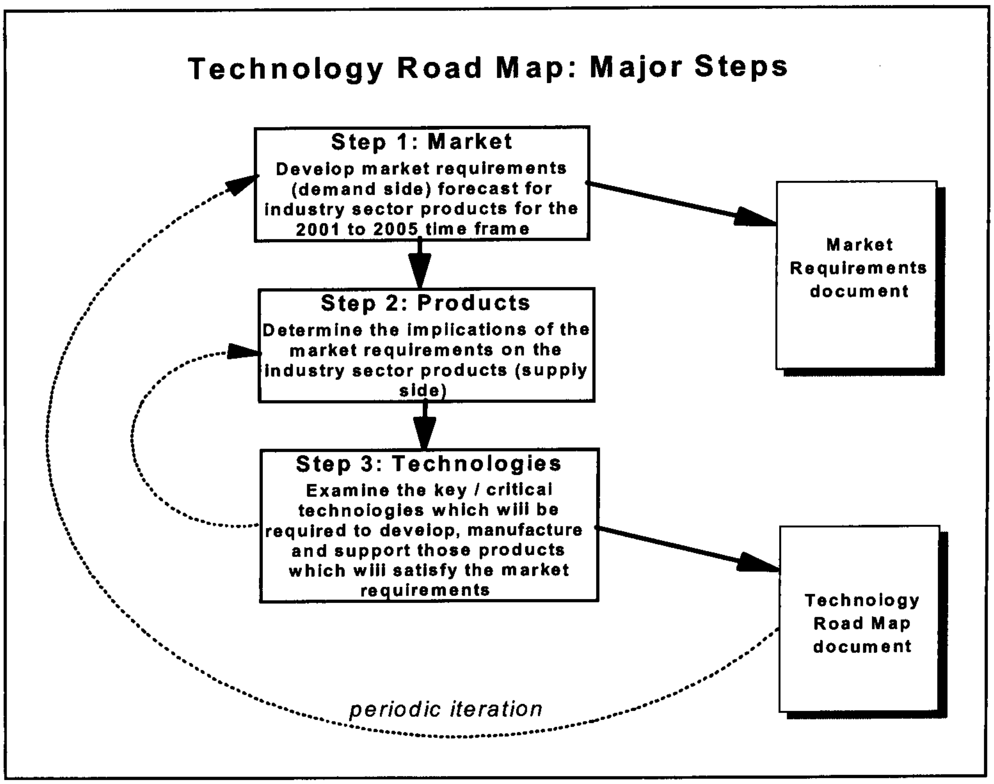

Figure 1

2.1 Step 1: Market Requirements Forecast

Step 1 assessed future market requirements. These requirements (the "demand" side of the equation) define the customers' cost and performance parameters as well as any environmental and regulatory requirements that will affect the industry sector's products. The market requirements are refined as they move down the supply chain from end users (e.g. the airlines) to platform integrators (i.e. aircraft Original Equipment Manufacturers or OEMs), to major system integrators, to subsystem integrators, to component suppliers. Each level in the supply chain is a customer for the lower levels' products, and translates the market requirements from its customers into requirements imposed on its suppliers. The market requirements information is largely non-proprietary and therefore capable of being shared by the participants of the Technology Road Map project. The TRM work plan implemented Step 1 as follows:

- ***Market Requirements Determination:*** The participating firms were asked to list for the time frame 2001–05 all anticipated customer requirements (including anticipated environmental and regulatory issues), regardless of the estimated costs of meeting these requirements. The "customer" was defined as the normal buyer of the products (e.g. typically the next higher tier level in the supply chain).

- ***Market Requirements Presentations:*** Selected CEOs presented their forecast market requirements at the TRM launch meeting on May 17, 1966. (This meeting also confirmed the go-ahead for the rest of the exercise.)

- ***Market Requirements Document:*** The presentations and discussions of the TRM launch meeting are reported in the "Proceedings of the Launch Meeting" (the Market Requirements document shown in Figure 1). They form the marketplace requirements basis for the TRM, and are consolidated in Section 3 of this report, "Market Basis / Drivers."

2.2 Step 2: Product Implications

Step 2 determined the characteristics of the products (the "supply" side of the equation) to be developed by the industry sector firms to successfully compete in this future market. This step dealt with proprietary information, and the information was shared by participating firms to the extent they wished to do so.

The TRM work plan called for the development of a **Product Plan**. Participating firms were asked to examine their strategic business plans and to identify their next-generation products, including the incremental modifications and changes to current products required to successfully compete in the future marketplace. To the extent that this product plan dealt with proprietary company products and plans, it was not shared with other firms.

2.3 Step 3: Technology Implications

Step 3 determined which key or critical technologies will have to be in place to competitively design, manufacture and support these products. These technologies were described in sufficient detail so that sector firms will be able to evaluate their current capabilities therein and determine their own technology gap, which they must close. This description of technologies did not deal with proprietary products information, and therefore could be shared. In fact, it became the Technology Road Map. The TRM work plan completed Step 3 in the following manner:

- ***Technologies List:*** From the Product Plan, the firms generated a list of required product and process technologies to develop, manufacture and support the products.

- ***Technologies Master List:*** The Industry Canada TRM support team combined the individual technologies lists into a generic, non-attributable master list, grouped under eight technology areas.

- ***Technologies Rationalization and Selection Meeting:*** The second all-participants meeting was held on June 26, 1996. The major tasks included selecting a number of critical technologies from the technologies master list for further analysis using the assessment criteria shown in Figure 2, and constituting eight Technology Working Groups to analyze the selected technologies. (The TWGs and technologies[3] are shown in Figure 3.)

- ***Technology Working Group Reports:*** Three months were allocated for the TWGs to produce their critical technology reports. Technology analysis was done in accordance with a template (Figure 4). The work was completed partly at meetings and partly through individual efforts.

- ***Draft TRM Report Meeting:*** The support team prepared a draft report that combined the TWG reports with contextual information into a two-volume document. The draft report was discussed at an October 29, 1996, meeting of all TWG members.

- ***CEO Meeting:*** The industry gave final approval to the Technology Road Map document November 26, 1996.

The feedback loops in Figure 1 illustrate the requirement to repeat the exercise periodically as markets and technologies evolve.

[3] The list of technologies was slightly modified during the work of the TWGs. Some technologies were combined with others and some were dropped. Figure 3 shows the final list.

Technology Ranking Criteria

Technology Working Group:

Technology:

Score (Range is 1 to 3):

1. Criticality assessment:

1.1 Environmental or other regulatory requirement:
(1 = advisory only; 3 = must have) ....

1.2 Customer requirement:
(1 = not customer driven; 3 = must have) ....

1.3 Competitiveness enhancement:
(1 = low; 3 = high) ....

2. Impact of not acquiring this technology:
(1 = firm loses competitive advantage;
2 = firm must exit a particular market;
3 = firm goes out of business) ....

3. Applicability:
(1 = single firm requirement;
2 = multiple-firm requirement;
3 = includes other industry sectors besides aircraft) ....

4. Time frame when technology is required:
(1 = required within five to ten years;
3 = required within one to two years) ....

5. Alternatives to the technology:
(1 = there are viable alternatives;
3 = no alternatives) ....

Total Score (Max.= 21): ....

"Show Stoppers":

The technology is achievable:	Yes ❐ No ❐
The technology will be available when required:	Yes ❐ No ❐
The technology is affordable:	Yes ❐ No ❐

Figure 2

TWGs and Critical Technology Reports

Design TWG:	Multidisciplinary Design and Optimization Advanced Wing Design Advanced Analytical Modelling and Design Practices — Engines Structural Analysis and Optimization — Airframe Structural Analysis and Optimization — Engines Computational Fluid Dynamics Analysis, Design and Validation — Aircraft Computational Fluid Dynamics Analysis, Design and Validation — Engines Advanced Landing Gear and Airframe Integration
Environment TWG:	Aircraft Noise Abatement — Development of Lower Engine Noise Technology Aircraft Emissions Reduction Replacement of Cadmium Coatings Replacement of Chromium Coatings
Maintenance, Repair &Overhead TWG:	Health and Usage Monitoring Systems Composite Structures — Non-destructive Test and Evaluation Repair of Metallic Materials Coatings and Surface Modification Technology for Repair Composite Structural Repair — Material Systems Composite Patches on Metallic Components
Management TWG :	ISO 9000 Quality Standards Continuous Improvement Product and Electronic Data Interchange Concurrent Engineering and Virtual Design Statistical Process Control
Manufacturing TWG:	Manufacturing Information Systems Casting Technologies Joining All Materials In-process Inspection Coating Processes Laser Materials Processing Fibre Composites High Velocity Machining Advanced Metal Forming Intelligent Process Control Metal Matrix Composites Ceramic Matrix Composites
Materials and Structures TWG:	Coatings and Surface Modification Treatments Composite and Hybrid Structures Smart Structures Energy-absorbing Structures Metallic Materials
Systems TWG:	Flight Systems: Flight Control Systems Environmental Control System Landing Gear Integration of Avionics (Including Communications, Navigation and Displays) Active Noise and Vibration Control Health Monitoring Systems
Visualization TWG:	Image Generation and Manipulation Advanced Display Media Virtual Mockup Virtual Environment

Figure 3

Critical Technology Report Template

Technology Working Group:
TWG name.
Critical Technology:
Technology name.
Goals:
The performance goals of the technology:
- are driven by customer requirements
- should be defined in quantitative and qualitative terms (without disclosing proprietary information)
- include economic (cost, etc.), time (cycle time improvements, etc.) and physical property (weight reduction, etc.) considerations.
Description:
Brief technical description of the technology.
Importance:
Why is the technology critical (e.g. regulatory requirements, customer demands, financial and other competitiveness issues)? When is the technology required? To whom is the technology critical? What happens if the technology is not available or implemented?
Alternatives:
Other technologies, non-technological solutions, product substitution, etc.
Each TWG should be familiar with the technologies under investigation by the other TWGs, so that linkages can be made among alternative or competing technologies.
Maturity and Risk:
What can the technology do today?
What incremental capabilities are required to produce the products required for the 2001–05 period?
What risks are associated in obtaining these incremental capabilities?
Availability:
Where is the technology currently available, from whom, how, cost considerations, etc.?
Breadth of Application:
How broadly can the technology be applied? Which areas of the Ontario aerospace industry? What other industry sectors, etc.?
Collaborators:
Potential sources of help in developing or acquiring as well as implementing the technology.
Examples: NRC, primes working with suppliers, etc.
Cost-Benefit Analysis:
Costs could include technology development or acquisition as well as implementation. Benefits are based on an estimate of market usage of the enabling technology.
References:
List of pertinent documents.
Contacts:
Resource persons for further information.

Figure 4

3. MARKET BASIS / DRIVERS

The Technology Road Map is not intended to be an extrapolation of existing product and manufacturing technologies. The TRM's guiding principle is that the process and results be driven by the needs of the marketplace in the period 2001–05. As noted in Section 2, "Methodology," the process started, appropriately, with descriptions from several industry leaders of the expected demands that this future market would place on their products in terms of performance and capabilities. (These views were fully reported in the Canadian Aircraft Design, Manufacturing and Repair & Overhaul Technology Road Map (Ontario Pilot Project) "Proceedings of the Launch Meeting" May 17, 1996.) For reference, the following summary is provided.

There are two marketplaces that must be satisfied: the **regulatory environment** in which the products are manufactured and operated, and the **customer.** The customer varies, depending on the level at which a firm operates in the supply chain. For an airline, it is the fare-paying passenger. For the aircraft manufacturer, it may be an airline, a corporation or a single owner. For a systems or components manufacturer, it may be any of the above or the aircraft manufacturer, as shown below.

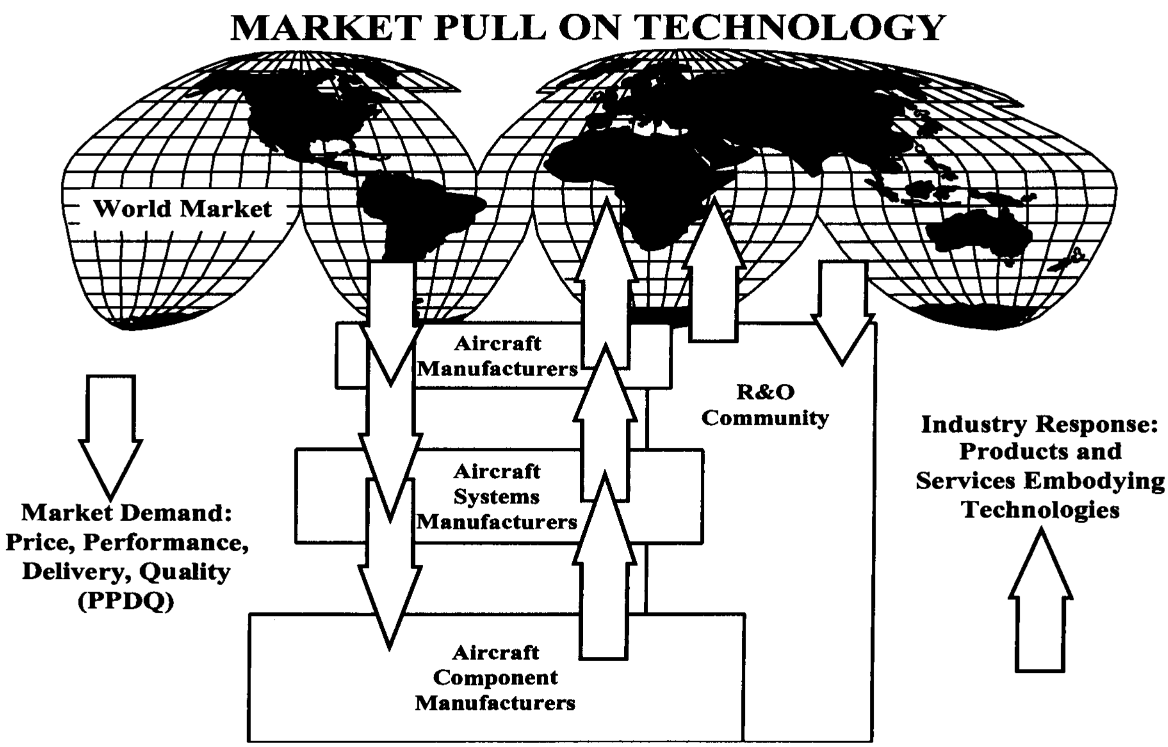

Figure 5

3.1 Regulatory Environment

The regulatory environment refers to all external influences imposed by regulatory agencies on the manufacture and operation of an aircraft. Technologies are required that will:

- reduce external noise, as measured on the ground during takeoff, flyover and landing
- reduce emissions from engine exhaust, crankcases, transmission housings and fuel tanks
- reduce or eliminate the use of hazardous materials in manufacturing, repair and maintenance
- eliminate manufacturing processes that use or produce toxic waste products
- improve flight safety by providing more accurate navigation systems and better pilot warning systems for ground proximity, wind shear, clear air turbulence, and avoidance of mid-air and ground taxi collision
- reduce flammability of cabins and other structures
- improve crashworthiness through new energy-absorbing materials and designs.

3.2 Customer

From the operator's perspective, **heavier** (payload), **further**, **cheaper, faster** and **more comfortable** are the key words. The ability to safely carry a full passenger load in comfort over long distances at the fastest speed, and at the lowest possible ticket price are crucial to airline competitiveness. At the same time, initial acquisition and operating costs must be held in check. Technologies that are incorporated must be cost-effective, not selected on the basis of "technology for technology's sake."

3.2.1 Heavier and Further

The maximum gross weight, range and fuel economy of a particular aircraft type are inextricably entwined. An aircraft's "payload" is more or less the difference between the empty structure weight (including all necessary systems and equipment) and the maximum gross weight. Since operators are more concerned with the payload they can carry than with the gross weight, reducing structure weight (of the aircraft and its systems and components) is a major concern for manufacturers. Technologies are required that will:

- decrease structure weight by 15–20 percent
- decrease powerplant weight

- increase powerplant fuel efficiency
- decrease landing gear weight
- decrease onboard systems weight by 20 percent.

3.2.2 Cheaper

Initial acquisition cost (comprised of non-recurring engineering and tooling costs on airframe, power plant and systems development, as well as fixed and variable costs during manufacturing) must be reduced by 15–30 percent. To achieve these economies, technologies are required that will:

- shorten the design cycle time by 20–50 percent
- reduce the manufacturing cycle time (and hence the work-in-process inventory) by up to 50 percent
- reduce the recurring costs of production by 25–30 percent
- reduce the need for physical tests, prototypes and mockups.

Direct operating cost also must be reduced. To achieve economies here (normally through improved fuel economy and reduced maintenance costs), technologies are required that will:

- increase powerplant fuel efficiency
- increase systems and component reliability by a factor of 2
- reduce maintenance costs by 20–30 percent
- provide more direct airport to airport routings
- reduce the needless removal and replacement of equipment assumed to be defective because of false or inaccurate warnings from built-in-test systems
- enable self-diagnosis of systems and equipment faults that provides maintenance engineering staff with a record, including the circumstances surrounding equipment fault or failure
- enable monitoring of equipment usage, with a view to predicting remaining useful safe life — "on-condition maintenance"
- reduce turnaround time at the airport (this includes refuelling and lubricants replenishment, galley servicing, cabin and washroom cleaning, passenger exit and boarding)
- reduce fuel-burn costs during taxiing and other non-value-added segments of the journey.

3.2.3 Faster

Airline schedules depend in part on the distance flown and the speed of flight. (Curfews, gate allocation at busy terminals and other externalities also affect scheduling, but are beyond the scope of this road map.) Technologies are required that will:

- reduce the influence of adverse weather on flight dispatch schedules and routes flown
- reduce the distance flown by enabling direct airport to airport flights, rather than following the arbitrary airways currently in use (while still maintaining the same level of safety as provided by the existing, fully-controlled Instrument Flight Rules environment)
- increase flying speed.

3.2.4 More Comfortable

Passenger comfort includes both environment (leg room, noise, etc.) and entertainment. A passenger may define the ultimate in comfort as being in his/her home or office, with his/her own amenities at hand. To the extent that this situation can be reproduced within the airborne environment, comfort levels will be improved. Technologies are required that will:

- reduce cabin noise and vibration, both passively and actively
- provide increased seat room
- provide at-seat entertainment and information systems equivalent to those found at home or in the office (multi-channel television, large-screen, high-definition-television-capable displays, computer display and communication capabilities, telephone, etc.).

3.3 Comparative International Goals

For comparison purposes, here are the goals set by the United Kingdom Innovative Manufacturing Initiative in September 1995 (note that these are **minimums**).

Target: Real cost and time reductions in next five years	Airframe	Power plant	Equipment
Manufacturing cost	35%	33%	28%
Manufacturing lead time	44%	50%	27%
Time to market	43%	55%	31%
Product introduction cost	50%	56%	26%
Cost of ownership	23%	40%	18%
Cost of design change	51%	48%	36%

4. RESULTS

The Technology Working Groups identified technologies that, from the viewpoint of Canada's Ontario-based aerospace firms, are critical for creating superior products, are required for the years 2001–05 and are able to meet the cost, performance and comfort expectations of operators and their passengers. The membership of the Technology Working Groups is listed in the Annex. The following sections summarize the eight technology areas.

4.1 Design

The market requirements projected for the years 2001–05 pose many challenges for the prime manufacturer. Foremost is accomplishing an integrated, balanced design that uses new technology judiciously for improved performance and costs, but without exposing undue program risks. This requires increasing reliance on advances in computational fluid dynamics for new aerodynamic designs of airframes and engines, using multidisciplinary design and optimization methods for improving integration of technologies, and exploiting new materials and joining technologies to improve weight, cost and durability. Active controls and smart structures will be used to improve performance, reduce weight and increase fatigue life. In order to reduce risks and uncertainties, technology demonstrator programs will be widely used to prove advanced features in airframes and engines by showing expected gains are achievable and affordable.

The prime manufacturer must also adopt new business processes to shorten cycle times for design and manufacture, which will reduce their cost and also give earlier access to market and increase sales. An integrated product development approach involving design-build teams, where engineering, manufacturing and procurement/finance work closely together to achieve the best design for cost and performance, appears most promising. However, the norm today is — and will be tomorrow — working with partners to spread risk, work and costs. The result is often a mixed team with several multinational partners and suppliers. Tasks become widely dispersed, and this requires highly effective electronic communications for the exchange of up-to-date information, using product data interchange for technical definitions and electronic data interchange for forms, etc., along with good security against unwarranted access. This also points to the need for compatible three-dimensional computer automated design (3-D CAD) systems, and common data bases for design, manufacturing, procurement and finance.

The eight critical design technologies chosen by the Design Technology Working Group for investigation are described in the following subsections.

4.1.1 Multidisciplinary Design and Optimization

Multidisciplinary design and optimization describes an integrated set of computer programs that correctly size and optimize the structural design of aircraft or engines to meet design requirements, while constrained by factors such as weight, cost, material properties and vibration or flutter considerations. The preliminary definitions of structure, systems and loads will become available for detailed design much earlier, substantially reducing design cycle time and also facilitating working with partners.

4.1.2 Advanced Wing Design

The ability to design and manufacture advanced wings is a critical technology for producing highly competitive aircraft in the future. The wing's aerodynamics must be state-of-the-art in cruise performance and high lift design, fully integrated and optimized with the rest of the airframe, with allowance for fuselage and powerplant interference effects. The wing structure and its systems must use new materials that reduce both weight and cost substantially, and their design must simplify and reduce maintenance requirements. Active controls and smart structures are expected to be integrated with the design to reduce weight and improve fatigue life.

4.1.3 Advanced Analytical Modelling and Design Practices — Engines

To further shorten development cycle times requires the ability to fully model, in three dimensions, all representations of an engine. This modelling capability must incorporate a set of rules representing pre-established design practices, and must use knowledge-based expert systems to identify potential problem areas at the early design stages as well as to ensure that the designed parts can be manufactured.

4.1.4 Structural Analysis and Optimization — Airframe

To maintain competitive leadership in future new aircraft designs requires the ability to define, early in the design cycle, an optimized airframe structure having light weight as well as improved fatigue and damage tolerance capabilities. This will be achieved by the extensive use of computerized methods for structural analysis and design optimization as well as for analysis of failure and fracture mechanics.

4.1.5 Structural Analysis and Optimization — Engines

In addition to the capabilities summarized above for airframes, the required goal is to develop computerized structural analysis and optimization methods to allow a complete, non-linear transient analysis of gas flow through the entire engine, combining heat transfer analysis, computational fluid dynamics and mechanical design parameters. This will include the analysis of cooled airfoils and active control of clearances and tolerances in complex assemblies.

4.1.6 Computational Fluid Dynamics Analysis, Design and Validation — Aircraft

Advanced computational fluid dynamics methods, including faster Navier-Stokes codes, adaptive gridding and rapid inverse design, comprise the key enabling technologies for aerodynamic design and optimization. They hold exceptional promise for improving aircraft performance and reducing the design cycle time for wings, high lift systems and engine installations. Methods based on three-dimensional Navier Stokes computations with adaptive gridding are expected to be in general use for design and analysis.

4.1.7 Computational Fluid Dynamics Analysis, Design and Validation — Engines

Future gas turbine engines will need refined aerodynamic design and optimization to achieve the substantial improvements in engine efficiency, noise reduction, development costs and operating costs required by the customers. Advanced computational fluid dynamics tools are crucial for designing fuel-efficient gas turbine engines.

4.1.8 Advanced Landing Gear and Airframe Integration

Landing gear manufacturers must provide fully integrated landing gear systems to aircraft manufacturers, incorporating advanced features such as active or semi-active damping, steerable main gear and improved materials. These require advanced analytical methods in the design process, including dynamic simulation techniques utilizing finite element method analysis.

4.2 Environment

Compliance with increasingly stringent international and domestic environmental regulations is one of the major challenges facing the firms involved in aircraft engine manufacturing as well as the small and medium-sized enterprises involved in the supply of metal surface finishing services.

These environmental regulatory pressures and the cost of compliance are expected to become even more severe within the next decade as the public's desire for a cleaner environment and improved workplace safety become more pronounced. In particular, the level of engine emissions, engine noise and the use of toxic chemicals in metal finishing processes will become prime targets for severe controls by environmental agencies. Consequently, these firms must pursue advancements and innovative solutions in response to these environmental regulations, while remaining competitive within international aerospace markets.

The Environmental Technology Working Group investigated four critical technologies, described in the following subsections.

4.2.1 Aircraft Noise Abatement — Development of Lower Engine Noise Technology

The potentially viable noise abatement technologies considered for investigation include innovative design concepts for quieter engine fans and compressors using computational fluid dynamics codes and computer aeroacoustics calculations for better prediction of flow interaction and acoustic propagation phenomena. Efficient attenuation liners, engine inlet/propeller interaction, efficient forced mixer nozzles and active noise control technologies were also considered for investigation.

4.2.2 Aircraft Emissions Reduction

Critical technologies considered for investigation and development in the reduction of nitrogen oxide (NOx) compounds, carbon monoxide (CO) and volatile organic compounds (VOCs) and smoke from engine emissions include: advanced combustor wall cooling through the use of advanced materials or new cooling techniques; expanded use of computational fluid dynamics codes for modelling pollutant formation chemistry; weak extinction performance and combustion instability to enable accurate prediction of the formation of NOx, CO and VOCs; improved fuel mixing designs to ensure good air-fuel mixing in the combustors; and multi-stage combustor concepts, which have very good potential for low emissions but may result in increased costs. To achieve these objectives, supporting technologies such as advanced combustion technologies test facilities and precision manufacturing capability will be necessary.

4.2.3 Replacement of Cadmium Coatings

Cadmium metal as an electrodeposit has been in industrial use as a corrosion preventive for many years. It gained particular prominence in the aerospace industry because of its galvanic similarity to aluminum and, for that reason, has been applied to many substrate metals. On the negative side, the metal and cyanide plating solutions are highly toxic, and present a considerable environmental risk. Elimination of cadmium coating processes could have a tremendous impact on Canadian aerospace programs. Some of the alternative technologies include electroless nickel, physical vapour deposition, aluminizing pack diffusion and ion implantation.

4.2.4 Replacement of Chromium Coatings

Chromium electroplating processes are routinely used to coat aircraft parts for wear resistance and hydraulic applications. The environmental and health reasons for replacing chromium are being accelerated by regulatory requirements. Some critical technologies considered as viable alternatives for further development are dry processes such as high-velocity oxy fuel and physical vapour deposition. The high-velocity oxy fuel process is a powder process that eliminates the liquid and mist (hexavalent chromium) toxic waste.

4.3 Maintenance and Repair & Overhaul

Maintenance refers to the day-to-day inspection of systems, equipment and structure, replenishment of fluids and general care of the equipment. Repair refers to restoration to an airworthy condition of an item or structure that has been damaged or become worn. Overhaul means disassembly, repair or replacement of damaged parts, reassembly and test of equipment and systems.

Maintenance and repair & overhaul needs must be taken into account at every step of aircraft design and manufacturing if an economic life cycle is to be achieved for the product. If the design is such that maintenance or repair are difficult, time-consuming or impossible, the aircraft will be uneconomic to operate and will find few customers.

In general, maintenance and repair & overhaul is a three-step process:

- The maintenance philosophy for the aircraft, system, part or component takes an operator to the point of deciding that something must be done to rectify a situation.
- Fault detection determines what must be done.
- Fault repair decides how to actually do it.

The maintenance philosophy has traditionally been based on a manufacturer's maintenance plan approved by the airworthiness authority, and on the manufacturer's assumptions about how the aircraft, equipment and systems are used in service. Because they are assumptions, they tend to be conservative, based on worst-case scenarios. For a careful operator, the result is higher-than-needed maintenance costs. A philosophy based on the actual service life of an individual aircraft would lead to lower maintenance costs. One way to implement such a philosophy is through use of a health and usage monitoring system.

Fault detection requires use of non-destructive test and evaluation techniques that, increasingly, must be reliable (always detect the fault, never give false indications), simple (low training requirements) and low-cost both to acquire and to operate.

Fault repair becomes increasingly challenging as new and exotic materials with higher performance demands made upon them move into the operational world. At any of these steps, companies may find a market niche and pursue a profitable business. Accordingly, the critical technology reports are high-level summaries rather than detailed analyses of a particular technology.

The Maintenance and Repair & Overhaul Technology Working Group investigated six critical technologies, described in the following subsections.

4.3.1 Health and Usage Monitoring Systems

A health and usage monitoring system installation will use multiple sensors connected to a central data recording system, to collect quantitative data in flight from systems and components throughout the flight vehicle. The data records the condition of the overall vehicle and individual components as well as the types of operations the vehicle has performed. The data is down loaded to ground-based computers for further analysis. Typically, the data records limit exceedances, and can be used to predict the health and remaining life of components.

4.3.2 Composite Structures — Non-destructive Test and Evaluation

The goal is to provide a simple technique to detect and quantify damages in composite structures. This technique must be low-cost, require minimum operator training, and address both impact and corrosion damages. It would replace the current, widely used, "coin tap" test, which has severe limitations. Currently available technologies meet some or all of the desired criteria, but are usually very expensive and require elaborate equipment.

4.3.3 Repair of Metallic Materials

Modern, specialized repair techniques strive to return a component to near-new condition using state-of-the-art cleaning, welding, brazing, machining and coating techniques. In making a repair, however, two main criteria have to be fulfilled: the continuing airworthiness of the component should not be affected; and the cost-benefit of implementing the repair must be demonstrated. The TWG identified a number of critical technologies involved in specialized repairs (those that exceed the "by-the-book" repair limits and schemes), each of which can be a niche market unto itself.

4.3.4 Coatings and Surface Modification Technology for Repair

Virtually all of the modifications mentioned in the Materials and Structures TWG critical report on coatings and surface modifications are applicable to repaired components, with the understanding that coating compositions suitable for a repair may not be the same as the optimum choice for a new part.

Coatings have the potential to improve the performance of a repaired part to even better than the original if a substantially improved coating is used. If the original part was uncoated, the repair may involve a coating to protect against an environmental attack that the uncoated original base material may well have resisted. The challenge lies in adapting these existing processes to specific products and repairs, and obtaining regulatory approval for them.

4.3.5 Composite Structural Repair — Material Systems

Existing high-temperature-cure composite repair technology provides acceptable solutions for the sophisticated airline or repair facility, but it is impractical for the owner/operator of either a smaller aircraft or a relatively small fleet. The focus of this critical technology is to define the characteristics of, identify, and/or develop a resin system that will simplify hangar and depot level repairs and that would be extremely user-friendly for smaller operators.

4.3.6 Composite Patches on Metallic Components

Although the use of composite patches to effect repairs on damaged or corroded metallic aircraft structures has gained fairly wide acceptance by military agencies, the use of this technology is in its infancy in civil aircraft structure applications. Significant challenges remain in obtaining civil airworthiness approval for its use. With the possibility of providing simpler, less obtrusive repairs in terms of weight, drag and use of fasteners, composite patches may also reduce repair costs through shorter application times. Three potential categories of applications have been identified: fatigue life enhancement; corrosion repair; and crack patching.

4.4 Management

In the past, companies in the aerospace sector have used varied and incompatible standards. These standards include quality assurance, data management, and engineering and manufacturing processes. The Management Technology Working Group recognized the importance of the need to create a management technology road map for the primes and, more importantly, for the second and third tier suppliers who will have to meet the ever-changing demands of the primes. The critical technologies chosen by the TWG are in essence a summary of the business philosophies that will govern the evolution of the Canadian aerospace industry over the next decade. In each case, despite the potential risk, it was agreed that second and third tier suppliers will have no other choice but to follow the Technology Road Map to remain competitive.

The Management Technology Working Group investigated five critical technologies, described in the following subsections.

4.4.1 ISO 9000 Quality Standards

The ISO 9000 series of quality standards is rapidly gaining international prominence. ISO 9000 is more than just a quality standard: it provides a common basis for understanding, designing and implementing basic quality systems. Used properly, the ISO 9000 standards allow companies to focus more effort on the unique features of their quality systems and to facilitate continuous improvement of processes and products. There have recently been major developments in the quality standards area, particularly with respect to the aerospace industry. This will continue. Many companies are already going beyond the issue of getting registered and are now getting the most value out of their ISO 9000 initiatives. They are adopting an advanced quality systems approach, with ISO 9000 as the basis. Aerospace suppliers need to be aware of this and respond accordingly.

4.4.2 Continuous Improvement

If companies are to remain viable in today's marketplace, they need to analyze and continuously improve all of their products, services and processes (administrative, technical, managerial and manufacturing). Employees at all levels — often working in teams backed up by management and supported by specialists — must be empowered to analyze and improve their own work processes. Measurements are used extensively by everyone to guide process improvement and monitor progress in achieving the company's goals.

4.4.3 Product and Electronic Data Interchange

Increasingly, competitive needs for sharing work and risk will require leaders of new aircraft programs to have versatile and effective electronic links with their partners and suppliers. These links will enable two-way product data interchange, including digital and video information for design, manufacture and business management. To stay competitive, lower tier suppliers must both connect into this data interchange system and expand their technical capabilities to work in an integrated product development environment.

4.4.4 Concurrent Engineering and Virtual Design

Taking competitiveness to a higher level demands a systematic approach to the early integration and concurrent application of all the disciplines that play a part in a system's life cycle. Competitive pressures from customers and primes will require that suppliers on any aerospace project be familiar with and utilize a concurrent engineering approach. The trend in the industry is for each successive tier to delegate downwards the responsibility for design and integration of systems to the lowest possible level. This approach will yield shorter development time, improved quality, lower manufacturing costs, and higher revenues.

4.4.5 Statistical Process Control

Producing high-quality products and services using high-quality processes requires understanding and then control of the factors that cause variation affecting quality. These can be accomplished using statistical methods commonly referred to as statistical process control. It can be used for both quality control and quality improvement. Aircraft manufacturers are increasingly turning to the use of statistical methods to monitor changes or variations in their manufacturing processes and bring them under control. Suppliers must be aware of and utilize these tools if they hope to remain competitive.

4.5 Manufacturing

Improved manufacturing capabilities are essential to the industry's success in producing superior products that will meet the cost, quality and performance expectations of their customers in the 2001–05 time frame. The number and diversity of these reports underscore the breadth and complexity of aircraft manufacturing.

The single, most important consideration in maintaining global competitiveness to emerge from this exercise is the requirement to be able to generate, transmit and utilize technical data by an effective, common methodology (OEM to supplier, designer to machine). All aspects of the process — design, analysis, process modelling, process planning/programming, process monitoring, process control/ real-time feedback and inspection — must be based on a common, three-dimensional definition that not only will maintain design integrity, but also will eliminate many wasteful reprogramming steps.

In addition, Canadian companies that specialize in certain processes (such as composites, ceramics, castings, forgings, specialty coatings, etc.) have capabilities that, if strengthened through the development and introduction of technologies specific to their speciality, could increase the Canadian share of world markets for these types of manufacturing.

The Manufacturing Technology Working Group investigated 12 critical technologies, described in the following subsections. As there were no representatives of the electronics industry in this TWG, manufacturing of electronic components or assemblies was not addressed.

4.5.1 Manufacturing Information Systems

Effective manufacturing information systems require two groups of technologies: those that enable electronic data interchange; and those that reduce the complexity of the planning process. These can be further defined as product data exchange standards, knowledge-based planning systems, manufacturing process modelling and open architecture control. The continued development of these technologies is essential to improve companies' internal operations and enable the sharing of product development with partners.

4.5.2 Casting Technologies

To compete internationally in the aerospace market, Ontario casting firms must develop capabilities in the following areas:

- the casting of components for repair and replacement applications, where key technologies include part measurement, electronic files generation for tool manufacturing, numerically controlled machine programming capabilities and measurement data interpolation

- the casting of very complex and/or very large parts, where key technologies include improved casting layout, improved design technologies and advanced simulation software.

Other technologies that require investigation include vacuum investment casting for turbine-engine hot-section components and hot isostatic press capability. As well, better coordination between manufacturers and Canadian suppliers of aerospace tooling is essential.

4.5.3 Joining All Materials

Newer materials are being used, or contemplated for use, in aircraft structures that are significantly more difficult to join than traditional material. A wide range of technology focus areas are listed that would address the shortcomings of current processes.

4.5.4 In-process Inspection

To maintain their competitive position, Ontario manufacturers must adopt in-process inspection technology to reduce cycle times and improve yields. The technologies required to provide this capability include automated flexible inspection devices, on-machine measurement, various software developments, and a variety of other inspection devices that can be adopted for the environment. Many of the technologies discussed are individually available, but they have not been integrated and optimized for the aircraft manufacturing environment.

4.5.5 Coating Processes

Aircraft parts manufacturing involves the continual adoption of new coatings and surface modification technologies to improve durability and performance, reduce operating costs, meet new environmental standards, and facilitate the development of new products/product lines. This study examines six major coating processes with respect to their application to aircraft manufacturing. The most promising technologies include arc bond sputtering (a hybrid of unbalanced magnetron sputtering), steered-arc vacuum arc deposition, chemical vapour deposition and ion vapour deposition.

4.5.6 *Laser Materials Processing*

Laser processing is an increasingly critical technology for aircraft manufacture, with the potential to improve component manufacturing quality and productivity, provide just-in-time flexibility, reduce cycle times, labour and tool costs, and adapt more readily to the demands of computer assisted design and manufacturing (CAD/CAM). Laser technology applications include fabrication (drilling, cutting/trimming, welding, micro-machining), surface modification (shock hardening, cladding, alloying, glazing, transformation hardening, laser physical vapour deposition) and forming (re-fabrication, free-form consolidation).

4.5.7 *Fibre Composites*

Fibre composite components are increasingly being incorporated in aircraft designs as a result of their significantly improved efficiency and lower life cycle costs. This study focuses on conventional pre-impregnation and just-in-time impregnation processes. Process modelling, fibre optic temperature and pressure sensors, and closed-loop cure control are specific technologies that require development to take full advantage of fibre composite construction.

4.5.8 *High Velocity Machining*

To remain competitive, airframe manufacturers have set new component/part design and manufacturing goals for themselves and for their suppliers: weight reductions of 15–20 percent; cycle time reductions of 25 percent; cost reductions of 20–30 percent; and direct operating cost reductions of 10–15 percent. High velocity machining provides significant and unique capabilities in all of these areas. To optimize these benefits, advances are required in tool design and machine tool structural design to minimize vibration, in the lubrication/cooling system to control heat production, in increased spindle/bearing life, and in improved ability to machine "hard" (i.e.: high-strength steel) materials.

4.5.9 *Advanced Metal Forming*

This study examines two areas of metal forming important to aircraft manufacture: cold forming of sheet metal and forging. In the case of cold forming, many technologies critical to process optimization are already in use in other industries (e.g. automotive), and the risk associated with developing others is acceptable. With respect to forging, Canada has a limited capability that could best be expanded by the transfer of appropriate technologies from more capable firms. Cost-benefit analyses and market studies should precede investment.

4.5.10 Intelligent Process Control

Intelligent process control is the key technology for optimizing manufacturing cycles, and is essential if Ontario component manufacturers are to meet the cost and quality goals being set by their customers. Intelligent process control is applicable to all manufacturing processes controlled by computer, cycle time reductions of 50–80 percent are achievable, and scrap can be virtually eliminated. Intelligent process control requires the development and integration of support technologies including precise process modelling, process monitoring systems, adaptive control methods, active vibration control systems and an open architecture control environment.

4.5.11 Metal Matrix Composites

Manufacturing processes are being sought that can adapt continuous fibre reinforced metal matrix composites to the aircraft industry. This material offers significant strength-to-weight improvements over conventional materials, both for the new product and retrofit markets. There is no alternative to the use of metal matrix composites to achieve these gains. Five metal matrix composite manufacturing processes have potential: foil-fibre-foil; wire winding; matrix-coated fibre; plasma spraying; and powder metallurgy.

4.5.12 Ceramic Matrix Composites

Ceramic matrix composites potentially offer superior performance in high-wear, high-temperature/ thermal-shock/steep-temperature-gradient environments. Although the potential for these materials is significant and is attractive to aircraft manufacturing and other industries, neither material production nor processing technologies are mature.

4.6 Materials and Structures

The use of advanced materials and structural technologies is important throughout the sector. New materials must be characterized, and effective means of incorporating them into practical products must be devised as they emerge. New structural concepts must continuously be conceived and evaluated. Coating technologies will be relied upon to deliver more versatile and durable structures under the constraints of cost and ever-tightening environmental requirements. Increasing use will be made of advanced composite and hybrid materials in order to take advantage of potentially large weight reductions, enhanced corrosion resistance and improved producibility. Smart structures will emerge in applications requiring their adaptability and where no other known technology can give comparable performance. Similarly, energy-absorbing structural technologies will be essential in meeting anticipated new, more stringent regulatory and performance requirements. New metallic materials will offer incremental performance improvements over current metals. In many such applications, no other materials are suitable now or in the foreseeable future.

The Materials and Structures Technology Working Group investigated five critical technologies, described in the following subsections.

4.6.1 Coatings and Surface Modification Treatments

Coatings and surface modification technologies will play an extremely important role in coming years. For the original equipment manufacturer, they offer a method of increasing efficiencies and improving structural integrity. They allow repair and overhaul contractors to offer their customers a repaired product that would be comparable in performance to a new part, for a fraction of the cost of a new part. For the aircraft operator, coatings will provide a direct cost-benefit from reduced spares requirements and a lower rate of in-flight incidents.

4.6.2 Composite and Hybrid Structures

This critical technology offers reduced structural weight (by 20–30 percent) through density reduction and higher permitted operating stress. For composites, a smoother external finish can yield lower drag and a more attractive appearance. Process improvements are expected to yield reduced manufacturing costs through parts count reduction and, for fibre metal laminates, the elimination of doublers. Significant improvements in product durability can be expected through improved fatigue resistance, resistance to impact damage in the case of fibre metal laminates, and improved resistance and/or tolerance to corrosion. Finally, fibre metal laminates can be exploited for fire and bomb containment, exploiting the capability of certain composites to endure elevated temperatures, avoiding the use of expensive, heavy stainless steel or titanium.

4.6.3 Smart Structures

The advantage of smart structures over more conventional structures is that they can adapt to their environment as the conditions around them change. Of the different smart structure technologies undergoing development, shape control, vibration control, loads alleviation, and loads and health monitoring are considered the most promising for aeronautical applications.

4.6.4 Energy-absorbing Structures

Regulatory requirements for crash survival, engine burst containment and bird strikes must be met. Strictness of these regulations and product liability concerns will increase in the near future. Also, vibration in fixed-wing aircraft and helicopters is a problem for crew and passengers, and can lead to shortened service life for structural components and system components. One method of solving these problems is energy-absorbing materials. A fundamental, competitive reality is the need to produce light-weight structures, while meeting energy-absorbing requirements.

4.6.5 Metallic Materials

New metallic materials offer, at a minimum, incremental improvements over conventional alloys in material properties such as strength, density, corrosion resistance, resistance to stress corrosion cracking, fracture toughness, elevated temperature resistance, weldability, formability, etc. This critical technology is comprised of three general categories of metallic materials: lightweight alloys; high-strength structural alloys; and high-temperature alloys.

4.7 Systems

The design and manufacture of aircraft is increasingly a cooperative arrangement, with responsibility and risk shared by several key partners. This intercompany teaming demands the implementation of systems engineering leadership to develop and ensure performance and interface of the many systems into one integrated aircraft. New engineering management skills and techniques are required which are not currently resident in aircraft manufacturing companies, particularly in the smaller and mid-sized firms. Systems engineering is not simply a mode of operation, it is also an engineering discipline requiring unique and modern technical skills and tools. Systems engineering skills, knowledge, training and implementation may be the greatest technological challenge facing the industry today.

The TWG identified a number of systems which were subsequently grouped into six categories on the basis of similar technology requirements. Each category offers significant technology advances that are within reach of appropriate Ontario companies. Of the six categories, four were selected for further investigation and are described in the following subsections.

4.7.1 Flight Systems

Flight systems operate and control an aircraft during flight. They include control surface systems, propulsion control systems, landing gear systems and interior environmental control systems. Technologies associated with these systems are diverse, including such innovations as fly-by-light, subsystem functional interchange (e.g. propulsive directional control), directional control for landing gears and electronics for environmental control.

4.7.2 Integration of Avionics (Including Communications, Navigation and Displays)

Currently, avionics are characterized by many individual subsystems, with separate instruments or displays for each function. Future avionics systems will be integrated to the extent that all subsystems share the same pool of knowledge and utilize standard modular electronics and common redundant displays.

4.7.3 Active Noise and Vibration Control

Active noise and vibration systems are required to improve passenger comfort and crew effectiveness by: reducing cabin and cockpit noise and vibration levels; increasing the performance characteristics of commercial and military aircraft by reducing vibration levels; increasing the lifetime of aircraft; and improving component life cycle costs by decreasing the fatigue loading produced by noise and vibration.

4.7.4 Health Monitoring Systems

The integration of health monitoring systems to monitor, to assess, and eventually to re-configure flight systems automatically will reduce crew workload and aircraft downtime, while providing an increased margin of passenger safety and comfort.

4.8 Visualization

Modern visualization technologies are being applied in several different aerospace environments: the aircraft cockpit, tactical mission workstations, and a host of ground-based engineering workstation environments. These technologies are currently being pursued by companies in the aerospace and other industries to try to gain an advantage in a tough international marketplace.

In the future, the use of advanced visualization technologies should result in a more competitive aircraft product through weight reduction, cycle time reduction, operational improvement, manufacturing cost reduction, DOC savings, and improvement in cockpit controls configuration. Ground-based engineering workstation display equipment will generate higher-resolution, more compelling 3-D imagery, and virtual environment applications will evolve where appropriate.

The Visualization Technology Working Group investigated four critical technologies, described in the following subsections.

4.8.1 Image Generation and Manipulation

The ability to generate and manipulate sophisticated digital images is key to visualization technologies because, if image generation/manipulation issues are not resolved, other visualization technologies cannot follow. Real-time imaging for aerospace applications involves: image acquisition, processing, fusion from several onboard sensor sources and, for many ground-based engineering applications, image synthesis and rendering (including true three-dimensional imaging) for the analysis, design and manufacture of aerospace systems. The overall goal, particularly in the cockpit environment, is to provide a real-time view of the outside world which is enhanced to simulate "clear vision," uncluttered by extraneous data and annotated to provide value-added cues and references.

4.8.2 Advanced Display Media

Advanced display media technology, especially as applied to the cockpit environment, is a key strategic visualization technology. There are two types of modern cockpit displays:

- head-down displays, such as flat-panel displays, multifunction displays and EFISs
- projection/overlay systems, such as head-up displays, helmet-mounted displays and enhanced/ synthetic vision systems.

Future trends in cockpit display technologies, certainly for military applications, suggest more reliance on helmet-mounted displays, much larger multifunction displays, and synthetic vision systems replacing the usual head-up displays. For shorter-term civilian applications (which typically lag behind military applications), head-up displays appear to be making inroads (e.g. in business jet cockpits).

4.8.3 Virtual Mockup

Virtual mockup, or virtual prototyping, is a specific application of virtual reality that has extremely important implications for the aerospace industry. The general goal of virtual mockups is to further enhance the computer assisted design, manufacturing and engineering (CAD/CAM/CAE) process so as to shorten design and development times, reduce life cycle costs and improve overall performance. With virtual mockups, a virtual environment can be created and used to develop and demonstrate simulation-based design using human-in-the-loop techniques. Full aerospace vehicle designs can be "virtually" tested and evaluated well before any physical prototypes are created. Virtual manufacturing is the next logical step in this process — enabling manufacturing and assembly design without the expense of physical prototype parts and tooling.

4.8.4 Virtual Environment

Applications of virtual environment, or virtual reality, technology are gaining in importance in many industries including aerospace. Virtual reality technology currently spans a wide spectrum of capabilities. In a sophisticated immersing environment, the operator usually wears a helmet-mounted display and employs hand-held devices and position trackers to experience a full range of sensory cues — visual, auditory, tactile and even olfactory. At the lower end of the spectrum, three-dimensional, computer-generated data and images created on personal computers or workstations produce something more like a local virtual space. For example, Boeing Computer Services is using a software product, Fakespace Boom, as an interface for a 3-D CAD system that evaluates the accessibility of aircraft cabins for maintenance workers. Virtual environment tools must be fully compatible with data sets down loaded from industry-standard 3-D CAD packages, primarily CATIA.

5. TECHNOLOGY REPORTS AND MARKET DRIVERS

Figure 6 is a matrix that relates the critical technology reports from the eight TWGs to the market drivers identified at the TRM launch meeting (summarized in the previous section). Figure 7 provides the numerical key necessary to interpret Figure 6.

Market Drivers	Critical Technology Reports (Identified by Number)							
	1	2	3	4	5	6	7	8
Regulatory								
noise reduction	5	1		2,4		3,4		
emissions		2		2,4	12			
hazardous materials		3,4		2	5	1		
toxic wastes		3,4				1		
flight safety						2,3,4,5	1,2,4	1,2
crashworthiness						4		
Heavier and Farther								
structure weight	1,2,4			3,4	7,8,11	2,4,5	1,2,3,4	
engine weight	3,5			3,4	11	4,5	1,2,4	
fuel efficiency	7		1		12	1,2,3,5	1,2,3	
landing gear weight	8			2,3,4	7	5	1,3,4	
systems weight				2,3,4			1,2,3,4	2
Cheaper								
design cycle time	1,3,6			1,2,3,4,5	1,2,6		1,2	1,3
manufacturing cycle time				1,2,3,4,5	1,2,3,4,6,7,8,10		1	3
recurring costs				1,2,3,4,5	1,3,5,9,10	1,2,4,5	1,2,3,4	
tests and prototypes	3			1,2,3,4,5	1		1,2,4	3
fuel efficiency	5,7				12	1,2,5	1,2,3	
reliability	5			1,5	3,5,8	1,2,3,5	1,2,3,4	2,3
maintenance			2,3,4,5,6	1,2	2,3,5,7,8	1,2,3,5	1,2,3,4	3,4
direct routing							2,4	1,2
needless removal			1			3	4	
self diagnostics			1			3	1,2,4	
usage monitoring			1			3	4	
Faster								
adverse weather							1,2,4	1,2
direct routing							2	1,2
Comfort								
cabin noise and vibration	2,5	1		1,2,4	3,8	3,4	1,3	
entertainment							2,3	1,2,4

Figure 6

Working Group	Technology Report
1. Design	1. Multidisciplinary Design and Optimization 2. Advanced Wing Design 3. Advanced Analytical Modelling and Design Practices — Engines 4. Structural Analysis and Optimization — Airframe 5. Structural Analysis and Optimization — Engines 6. Computational Fluid Dynamics Analysis, Design and Validation — Aircraft 7. Computational Fluid Dynamics Analysis, Design and Validation — Engines 8. Advanced Landing Gear and Airframe Integration
2. Environment	1. Aircraft Noise Abatement — Development of Lower Engine Noise Technology 2. Aircraft Emissions Reduction 3. Replacement of Cadmium Coatings 4. Replacement of Chromium Coatings
3. Maintenance and Repair & Overhaul	1. Health and Usage Monitoring Systems 2. Composite Structures — Non-destructive Test and Evaluation 3. Repair of Metallic Materials 4. Coatings and Surface Modification Technology for Repair 5. Composite Structural Repair — Material Systems 6. Composite Patches on Metallic Components
4. Management	1. ISO 9000 Quality Standards 2. Continuous Improvement 3. Product and Electronic Data Interchange 4. Concurrent Engineering and Virtual Design 5. Statistical Process Control
5. Manufacturing	1. Manufacturing Information Systems 2. Casting Technologies 3. Joining All Materials 4. In-process Inspection 5. Coating Processes 6. Laser Materials Processing 7. Fibre Composites 8. High-velocity Machining 9. Advanced Metal Forming 10. Intelligent Process Control 11. Metal Matrix Composites 12. Ceramic Matrix Composites
6. Materials and Structures	1. Coatings and Surface Modification Treatments 2. Composite and Hybrid Structures 3. Smart Structures 4. Energy-absorbing Structures 5. Metallic Materials
7. Systems	1. Flight Systems: a. Flight Control Systems b. Environmental Control System c. Landing Gear 2. Integration of Avionics (Including Communications, Navigation and Displays) 3. Active Noise and Vibration Control 4. Health Monitoring Systems
8. Visualization	1. Image Generation and Manipulation 2. Advanced Display Media 3. Virtual Mockup 4. Virtual Environment

Figure 7

6. SUMMARY

This Technology Road Map pilot project, co-sponsored by the Ontario Aerospace Council, was led by Ontario aerospace companies in partnership with Industry Canada, the National Research Council and the Department of National Defence. Since this was the first project of this kind undertaken by the participants, it was a learning experience. The following is a list of observations made by some or all of the participants, and is not exhaustive.

Technology road maps are always going to be "works in progress." This particular TRM, based on "market pull," will have to be revisited as market demands change, as Canadian industry expands into new market niches, as regulatory changes shift the technology focus, as new technologies mature, etc. For these and other reasons, TRMs must be reviewed and revised on a regular basis to ensure that they provide timely, accurate information.

The TRM process itself provides many benefits to participants:

- The Canadian aerospace industry sector, although internationally competitive in many product lines, consists of "niche" focussed companies, and consequently is not well integrated vertically or horizontally. The TRM process is a unique networking opportunity whereby new relationships and understandings are developed, strengthening the whole industry and opening the door to increased cooperation.
- It will help build stronger partnerships among industry, government and professional and educational institutes.
- It is a benign environment where companies can identify, and agree on, the critical, strategic technology issues facing their industry.
- It provides an opportunity to improve the long-term technology focus for companies.

The TRM provides strategic guidance to both the industry and the government. This new partnership has produced a planning document and an ongoing process that will help:

- companies choose a winning combination of technologies
- government assess programs and policies in light of a recognized list of industry's priorities
- professional and educational institutes to focus service to their clients and to form mutually beneficial partnerships with companies
- promote partnerships and teaming that will result in financial economies and timely technology adoption.

Due to the nature of Technology Road Maps and the fact that this was a pilot project, the following activities need to be undertaken to maximize the value of the TRM.

The core TRM team should seek feedback from all participants to confirm:

- the relevance of this road map
- the appropriateness of the process, and ways in which it could be improved
- how participants intend to use the TRM.

Government participants should advocate the use of the TRM in federal government policy and decision making.

As a co-sponsor, the Ontario Aerospace Council should promote:

- the adoption of the TRM results within the strategic technology and business planning of its member companies
- the consideration of the TRM results in the Ontario government's policies and programs.

The TRM should be tested to confirm the selection and analysis of the strategic technology areas. This is best accomplished by taking the results to Canadian firms outside Ontario. This will:

- offer new networking opportunities to Canadian aerospace firms
- present the results to the most logical client base
- be the first step in expanding the TRM to all Canadian aerospace firms.

Annex: Technology Working Group Membership

1. Design TWG Members

Louis Chan, National Research Council - IAR
Ralph Darlington, Messier-Dowty Inc.
Brian Eggleston, Bombardier deHavilland (TWG Leader)
Ron Helm, Litton Systems Canada
Dave Kenny, Pratt & Whitney Canada
John Mitchell, Fleet Industries
Peter Trau, Industry Canada (TWG Scribe)

2. Environment TWG Members

Hilaire Bonneau, Pratt & Whitney Canada
Walter Dabrowski, Messier-Dowty Inc.
Roger Eybel, Messier-Dowty Inc.
Maria Korotkin, Cametoid Ltd.
Helen Lakusta, Litton Systems Canada Ltd.
Des Newman, Cametoid Ltd. (TWG Leader)
Lawrence Otupiri, Industry Canada (TWG Scribe)
Roque Panza-Giosa, Bombardier deHavilland
Jeff Petzke, Bombardier deHavilland
Jeffrey Pritchard, Vac Aero International Ltd.
Sam Sampath, Pratt & Whitney Canada
Thomas Scarinci, Rolls Royce Canada Ltd.
Edward Struckholt, McDonnell Douglas Canada Ltd.

3. Maintenance and Repair & Overhaul TWG Members

Don Butler, Cametoid Ltd.
Alistair Davie, Comtek Advanced Structures Ltd. (TWG Leader)
Chris Eaves, Diamond Aircraft
Bob Hastings, Department of National Defence, CRAD
Harvey Pellegrini, Ontario Centre for Materials Research
Ben Pettit, Sensor Technology Ltd.
Michael Piersdorff, Industry Canada (TWG Scribe)
Don Rudnitski, National Research Council – IAR
Raj Thamburaj, Orenda Aerospace Corp.
Bill Walker, Eurocopter Canada Ltd.

4. Management TWG Members

Bob Atkinson, Industry Canada (TWG Scribe)
Ron Beach, Department of National Defence, DGIIP
Margo Carson, Ontario Ministry of Economic Development, Trade and Tourism
Ralph Darlington, Messier-Dowty Inc.
Chris Eaves, Diamond Aircraft
Brian Eggleston, Bombardier deHavilland
Robert Hastings, Department of National Defence, CRAD
Stuart Johnson, Pratt & Whitney Canada
Simon Monk, AlliedSignal Aerospace Canada
Bruce Phemister, Messier-Dowty Inc.
Lisa Roberts, Diamond Aircraft (TWG Leader)
Dave Thomas, Pratt & Whitney Canada

5. Manufacturing TWG Members

Grant Allan, Manufacturing Research Corporation of Ontario
Bert van den Berg, National Research Council - IMTI
Ken Birch, Industry Canada (TWG Scribe)
Ashok Koul, National Research Council - IAR
Barry Leigh, Bombardier deHavilland
Helium Mak, National Research Council - IMTI
Peter Meyer, Fleet Industries
Harvey Pellegrini, Ontario Centre for Materials Research
Karl Pfister, Diamond Aircraft
Bruce Phemister, Messier-Dowty Inc.
Bill Reil, Reil Industrial Enterprises
Kevin Ronan, Deloro Stellite Inc.
Raman Sood, Ceramics Kingston Céramiques
Adrian Spiller, National Research Council - IRAP
Raj Thamburaj, Orenda Aerospace Corp.
Dave Thomas, Pratt & Whitney Canada (TWG Leader)
Don Uffen, Diamond Aircraft
Lijue Xue, National Research Council - IMTI
Kam Yan, Cametoid Ltd.

6. Materials and Structures TWG Members

Gopala Gowda, National Research Council - IRAP
Jean-Pierre Immarigeon, National Research Council - IAR
Colin Leach, Pratt & Whitney Canada
Barry Leigh, Bombardier deHavilland (TWG Leader)
Lia-Fong Martin, Pratt & Whitney Canada
Peter McGeer, Ontario Centre for Materials Research
Brian Oakley, Fleet Industries
Ben Pettit, Sensor Technology Limited
David Simpson, National Research Council - IAR (TWG Scribe)
Raj Thamburaj, Orenda Aerospace Corp.
Don Uffen, Diamond Aircraft
Bill Walker, Eurocopter Canada Ltd.
Kam Yan, Cametoid Ltd.

7. Systems TWG Members

Bruce Bailey, Canadian Marconi Company
Chuck Glass, Diamond Aircraft
Ron Helm, Litton Systems Canada Ltd.
Chun Ho Lam, AlliedSignal Aerospace Canada
John Leadbeater, Menasco Aerospace
Barry Leigh, Bombardier deHavilland
Ron Ruta, Litton Systems Canada Ltd.
Ed Traczyk, Bombardier deHavilland (TWG Leader)
Jack Wallace, Sensor Technology Ltd.
David Zimcik, National Research Council - IAR (TWG Scribe)

8. Visualization TWG Members

Jim Farrell, Litton Systems Canada Ltd. (TWG Co-Leader)
Ray Giustini, Canadian Marconi Company
Sion Jennings, National Research Council - IAR
Bob Kobierski, Canadian Marconi Company
Barrie Leach, National Research Council - IAR (TWG Scribe)
Bill Noble, Department of National Defence
Jeff Petzke, Bombardier deHavilland
Elias Politis, National Research Council - IAR
Ron Ruta, Litton Systems Canada Ltd. (TWG Co-Leader)
Lou White, Canadian Marconi Company

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DATE DE RETOUR
