FORUM INNOVATION AÉROSPATIALE

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WHITE PAPER

INNOVATION POWERS SUSTAINABILITY FOR THE AEROSPACE INDUSTRY

AS DESIGN, AS MANUFACTURED, AS USED, AS DISPOSED.

ORGANISED BY

AÉRO MONTRÉAL

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380 Saint-Antoine Street West
Suite 8000
Montréal (Québec) H2Y 3X7

Strategic Partner: Industrie Canada Industry Canada

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This document was written by Isabelle Deschamps, ing., MBA, DBA, Associate Professor in Innovation Management, École Polytechnique de Montréal, Christian Eve-Levesque, B.ing., M.Ing. and Maria Macedo, Ph. D., MBA, under the guidance of Aéro Montréal's Innovation Working Group.

Aéro Montréal's Innovation Working Group

The Innovation Working Group's mandate is to establish Québec's aerospace innovation strategy , to identify and coordinate projects in support of the innovation strategy in collaboration with other organizations involved in innovation in order to maximize the output of all stakeholders.

Members of Aéro Montréal Innovation Working Group

- **Patrick Champagne,** President, Innovation Working Group Aéro Montréal, Vice President, Cockpits and Systems Integration, Esterline CMC Electronics inc.
- **Alain Aubertin,** Vice President, Business Development, CRIAQ
- **Sylvie Béland,** CNRC
- **Nihad Ben Salah,** R&D Group Leader – Engineering, Héroux-Devtek
- **Nadia Bhuiyan,** Associate Professor and Associate Director, Concordia Institute for Aerospace and Design Innovation
- **Stéphane Blais,** Project Manager, Air Operations, Marinvent
- **Mathieu Boisclair,** Section chief, Strategic Technology, Bombardier Aerospace
- **MarieChantal Chassé,** President, JMJ Aéronautique
- **Sylvain Cofsky,** President, GARDN
- **Jean Colpin,** Industrial Advisor, McGill Institute for Aerospace Engineering
- **Mathieu Demers,** Engineering Manager, Avianor
- **Pascal Désilets,** General Director, Centre de technologie en aérospatiale
- **Marie-Christine Désilets,** Director, Engineering Solution, L-3 MAS
- **Clément Fortin,** President and Chief Executive Officer
- **Pierre-Alexis Joumel,** Canada R&T Manager, Airbus Group
- **Fassi Kafyeke,** Director, Strategic Technology, Bombardier Aerospace
- **Denis Lacroix,** Director, PARI-Québec Program, CNRC
- **Éric Laurendeau,** Associate Professor, École Polytechnique
- **Dominique Leroy,** Advisor, Aerospace, Defence and Marine Branch, Industry Canada
- **Hany Moustapha,** Professor, Director AERO-ETS and Advisor Pratt & Whitney Canada
- **Yves Rabellino,** Director, Research and Technology, Pratt & Whitney Canada
- **Normand Raymond,** Ministry of Finance and Economy of Québec
- **Pierre Rioux,** Director of Research and Development, Bell Helicopter Textron Canada
- **Marc St-Hilaire,** Vice President Technology and Innovation, CAE Inc
- **Marc-André Talbot,** Director Engineering, Thales Canada, Aerospace
- **Priti Wanjara,** Group Leader, Metallic Products Manufacturing Aerospace, NRC

Communauté métropolitaine de Montréal Québec Canada

table of contents

FOREWORD 4

EXECUTIVE SUMMARY 5

PROGRAM 9

FORUM REPORT 11

OUR PARTNERS 38

foreword

Suzanne M. Benoît
President
Aéro Montréal

Patrick Champagne
President, Innovation Working Group
Aéro Montréal
Vice President, Cockpits and
Systems Integration
Esterline CMC Electronics

In an increasingly competitive industry, where the fight against climate change is imposing new rules, every company needs to step up its pace of innovation to reduce the overall environmental footprint of future aircraft, throughout their life cycle.

Aéro Montréal, Québec's aerospace cluster, in collaboration with CRIAQ, the Consortium for Research and Innovation in Aerospace in Québec, is proud to have organized the fourth edition of the Aerospace Innovation Forum. Under the theme **"Innovation Powers Sustainability For the Aerospace Industry,"** the Forum aimed to highlight the latest technological trends in the industry as well as international best practices in the design, manufacture, operations and end-of-life management of aerospace products.

By holding this international event, Québec's aerospace industry reaffirmed its position as a leader in innovation as well as its commitment to reduce the environmental impact of the industry and global aviation. Accordingly, it has significantly strengthened its innovation system over the past decade. By leveraging cooperation among its key players and the research community, cluster members are implementing structural projects in innovation which are creating a ripple effect throughout its supply chain. Québec's goal is to develop new leading-edge technologies and ensure its international competitiveness.

In terms of major projects arising from the work of the cluster, Aéro Montréal is proud to support the Greener Aircraft Catalyst Project (SA²GE), funded in part by the Government of Québec, and the Technology Demonstration Program, funded in part by the Government of Canada. These two technology demonstration programs promote collaboration among research centres, universities, SMEs, OEMS and major manufacturers, both in Québec and Canada, in the development of new products. This approach, based on international best practices, fosters the growth of companies and their integration into future aircraft platforms.

Since the first edition in 2007, the Aerospace Innovation Forum has aimed to be a unifying event that highlights the vision of world leaders in innovation. We hope that the discussions and business meetings that took place have allowed participants to identify possible solutions for making our industry a model of sustainable development.

To help industry players in this endeavour, this White Paper is intended to provide a comprehensive account of the main themes that were discussed during the Forum. It also offers various recommendations and lines of inquiry that will enable the aerospace industry to meet the challenges it faces.

Happy reading!

executive summary

MONTRÉAL, A PILLAR OF THE CANADIAN AND QUÉBEC AEROSPACE INDUSTRY

The Canadian aerospace industry is the fifth largest in the world and the second largest relative to the size of its economy. It generates revenues of $22.8 billion per year, employs 66,000 people, exports 80% of its production. This industry includes a large commercial aircraft manufacturer and a broad range of world leaders in different segments - helicopters, landing gears, simulators, engines, aerostructures and maintenance and repair services.

Québec has contributed significantly to Canadian aerospace's success. From 1990 to 2013, the aerospace industry in Québec recorded an average annual revenues growth of about 5.3%, despite the recession and the recent rise in Canadian dollar against the U.S. dollar. In 2013, sales rose compared to 2011, reaching $12.05 billion.

Aéro Montréal, Québec's aerospace cluster, plays a key catalyst role for the industry. Some 98% of Québec's aerospace activity is concentrated in Greater Montréal. For Canada as a whole, the aerospace industry in Québec represents about 70% of R&D, 60% of GDP, 60% of exports, 55% of sales and 50% of the workforce. Québec's aerospace cluster is distinguished by a high degree of specialization and a reputation as one of the main aerospace development centres thanks to the presence of world leading OEMs, integrators, equipment manufacturers and specialists in MRO (Maintenance, Repair and Overhaul) as well as subcontractors and suppliers of specialized products and services. Québec's aerospace industry has developed an international expertise in areas as diverse as the manufacture of regional and business jets, turboprops, avionics, engineering and development, the design of landing gears and business aircraft interiors, the qualification and certification of aircraft and flight test services.

GENERAL IMPRESSIONS AND THEMES OF THE FORUM

Four major trends emerged from the presentations and discussions that took place during the Forum.

Theme 1: Change and globalization are a daily reality for aircraft manufacturers and their partners. Change is sweeping through the aerospace industry. The major trends of recent years are continuing, the industry has truly globalized, and markets and production sites are now located throughout the world. Managing and succeeding in such an environment constitutes a real challenge. Supply and demand are dispersed throughout the planet, and these factors are changing rapidly.

Theme 2: Uncertainty and risks. The global context of change is complicating aerospace project cost and benefit calculations. These projects take decades and involve multiple partners, international suppliers and customers who are operating in an increasingly unstable and changing environment.

Theme 3: Complexity and integration. All industry leaders attending the Forum agreed that strategy, commercial and financial analysis models are complex. They must integrate harmoniously not only technical and economic data, but also adapt and renew themselves vis-à-vis changing data, taking into account sustainable development.

Theme 4: Technological and systemic innovation. Various specialists took turns during the Forum to report on technologies and work methods being employed at all stages, from design to manufacturing. Research is collaborative and is taking place within shared research infrastructures. Both human and material resources are shared, technologies are intelligent and teams are multifunctional. There are challenges in terms of the integration of design and interoperability of systems and platforms.

SUMMARY OF PRESENTATIONS AND CONTENT OF THE WHITE PAPER

The "domino" effect of systemic changes in the aerospace industry

Key issues and themes raised during the Forum are connected, one to the other, since the anticipated changes are systemic. This is especially true when the concepts of sustainable development are integrated with those of socio-economic and technological development. As shown in Figure 1, which will serve as a backdrop for presenting, in turn, the various presentations and conclusions of the Forum, all these changes in the aerospace industry are interrelated and will have an impact on each other in a domino effect.

FORUM CONCLUSIONS

A conviction emerged from the Forum that the changes in the aerospace industry are profound and ongoing. Four (4) major waves of change are emerging, and inspire the eight (8) following recommendations to facilitate the adaptation, resilience and performance of Québec's aerospace industry in the coming years.

Change No. 1: Profound and sustained transformations in supply and demand, stimulating the development of new products: Aircraft must incorporate multiple parameters which meet economic and regulatory requirements, but also the imperatives of sustainable development in terms of pollution, noise, recycling and end-of-life management.

Figure 1: Integrated chart of forum themes and conclusions

CHANGES IN GLOBAL EXTERNAL FACTORS IN THE WORLD (SECTION 1)

Systemic, intelligent, multidisciplinary technologies, integrated design and manufacturing, new architectures and materials.	Globalized economy, growing emerging countries, economic uncertainty and social instability.

CHANGES IN STRATEGIES, MANAGEMENT SYSTEMS AND ORGANIZATIONAL MODES (SECTION 2)

Immovation chains decentralized toward Tier 1, collaborative innovation modes, increased role of SMEs in the industry.	Local and global supply chains relocated and reconfigured based on supply and demand.

CHANGES IN COMMERCIAL AND FINANCIAL TARGETS AND IN RISK TAKING (SECTION 3)

Products responding to environmental requirements in terms of pollution, noise, recycling and waste.	Business and revenu model based on efficiency, reliability and development costs at reasonable and shared costs.

CHANGES IN THE ROLE OF INDUSTRY PLAYERS: RESEARCH INFRASTRUCTURES, CLUSTERS AND GOVERNMENTS (SECTION 4)

Research infrastructures
Structural innovations: the role of aerospace clusters
Government financing and programs
Change in paradigm and tools for managing and sharing knowledge in a more open innovation process
Commercial innovations: multiple opportunities and parallel markets: military and space

Change No. 2: Rapid, and more integrated, technological innovation: System engineering is becoming key, technologies are systemic and more intelligent, therefore interconnected; teams are multidisciplinary, design and manufacturing are integrated with more simulation, new aircraft architectures are required and demand new materials and manufacturing and assembly processes.

Change No. 3: Industry players are more international and geographically dispersed, as well as increasingly integrated amongst themselves, and need to enhance coordination upstream (innovation) and downstream (manufacturing): Innovation is decentralized towards integrators/Tier 1, and therefore cascading to other subcontractors; innovation modes are more collaborative.

Change No. 4: Business strategies and business models are evolving locally and globally: Local and global supply chains are relocated and/or reconfigured depending on supply and demand, as are socio-economic factors in terms of efficiency, reliability, and speed of development at reasonable and shared costs.

SUMMARY OF RECOMMENDATIONS

Eight recommendations were developed following the Forum. They encompass various funding mechanisms for innovation, but also best management practices, more effective coordination and collaboration tools, more advanced technologies, stronger commercial and international linkages, and skilled labour.

Recommendation 1: Continue to apply recommendations of the Emerson Report to strengthen the government's strategic and financial support of the aerospace industry.

Speakers at the Forum all argued in favour of the central role of government in supporting the aerospace industry to prioritize, focus, coordinate, reduce risks and accelerate the development and commercialization of innovative products and processes. Among others, members of the aerospace industry welcome the Emerson Report, which recommends that the government's central role in prioritizing and supporting the aerospace industry must be maintained and strengthened.

Recommendation 2: Increase the capacity and the competitiveness of the industrial supply chain and strengthen dynamic ties among players (OEMS, integrators and subcontractors).

More support is needed for SMEs that are performing well, which qualify as suppliers to major local prime contractors, and which are often fast growing. This will allow them to become more international and be more competitive globally in terms of innovation and cost. This will require the implementation of best management practices, as well as world-class business networking and investments in leading-edge technologies.

Recommendation 3: Increase the innovation capacity and technology absorption of all industrial players (including SMEs) and develop more fluid and interactive links among innovation players.

We need to increase the innovation capacity of SMEs "upstream," namely at the stages of research and development and design, as well as their capacity for international marketing. This will increase their competitiveness in a globalized industry that requires parallel improvements in cost, new products, and adaptation to new customers.

Recommendation 4: Reduce risks and delays in innovation through collaborative innovation at all levels of the aerospace supply chain.

The era of open and collaborative innovation is well under way, and is here to stay. We need to encourage and support more collaboration and the sharing of resources and infrastructure in R&D, demonstration and manufacturing, both in the vertical supply chain and in terms of horizontal cooperation among stakeholders in the industry who have complementary skills.

Recommendation 5: Maximize the use and exchange of resources and leverage shared infrastructures.

Vertical collaborations (in the supply chain) and horizontal collaborations (among complementary actors) promote closer ties and foster major catalyst projects. To facilitate this, we should support the establishment of various mechanisms, infrastructures and shared resources that encourage and financially support the pooling, sharing and mobility of equipment, tools and machinery among aerospace industry players, namely research centres, universities and companies.

Recommendation 6: Ensure a constant supply of qualified manpower and the upgrading of technical, operational and managerial skills of industry players having to constantly adjust to new ways of working and managing.

Support is needed for knowledge transfer, technical and managerial training, as well as continuous improvement of the expertise of all employees who are, more than ever, the pillars of successful aerospace companies.

Recommendation 7: Support, through public-private partnerships as well as local programs and international initiatives, the achievement of various sustainable development objectives of the industry.

In order to meet the commercial and environmental imperatives of the industry and their customers, while reducing the financial and technical risks of the efforts required, aerospace companies need to integrate all aspects of sustainable development and ecological footprint from the very start of any innovation project. To support them and share the financial risks, various avenues of indirect support from the various levels of government are proposed.

Recommendation 8: Continue alignment of university research at high technological readiness levels (TRL) with initiatives stemming from the Emerson Report.

Significant progress has been made in the last 20 years in the dialogue between universities and aerospace companies. However, we should continue to encourage new joint initiatives through joint training programs, industrial internships, technology demonstration programs, and subsidized projects at higher levels of technology readiness (TRL 5-6).

program

FORUM WELCOMING REMARKS
Suzanne M. Benoît, President, *Aéro Montréal*
Patrick Champagne, President, Innovation Working Group, Aéro Montréal and Vice President, Cockpits and Systems Integration, Esterline CMC Electronics
Clément Fortin, President and Chief Executive Officer, CRIAQ
Maria Della Posta, Chair of the Board, Aéro Montréal and Senior Vice President, Sales and Marketing, Pratt & Whitney Canada

FORUM OPENING REMARKS
Nicolas Marceau, Minister of Finance and the Economy, Québec

THE UNITED STATES: AN AEROSPACE NATION
Ambassador Duane e. Woerth, U.S. Permanent Representative to ICAO council

VISION OF LIFE CYCLE OF MAJOR AEROSPACE PLATFORMS
Moderator:
Hany Moustapha, Professor and Director, AEROETS, École de technologie supérieure
Panelists:
Robert Dewar, Vice President and General Manager, CSeries, Bombardier Aerospace
David Hills, Director, Research & Technology, Airbus S.A.S.
Bruno Stoufflet, Vice President, R&D and Advanced Business, Dassault Aviation

THE REVIEW OF AEROSPACE AND SPACE PROGRAMS AND POLICIES: AN ACCOUNT OF A YEAR OF ACTION
The Honorable James Moore, Minister of Industry, Canada

VISION DU CYCLE DE VIE CHEZ LES MOTORISTES
Moderator:
Hélène V. Gagnon, Vice President, Public Affairs, Communications and CSR, Bombardier Aerospace
Panelists:
Alan Epstein, Vice President - Engineering Technology and Environment, Pratt & Whitney, a division of United Technologies Corporation
Pierre Guillaume, Chief Technology Officer, SNECMA
David Thibes, Chief Executive Officer, Turbomeca Canada

LUNCH/CONFERENCE - INNOVATION: THE HEART OF BOMBARDIER'S AEROSPACE STRATEGY
Guy Hachey, President and COO, Bombardier Aerospace
Introduced by Joseph C. Anselmo, Editor-in-Chief, Aviation Week & Space Technology

WORKSHOP ON CONCEPTION: "VIRTUAL SIMULATION AND ITS IMPLICATIONS FOR THE INDUSTRY"
Moderator:
Clément Fortin, President and Chief Executive Officer, CRIAQ
Panelists:
Jacques Duysens, Chief Operating Officer, Silkan
Emilio Di Zazzo, Strategic Account Manager - Aerospace & Defence Canada, PTC
Michel Tellier, Vice President Aerospace & Defence Industry, Dassault Systèmes
Cameron Mackey Enterprise Engineering Director, Helix Enterprise Collaboration Systems

MANUFACTURING WORKSHOP: "CHALLENGES AND OPPORTUNITIES OF ADVANCED AUTOMATION"
Moderator:
Éric Beauregard, President, AV&R Aerospace
Panelists:
Alain Ouelette, Manager - Global Automation and Instrumentation R&D Center, GE Aviation
Chris Blanchette, National Account Manager, Distribution - Assembly and Aerospace Automation, FANUC America Corporation
Miguel A. Castillo Acero, Vice President Technology Development, Aernnova

HOW TO DO BUSINESS WITH EADS?
Dave Williams, Vice President Procurement, Airbus Americas

CEAN SKY 2: GEARING UP FOR AN INNOVATION LEAP INEUROPE
Giuseppe Pagnano, Coordinating Project Officer, Clean Sky Joint Undertaking

TRENDS IN AEROSPACE SYSTEMS
Dave Carter, Vice President, Engineering & Technology, UTC Aerospace Systems

THE MORE ELECTRICAL AIRCRAF IS A DEEP TRANSFORMATION OF OUR INDUSTRY: SAFRAN'S VISION
Serge Bérenger, Vice President Strategy and R&T, Hispano-Suiza, Groupe SAFRAN

NEXT GENERATION FIGHTER INNOVATIONS
Billie Flynn, Former pilot Royal Canadian Air Force Fighter and Lockheed Martin Test Pilot

WORKSHOP ON MANIFACTURING: "ADDITIVE MANUFACTURING: WHAT TRENDS FOR THE FUTURE?"
Moderator:
Eric J. Amis, Director, Physical Science, United Technology Research Center
Panelists:
Thomas Chiang, Manufacturing R&D Engineer, *Bell Helicopter, Textron*
Julien Chaussée, Engineering Specialist, Advanced Structures - Core Engineering, Bombardier Aerospace
Scott Martin, Senior Manager, Next generation composites fabrication processes, The Boeing Company

WORSHOP ON CONCEPTION: "THE TRANSFORMATION OF RELATIONS BETWEEN TIER 1 AND SMES"

Moderator:

Raphaël Duflos, Vice President, Procurement, AEROLIA

Panelists:

José Luiz Rodriguez Ramos, General Manager, *Chihuahua Aerospace Cluster*

Jean Blondin, President, *Abipa*

HOW TO DO BUSINESS WITH FINMECCANICA GLOBAL SERVICES ?

Marco Bona, VP International Programs, *Finmeccanica Global Services*

HOW MROS INNOVATE TO EXTEND THE LIFECYCLE OF AIRCRAFTS ?

Moderator:

Marc-André Duranceau, Vice President, Aerostructures and Aircraft Service, L-3 Communications MAS

Panelists:

Amy L. Gowder, Vice President, Kelly Aviation Center

Gavin Simmonds, General Manager, AJW Technique

END OF LIFE MANAGEMENT: WHERE DOES THE AEROSPACE INDUSTRY STAND ?

Moderator:

Bruce Parry, Manager - Corporate Social Responsibility, Bombardier Aerospace

Panelists:

Robert Cadieux, Manager, Environment and Sustainable Development, *Pratt & Whitney Canada*

Kahina Oudjehani, Design for Environment Lead, *Bombardier Aerospace*

LUNCH-CONFERENCE - CGI INNOVATION IN AERO-NAUTICS TO SIGNIFICANTLY IMPROVE OPERATIONAL EFFICIENCY - "THE MISSING LINKS THEORY"

Vincent Berthelon, Vice President, *CGI Business Consulting France*

Introduced by **Yves Robins,** Senior Vice President, European Union and NATO Affairs

WORKSHOP ON OPERATIONS: "DPHM (HEALTH MONITORING) AND INNOVATION - WHAT ARE THE CHALLENGES FOR THE FUTURE ?"

Moderator:

Dr Prakash Patnaik, Program Leader of the Air Defence Systems (ADS), National Research Council Canada

Panelists:

Thibaud Lebreton, Project Manager, Research and technology, Safran Engeneering

Vincent Raymond, R&D Mechanical engineering specialist, Héroux-Devtek

WORKSHOP ON CROSS-INDUSTRIES: "LIFE CYCLE MANAGEMENT IN OTHER MAJOR INDUSTRIES - WHAT LESSONS FOR THE AEROSPACE INDUSTRY ?"

Moderator:

Jean Simard, President and General Manager, Aluminium Association of Canada

Panelists:

Edouard Clément, Managing Director, Quantis

Sebastien Zinck, Manager, Eco-Design and LCA, Steelcase

Gilbert Delabrousse, Senior PLM Consultant, PCO Innovation

HOW TO DO BUSINESS WITH BOEING DEFENSE, SPACE AND SECURITY ?

Ian Smith, Project Manager Canada, International Strategic Partnerships, The Boeing Company, Defense, Space and Security

WORKSHOP ON CERTIFICATION: "THE FUTURE OF CERTIFICATION – CHALLENGES AND OPPORTUNITIES"

Moderator:

John Maris, President, Corporation Marinvent

Panelists:

Martin Eley, Director General of Civil Aviation, Transport Canada

Sergey Zheltov, General Director, GosNIIAS

Malcom Imray, Airworthiness Engineer, National Research Council Canada

WORKSHOP ON OPERATIONS: "INNOVATION AND CHALLENGES IN NEW NAVIGATION AND SURVEILLANCE TECHNOLOGIES"

Moderator:

Stéphane Blais, Project Director, Flight Operations, Marinvent Corporation

Panelists:

Steve Bradford, Chief Scientist for Architecture, NextGen Development

John Studenny, Director of Systems Engineering, Esterline CMC Electronics

HOW TO DO BUSINESS WITH BOMBARDIER AEROSPACE ?

Louis Bouchard, Supply Chain Manager - Strategy, Communication and CSR, Bombardier Aerospace

forum report

INTRODUCTION: DO PAST ACHIEVEMENTS AND SUCCESSES GUARANTEE THE FUTURE?

ACHIEVEMENTS AND POSITIONING OF THE CANADIAN AND QUÉBEC INDUSTRY

As affirmed by the presence at the Forum of the Honourable James Moore, Minister of Industry, Canada is a world power in the aerospace sector. Its aerospace industry is the fifth largest in the world and the second largest relative to the size of its economy. The Canadian aerospace industry generates revenues of $22 billion per year, has 66,000 employees, exports 80% of its production and ranks second in the nation in terms of research and development intensity. This industry includes the third largest aircraft manufacturer in the world, Bombardier Aerospace, and a wide range of world leaders in different segments: civil helicopters, landing gears, simulators, small-size turboprops and turbojets, aerostructures and MRO. It is a strategic sector of the first order for the Canadian economy.

Québec has contributed significantly to Canada's aerospace success and will continue to get support from the provincial government in place, which depends on the industry to enhance Québec's competitiveness and prosperity. From 1990 to 2013, Québec's aerospace industry enjoyed an average annual growth of 5.3% in sales, despite the recession and the recent rise of the Canadian dollar against the U.S. dollar. In 2013, total sales amounted to $12.05 billion. Aéro Montréal plays a key role as a catalyst for this industry throughout Québec. However, with a concentration of 98% of Québec's aerospace business, the Greater Montréal region has established itself as one of the main development centres in aerospace in the world thanks to the presence of four world-class OEMs and 15 equipment manufacturers and integrators, and a network of over 200 specialized SMEs , plus several major research centres and training organizations.

As such, the Greater Montréal region accounts for 70% of Canadian aerospace R&D, 60% of exports, 55% of sales and 50% of the workforce. Finally, 80% of Québec's aerospace production is exported.

GENERAL IMPRESSIONS AND THEMES OF THE FORUM

Change and globalization are the daily reality for aircraft manufacturers and their partners. Change is sweeping through the aerospace industry. The major trends of recent years are continuing while the supply chains and relations between customers and suppliers are becoming more international. Managing and succeeding in such an environment constitutes a real challenge. Supply and demand are dispersed throughout the planet and these are changing rapidly.

Uncertainty and risks. The global context of change is complicating aerospace project cost and benefit calculations since these take decades and involve multiple partners, international suppliers and customers who are subject to geopolitical changes. This is calling into question traditional ways of making decisions, investing, designing and manufacturing aircraft. It is becoming more difficult to properly assess all aspects of a project, and in particular the risks of all kinds.

Complexity and integration. All industry leaders attending the Forum agreed that strategy, commercial and financial analysis models are complex. They must take into account and seamlessly integrate not only a multitude of social, technical and economic data, but also adapt and renew themselves vis-à-vis changing data in a dynamic environment. This is all the more necessary in the context of sustainable development, made essential by economic, ecological and social factors that are becoming imperatives and sources of inspiration for future products in the aerospace industry.

Technological and systemic innovation. Many experts took turns during the Forum to report on technologies and work methods which are continuing to advance at an accelerated pace. New technologies are being used at all stages of the life cycle of aerospace products. Smart technologies are being integrated, teams are becoming multifunctional, and research is collaborative within shared research infrastructures. Challenges exist in terms of integration of design and interoperability of systems and platforms. Beyond innovation, effectiveness, efficiency, maintainability and safety are also factors.

THE “DOMINO” EFFECT OF SYSTEMIC CHANGES IN THE AEROSPACE INDUSTRY

The Forum casts a positive light on an aerospace industry in constant transformation. The various presentations and discussions during the Forum demonstrated the dynamism of industry members, and the many testimonies collected highlighted the numerous technical and commercial successes of major players. However, it is clear that the battle has not been won and that major changes are coming. Challenges related to these profound changes, and the many themes raised during the Forum, are connected to each other, since the anticipated changes are systemic. This is especially true when concepts of sustainable life cycle management are integrated with to those of technological development. A global vision is therefore required.

Companies must learn not only to manage technological innovation, but also organizational and relational innovation, as well as commercial innovation, in order to meet current and future challenges caused by transformations in the industry at the local as well as global levels.

As shown above (Figure 1), all these changes in the aerospace industry are interconnected and in turn are having an impact on each other, in a domino effect.

SECTION 1. MAJOR TRENDS IN THE AEROSPACE INDUSTRY

1.1 ECONOMIC TRENDS

Even though the aerospace industry is still heavily concentrated in Europe and North America, strong foreign supply and demand is leading to a decline in some areas in favour of a pronounced growth in many emerging countries. As pointed out by Guy Hachey, President and Chief Operating Officer of Bombardier Aerospace, 80% of the demand came from North America and Europe between 1993 and 2012, but will decline to 50% for the period 2013-2033.

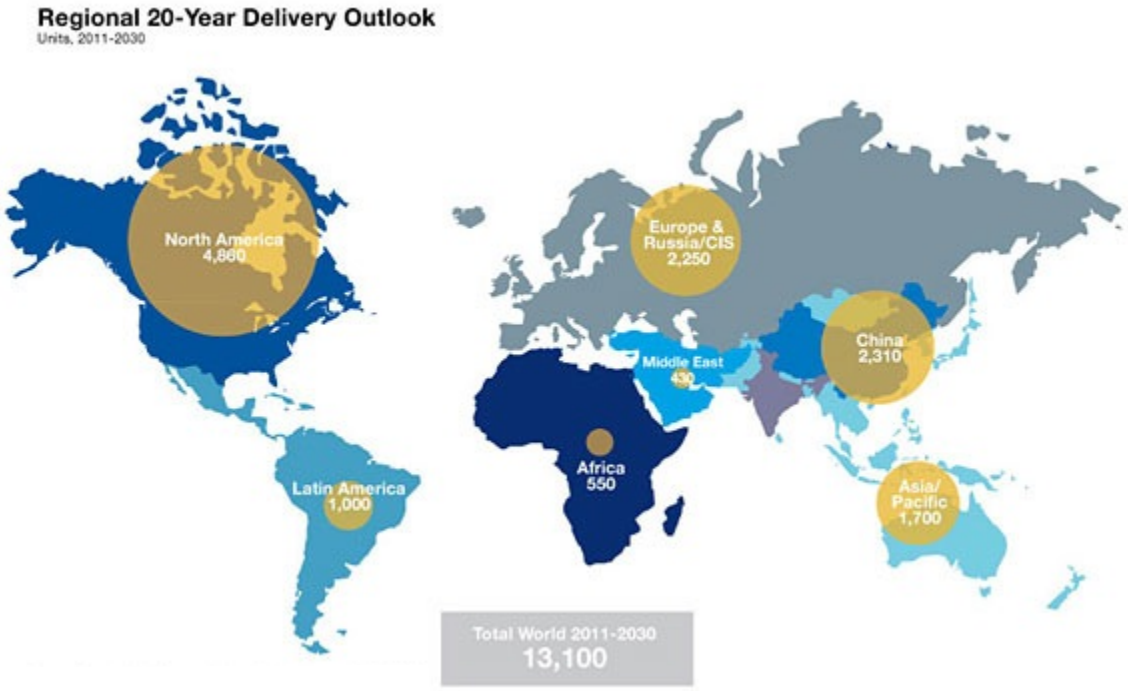
This heavy geopolitical trend is continuing with the creation of new development hubs with the support of local governments such as China, India, Morocco and Mexico. Governments are increasing their support in emerging countries: *"The aerospace industry is being transformed by developing countries willing to use the resources and influence of the state to develop their own aerospace industry. The actions of these countries is creating many new challenges for Canadian aerospace companies."*
- Guy Hachey, Bombardier Aerospace

International relocation and decentralization of manufacturing and innovation activities are increasing. To take advantage of opportunities in emerging markets and ensure that they remain competitive, major European and North American groups are becoming more globalized and relocating their activities: *"At the same time, the aerospace supply chain is globalizing as manufacturers such as Boeing, Airbus and Lockheed Martin travel the world in search of systems and components, reducing the number of suppliers with which they are willing to do business, and forcing them to invest in the research and design of systems that are consistent with their requirements in terms of performance."*
- Guy Hachey, Bombardier Aerospace

Large groups in Québec are proving to be leaders in this movement. Bombardier Aerospace has established strong manufacturing and assembly units in Mexico and Morocco (among others), as well as being a pioneer in the implementation of a "Design & Build" model, giving more responsibilities to its suppliers than the traditional "Build to print" approach.

Canadian and Québec companies, even SMEs, should consider becoming more international to align themselves with these new production models and find a place in the delocalized supply chain: *"It takes years to develop and to market a new aircraft which will remain in service for decades. A company that is excluded from the supply chain today risks losing sales and missing business opportunities for decades."*
- Guy Hachey, Bombardier Aerospace

Figure 2: Aircraft sales forecast by region for the period 2011-2020



Source: Bombardier Commercial Aircraft market forecast 2011-2020

1.2 MAJOR TECHNOLOGY AND ENVIRONMENTAL TRENDS

Development cycles

The main challenges and opportunities with which Canadian aerospace companies (companies contributing nearly 70% of aerospace industry employment and revenues) will have to contend over the next three years are:

- global economic conditions;
- introduction of new or improved products and services on the market;
- development of new markets;
- increased participation in the supply chain of T-1 suppliers and OEMs in Canada and abroad;
- intensification of competition from emerging countries;
- reduced production costs demanded by customers.

These major industry changes are applying pressure to substantially and continuously reduce development costs. Development cycles for new products must be ever-shorter in order to offer products that are more efficient in terms of avionics, weight, engine fuel efficiency and aerodynamics. According to Dave Carter, Vice President, Engineering and Technology at United Aerospace Systems, a more systemic approach is required in systems engineering, system simulation tools and validation systems.Product life cycle: World best practices

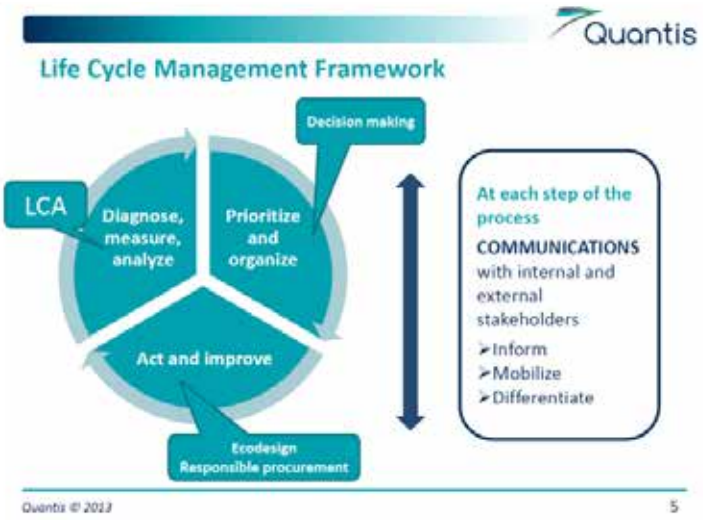
Product life cycle: World best practices

The Forum offered an opportunity to discuss sustainable development, and in particular life cycle management, as specialists in various industries came to share their practices and successes in aerospace. Analysis of the life cycle of a product is not something unique to the aerospace sector. It is possible to accelerate the learning curve in Québec's aerospace sector by drawing on best practices from other industries and transferring them to aerospace. Life cycle management is a generic practice in which most of the concepts are directly relevant and applicable to all industries. According to Jean Simard, President of the Aluminium Association of Canada: *"Life cycle management is a flexible integrated framework of concepts, techniques and procedures to address environmental, economic and social aspects of products and organizations to achieve continuous improvement from a Life Cycle perspective."*

An interesting approach in the form of process was proposed by Edouard Clément, CEO of Quantis, where everything begins with a clear description of the situation: diagnosis, measurement and analysis. This description then allows decisions to be made based on priorities, to act globally and improve effectively (see Figure 3).

Product life cycle management is a good way to standardize discussions in an industrial network. According to Gilbert Delabrousse, Senior PLM Consultant at PCO Innovation, product life cycle management is allowing the auto industry to manage subcontracting more effectively and to obtain more robust data to meet environmental regulations. In sectors with less technological aspects, such as Steelcase in the manufacture of office furniture, product life cycle management allows for the development of products that are healthy for consumers and the environment while creating ideal conditions for their second life through reuse or recycling. Taking into account product life cycle management is becoming a key aspect of organizational social responsibility while proving to be an increasingly powerful competitive advantage.

Figure 3: Quantis lifecyle management



Source: Édouard Clément, Quantis

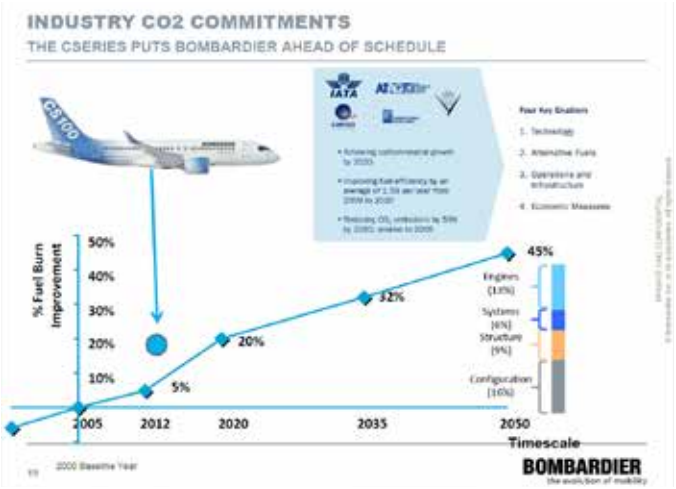
In general, trends in terms of business practices and government regulations are requiring that the development and use of new products are integrated with product life cycle management, including the end-of-life phase and resulting dismantling and recycling considerations. As such, Bruno Stoufflet, Director of Forecasting and Scientific Strategy, Dassault Aviation, presented several challenges and trends in this regard, among others those involving aging aircraft, which pose a challenge from the perspective of the gradual elimination all chromate-based maintenance products.

Life cycle management – OEM'S Vision

The aerospace industry is committed to significantly reduce carbon dioxide (CO_2) emissions over the next few decades. Increases of CO_2 emissions must be halted by 2020 and by 2050 they should be at half the level they were in 2005. This goal by the industry is prompting OEMs to develop more economical aircraft. As pointed out by Robert Dewar, Vice President and General Manager, CSeries, this new aircraft, with a 20% reduction in fuel consumption, is placing Bombardier Aerospace in a good position. Indeed, the new aircraft is almost a decade ahead of industry objectives (see Figure 4).

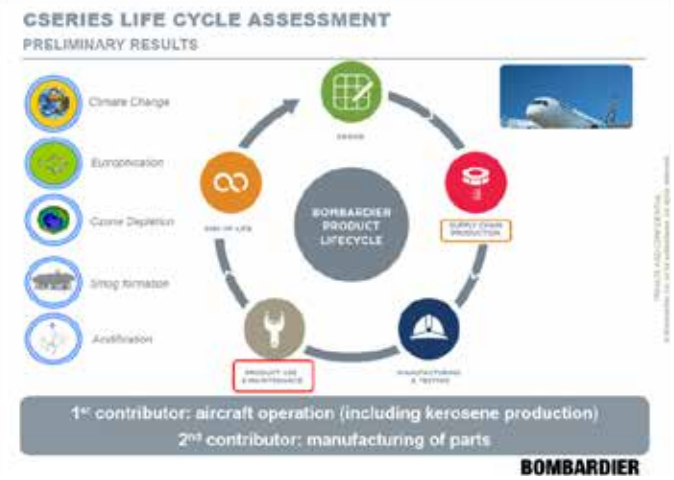
In this regard, an integrated approach to life cycle management is necessary to achieve the major objectives being set by the aerospace industry. Analysis of the life cycle of products must be present in all phases of product development. According to analyzes conducted by Bombardier Aerospace, the two phases having the greatest impact on overall environmental impact are: 1) operation - including the production of kerosene; and 2) the manufacture of parts (see Figure 5). In addition, beyond an integrated approach, it is also important to segment the different phases of the development process to analyze the inputs, the harmful outputs and the cause and effect between them. This continuous improvement approach allows, for example, to eliminate the use of chromates for landing gears or implementing dry machining processes that are much less polluting.

Figure 4: Engine performance improvement goals



Source : Robert Dewar, Bombardier Aerospace

Figure 5: Life cycle vision at Bombardier



Source : Robert Dewar, Bombardier Aerospace

Life cycle management and reduction of environmental impacts – Engine manufacturers' vision

While improving engine performance is not the only way to enhance the overall environmental impact of aircraft, this aspect has a significant impact in terms of CO_2 and nitrogen oxide (NOx) emissions and noise pollution. For example, as explained by Robert Cadieux , Director, Environment and Sustainable Development at Pratt & Whitney Canada , the new PurePower® engine for the new CSeries aircraft generates 16% to 20% fewer emissions.

In addition, the various innovations introduced by engine manufacturers can benefit multiple platforms at the same time. As such, this new engine could also be beneficial for other platforms such as the Mitsubishi MRJ, the second-generation E-Jet by Embraer, the Irkut MS-21, or the Airbus A320neo.

According to all the panelists in the plenary session on the life cycle vision of engine manufacturers, the key to success is to work more closely throughout the innovation chain to develop more integrated and effective systems. Active collaboration is necessary to achieve industry objectives in the following four areas:

- technological advancement;
- operational efficiency;
- improvement of infrastructures;
- economic incentives.

Also, as explained by Dr. Alan Epstein, Vice President, Technology and Environment at Pratt & Whitney, a somewhat different approach is used effectively within his organization, in which it tries to reuse parts that are still useful even though the engine is not. Just because an engine has reached its end of life doesn't mean that all the components are automatically obsolete. In fact, approximately 78% of the raw material purchased for manufacturing an engine is currently recycled. However, the complexity of the materials needed requires an approach to reuse rather than recycle.

David Thibes, General Manager at Turbomeca Canada, confirms these trends. Founded in 1956, Turbomeca has now delivered nearly 100,000 engines. The four core values of Turbomeca are: safety, reliability, customer proximity and innovation. It is currently working on projects involving a modular engine design with a dual compressor, more compact and efficient in terms of consumption, as well as a hybrid engine running on biofuel. The targets to reduce impacts are:

- 2015: - 15% CO_2 - 15% NOX - 5db for noise
- 2020: - 22 % CO_2 - 60% NOX - 10db for noise
- 2030: - 35% CO_2 - 80% NOX

End-of-life management and the global vision of aircraft manufacturers

It emerged from the presentations at the Forum that end-of-life management should be an integral part of the concerns of aircraft buyers and operators. The prerogatives of sustainable development will necessitate the emergence of effective end-of-life aircraft management solutions, and in the near future.

According to the Aircraft Fleet Recycling Association (AFRA), more than 12,000 aircraft will have completed their useful life in the next 20 years. Considering that the European Union has already ordered the auto industry to take over the management of end of life products, there is no doubt that eventually, the legislature will also have a similar requirement for the aerospace industry.

In this regard, Bombardier has launched a project targeting end-of-life aircraft management involving improving the "recyclability" of a CRJ200 that has reached its end of life. It is seeking primarily to create new uses from the parts of the aircraft, for example, reusing portions of wings to make furniture.

David Hellis, Director of Research and Technology at Airbus Americas , said that life cycle management is part of his company's DNA and it is working on multiple projects involving all stages of the life cycle: design, procurement, manufacturing, aircraft operations and end-of-life management. For example:

- 53% of efforts to improve energy efficiency are being invested in materials;
- a special effort is being placed on the health of passengers, with devices to remove VOCs and ozone;
- the assembly plant in Toulouse is lit by solar panels;
- hazardous substances have been removed and replaced with biodegradable products; for maintenance, fewer harmful cleaners and fewer amounts of paints and solvents are used.

Simulation, design, automation technologies

Virtual simulation has many implications for the aerospace industry, and for all stakeholders. We are witnessing a paradigm shift, according to Jacques Duysens, head of operations and director of simulation activity at SILKAN (see text box).

Virtual simulation is a discipline that now involves all phases of product development. Optimized numerical simulation reduces overall development costs and the entry into service cycle. In fact, simulation plays a critical role in product development. It enhances finished element analyses to improve the reliability and quality of products. Simulation data management is now being added to maximize the use of information generated by different analyzes, either to validate models or identify trends.

Although the trend is to reduce or even eliminate physical prototypes, several issues and challenges are still present, especially in regard to multi-scale, multidisciplinary analyses and the interoperability of the various systems available. Much work is still needed to ensure the aerospace industry can fully benefit from simulation technologies throughout the global aerospace ecosystem. According to Michel Tellier, Vice President, Aerospace and Defence, at Dassault Systèmes, there is still a major gap between development work being carried out by universities and what is actually being used by the industry.

> ***Old Paradigm:*** *Experiments are the qualification tests; proof that something does or does not "break". Simulations are used to understand the behavior observed and, generally, after the fact.*
>
> ***New Paradigm:*** *Experiments explore the physics or mechanics and provide data to validate predictions. Simulations are asked to predict with quantifiable confidence and across the operational space.*
>
> ***Decision-making*** *is therefore increasingly based on Modeling and Simulation to obtain validated, science-based predictions. Validation needs to assess the uncertainty, including lack-of-knowledge, and its effect on the predictions and the decisions they support.*
>
> Source: Jacques Duysens, Silkan

Automation of manufacturing processes

Trends in the aerospace industry are requiring that new part designs are of the best quality, available at lower cost and for longer times – all in an increasingly short cycle time. These constraints are making the automation of manufacturing processes indispensable. According to two speakers at the Forum, Chris Blanchette, National Account Manager, Distribution - Assembly and Aerospace Automation, at Fanuc America, and Pédro Pomar, Industrial Engineer at AERnnova, automated manufacturing solutions will improve several aspects of manufacturing, including repeatability, rigidity, flexibility and reduced production costs.

To effectively implement an automated process, it is essential to conduct a rigorous and transparent analysis of existing manufacturing processes. Good planning and involvement of all stakeholders is a recipe for success for this type of systemic and multifunctional project. The vision of the future regarding the use of robotic manufacturing systems in the aerospace sector is for their increased use. Compared to the automotive sector, where the most important criteria are volumes and low costs, a similar growth should be observed in the aerospace industry, but following criteria specific to the industry, namely flexibility and repeatability.

> *"Automation is not a magic wand: if you automate a manufacturing process which gives poor quality parts, you will get a larger amount of poor quality parts at low prices."*
>
> Source: Alain Ouellette, GE Aviation Bromont

Advanced (or additive) manufacturing

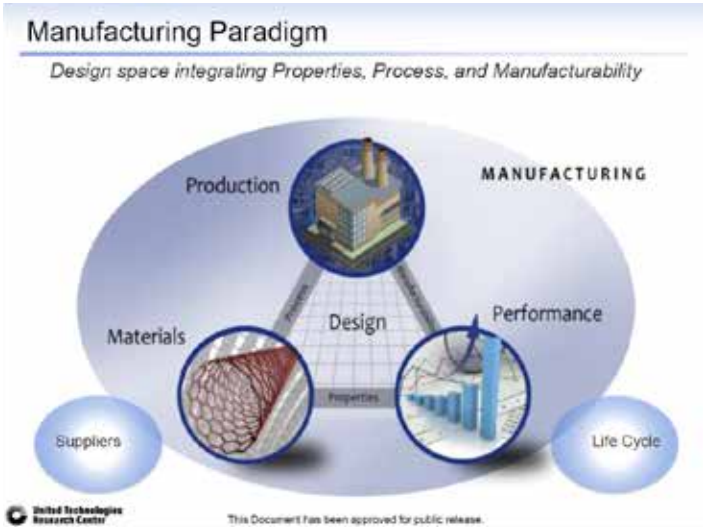
One of the trends presented during the Forum involved advanced (or additive) manufacturing. The constant development of new technologies and ongoing objectives for ever-more efficient specifications are exerting pressure on manufacturing technologies. There are several growing needs in terms of manufacturing technology in general, such as reducing cycle times in bringing products to market, reducing environmental impacts and weight optimization. There are additional challenges specific to additive manufacturing, such as the additional geometric complexity or increases in options for choice of materials. Despite these constraints, additive manufacturing methods result in numerous advantages such as rapid prototyping, the low-cost manufacture of certain tools in a short time, the manufacture of certain parts for flight tests – and even some parts directly for production. According to Scott Martin, Senior Manager, Next Generation Composites Manufacturing Processes at Boeing, the company is already using additive manufacturing for more than 200 parts in 10 of its platforms.To maximize the potential of advanced manufacturing technologies, they should be integrated into the very early stages of design. Advanced manufacturing processes require a "design for functionality" approach.

According to Julien Chaussée, Specialist Engineer, Advanced Structure and Central Engineering at Bombardier: *"Additive layer manufacturing brings all sorts of freedom: They need to introduce that mind-set within the beginning phase of the design; reproducing same parts with that new manufacturing process won't reach its full potential."*

According to this specialist, in order to facilitate this integration, certain specific actions can be identified:

- share knowledge about the growing feasibility of this type of process with designers;
- add this design for functionality method to software optimization tools;
- strengthen the robustness of equipment;
- assure the reproducibility of raw materials from one supplier to another;
- establish standards regarding specifications and compositions of raw material;
- reduce equipment operating costs.

Figure 6: Manufacturing Paradigm



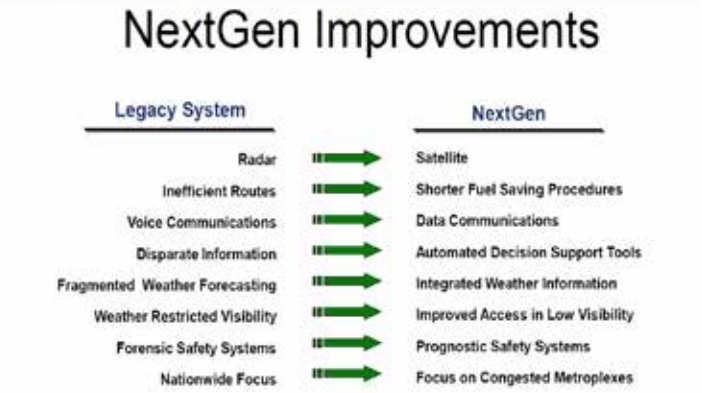
Source: Éric J. Amis, United Technology Research Center

Navigation : Innovation and challenges

The basic principles of air navigation include the processes of planning, registration and movement control of an aircraft. Navigation systems have evolved over time; several high-performance technologies are now available prioritizing traffic that is both safe and effective. Like any technology sector, the acquisition of new avionics systems must be justified by the benefits they bring. This was underscored by conference speaker John Studenny, Director of Systems Engineering at Esterline CMC Electronics: *"NextGen Air Transportation system(4) is intended to reduce aviation fuel consumption, reduce emissions and airspace congestion. The airspace will become a 'NextGen' Airspace."*

Like many current aerospace initiatives, an integrated and systematic approach will achieve the greatest benefits and this approach, through the NextGen program, requires changes at several levels shown in Figure 7. One can also observe this integrative approach at NAV Canada in order to improve its coverage of surveillance and communications systems through the Aireon system. Using the Iridium satellite constellation, consisting of more than 66 satellites, it provides 100% coverage of the territory with significantly reduced cones of silence. This reduction in communication separations allows for a more efficient use of airspace, reduced customer costs and a lower environmental impact.

Figure 7: NextGen Improvements



Source: Steve Bradford, NextGen, FAA

Diagnostics, Prognostics and Health Monitoring (DPHM)

Although the Forum allowed participants to learn about this emerging field, it appears that many of the technologies in areas such as DPHM may not be commercialized in the short term due to lack of technological advances and commercial justification. Firstly, there is still a lack of basic scientific knowledge. Secondly, the various innovations related to DPHM are not yet essential to the commercialization of aerospace products since the current regulation does not yet make them mandatory.

Nevertheless, several initiatives aimed at improving the health of aircraft systems reflect activity being carried out in this area in the aerospace industry. For example, the research of Dr. Prakash Patnaik, Director of the Air Defence Systems program at the NRC, is targeting the integrated management of an aircraft's condition. This research has considerable potential since it provides, among other things, for cost reductions in the total life cycle of products and an increase in the effectiveness of the maintenance strategy and the lifespan of structures. Also, EWIS Health Monitoring, a division of the Safran group, is actively investigating practical solutions to improve the DPHM of aircraft. For example, reflectometry technology, smart sensors or the integration of sensor networks. Finally, development work to improve DPHM is not limited solely to the fuselage and aircraft avionics.

Héroux-Devtek, which specializes in the design and manufacture of landing gears, also is undertaking several research and development projects aimed at improving DPHM. For example, proximity sensors, wheel speed sensors, or temperature sensors for brakes and tire pressure. These projects aim to better detect the presence of corrosion and fatigue cracks to improve safety, reduce the number of inspections, increase the life of the unit and reuse data for the future design of other products.

DPHM is an investment that pays back over the long term. ÀThe integration of intelligent systems always adds an additional level of complexity, higher costs and extra weight to the aircraft. But indirectly, these systems can provide many savings in terms of maintenance and durability. However, these systems are still currently considered "interesting" rather than obligations. This approach will nevertheless lead to change over the long term when the complexity of the systems is mastered to obtain maximum added value or when the regulatory environment requires them.

SECTION 2. CHANGES IN STRATEGIES, MANAGEMENT SYSTEMS AND ORGANIZATIONAL MODES IN THE AEROSPACE INDUSTRY

2.1 CURRENT HIERARCHICAL STRUCTURE OF THE AEROSPACE INDUSTRY: CHANGES IN SIGHT

Certain operational responsibilities and initiatives in aerospace innovation are increasingly decentralized or the subject of cooperation. This is requiring more interactive ties as opposed to hierarchical ones between the players in this industry.

The current model remains a multi-level hierarchical structure. Full control of all phases, from design to marketing, is concentrated at the top structure of the pyramid. Québec's aerospace industry is no exception to this trend, being dominated in terms of number of employees by major prime contractors which employ more than 60% of industry personnel .

Complexity requires intensifying and better coordinating interrelationships among aerospace companies

The various presentations and panel discussions held during the Forum all confirmed the general trend of increased complexity. This is requiring a reorganization in the relationship between integrators (Tier 1) and various subcontractors (Tier 2 and more), including SMEs at the bottom of the hierarchy of the supply chain. According to Dave Carter, Vice President, Engineering and Technology, at United Technologies: *"Airplane economics drive new platform launches with more electric and more intelligence prevalent in new aircrafts. System complexity is increasing and requires greater emphasis on system engineering, system tools and systems validation."*

The Tier 1's have been given more responsibility in recent years in terms of innovation. In turn, the Tier 1's want to share certain responsibilities, including financial risk, with their suppliers, including SMEs. The combination of economic pressures (lower costs from an increasingly globalized supply chain) and evermore complex new technologies to be mastered – along with a more restrictive environmental context – is making innovation increasingly indispensable. In addition, given that these innovations are systemic, all players in the chain must be involved. This trend was confirmed during the Forum by, among others, Bruce Parry, of the Corporate Social Responsibility department of Bombardier Aerospace: *"There are many mechanisms across the world tackling this increase [of environmental regulations] promoting innovation through cooperation and partnership."*

These changes in the long-term vision of product development, supported by a global vision of markets and a global network of suppliers, were underscored by the presentation of Airbus at the Forum (see box). All leaders of the industry shared this overall vision and the business practices promoting new approaches for closer coordination and ongoing collaboration, resulting in the development of partnerships over the longer term. They include, among others, Scott King of Northern Irland Advanced Composites and Engineering Center (NIACE): *"All our participants have a desire to perform and increase R&D, work collaboratively, build new networks, share capabilities and knowledge."*

> ***Vision of a large group: EADS – Airbus Americas***
>
> *For a large group such as Airbus Group, as noted in a presentation by Dave Williams, Vice President Supply Chain, Airbus Americas, a global leadership vision is required through the establishment of integrated platforms and systems. The ultimate goal is to achieve profitability in the context of globalization by balancing revenues and activities of the group. To achieve this, Airbus Group needs to focus on its core activities and optimize its financial resources while providing consumers with high quality services. According to forecasts, the increase in demand for aircraft offers new opportunities in terms of supply.*
>
> *Over the next 20 years the aircraft fleet will increase by nearly 19%, i.e. 29,000 aircraft will be sold. The global vision of Airbus Group for 2050 was developed as part of the "Smarter Skies" program. This program aims to develop faster takeoff, reduce noise, and improve aircraft flight in terms of altitude, etc. Airbus Group has also identified major challenges such as space management, and the use of robotics, etc. To achieve this, Airbus Group wants to set up a network of world-class suppliers to offer the best aircraft in the world.*

Managing coordination requires improving the management of expertise and technology innovation in general

Trends in the supply chain are affecting the technological innovation process since innovations now come potentially from everywhere, from internal divisions as well as external partners. For example, Bombardier Aerospace is working to build and document its portfolio of technologies and internal talent in order to offer new products more quickly (and refresh existing ones), according to consumer needs. Bombardier Aerospace also has a strategy to use more technologies coming from outside to find ways to differentiate itself from competitors. It is looking for talent to innovate on the managerial level and improve its management processes since product innovation also involves reinventing leadership, especially at the operational level. Indeed, it is increasingly relocating closer to demand in emerging countries. It is also requiring the establishment of business units that are managed independently in terms of business development, market intelligence, understanding of customer needs, planning operations and achieving high levels of quality.

2.2 REORGANIZATION AND RELOCATION OF PRODUCTION CHAINS

Local reorganization of the Québec cluster

During the Forum, some OEMs, SMEs or subcontractors discussed their challenges and visions of success factors that are enabling them to remain competitive. Many of these companies have managed to grow and diversify by taking advantage of new opportunities in the global aerospace industry. To do so, substantial investments are required to strengthen and expand operational, technological and human capacities. Three trends are noteworthy:

- Investments are being made abroad to benefit from the shift in demand. These changes require organizational changes and disciplined management since companies are now being called upon to develop and manage international networks.
- It nevertheless appears that major investments are also being made to strengthen the local supply chain of Québec's aerospace industry.
- Montréal is already attracting a major share of foreign investments. However, several local players, in turn, are establishing manufacturing and innovation facilities abroad.

General relocation trends by major contractors

During his presentation, Dave Williams, Vice President of Procurement at Airbus Americas, explained the objectives of locating his company's activities. Airbus Group wants to increase its international presence in order to arrive at a ratio of 50% in Europe and 50% in the rest of the world.

Currently, Airbus Group has a presence in India, China, Brazil, the United States and Canada, and it plans to increase its presence in other countries such as Mexico. The ultimate goal is to develop long-term partnerships with suppliers in these countries. The criteria that Airbus Group considers when setting up in a country are: access to markets and resources, costs and risk management.

The competitiveness of Canada and Québec on the world stage

The competitive advantages of Québec are such that the Québec aerospace cluster is competitive globally. However, local players need to increase their individual competitiveness so that major foreign prime contractors will establish a presence here and develop business relationships with them.

For example, the presence of Airbus Group in Canada has been beneficial: revenues increased by $72M in 2000 to $450M in 2012, with an increase of 1,700 local employees in 2012. According to Mr. Williams: *"Canada is a highly rated country with several advantages such as access to resources, risk sharing, access to research infrastructures and the knowledge of other key industry players, as well as acceptable production costs. However, these benefits are slim compared to other countries such as France, China, Italy and Brazil who are close behind. To ensure that Canada maintains its competitive advantage over other countries, it has to remain at the top of the First Tiers and achieve first in class."*

Impacts on internal management and inter-company relations

Some workshops and discussions focused on the transformation of relations between prime contractors and Tier 1 suppliers, those situated on the first and second rung in the supply chain industry, and SMEs.

It is clear that adjustments in customer-supplier relationships have taken part on both sides and that SMEs should be prepared to face many changes, for example, to become specialized in order to take advantage of global opportunities that are emerging. For two Forum panelists, Michel Thiffault of Messier-Bugatti-Dowty, and Marc André Duranceau, Vice -President, Aerostructures and Aircraft Services at L- 3 MAS, it is clear that structural changes in the industry are catalysts for change. This is an opportunity to work together and SMEs must therefore be ready to evolve.

Communication between prime contractors and SMEs is essential because it will allow both parties to create value together. In a relationship between Tier 1 and SMEs, what is important is to maximize the added value of the partnership and to listen carefully to the market. Recommended key success factors for SMEs are: structure a realistic plan, know where you want to go and follow this road map without improvisations.

An interesting case was presented by Raphaël Duflos, Vice-President, Supply, at Aérolia, a Tier 1 specializing in equipped fuselage aerostructures whose mission is to offer its customers the best metals and composites. 77% of Aérolia's activities are subcontracted outside the company, and given the context of globalization, the supply chain is changing significantly. These changes ensure that the business relationships Aerolia has with its customers (aircraft manufacturers) and its subcontractors (SMEs) are changing. Aerolia offers SME subcontractors considerable business opportunities, but these could be a threat to their survival if SMEs cannot manage the risks inherent in growth and diversification, as well as international expansion.

From the point of view of subcontracting SMEs, since the markets have now become global, they must develop partnerships with larger companies, either Tier 1 or prime contractors. These partnerships reduce commercial and financial risks, and also lead to the acquisition of management know-how. They force SMEs to expand their technical and operational capabilities and be more integrated in order to occupy a choice spot in the value chain.

For example, in 2010, Aerolia and six SME partners created an aerospace park in Tunisia. This project was made possible because all the companies were complementary. They were able to share a vision, the risk, responsibility and the development of knowledge. Based on this successful experience, Aerolia managers believe that the success of a partnership between a large company and a small business rests in good communication, a relationship of trust, as well as the ability of the SME to demonstrate that it is an innovative and efficient company that can at all times meet the demands and needs of a large company.

Jean Blondin, President of ABIPA, confirmed these new opportunities for SMEs and the challenges involved. ABIPA is a Québec company founded 30 years ago specializing in the machining and welding of components used in the field of aeronautics. It faces very intense competition, thereby differentiation becomes paramount and must be anchored in being closely aligned with the needs of consumers. It is important to become the best in the market and be able to deliver according to customer needs. Jean Blondin says it is crucial for SMEs to listen carefully to the needs of their consumers. Customers of aerospace SMEs expect to work with specialists. As a result, SMEs must define their "core business" in relation to the needs of their potential customers, adapt to the new global environment, and work hard to offer the best possible price.

ABIPA is seeking a greater integration in the global supply chain in order to reduce costs and share risks. The industry is changing; it is now international with the creation of parks or clusters in countries such as China, Morocco and Mexico. The industry has become more competitive with the arrival of big new players like Mitsubishi and other prime contractors from emerging countries. Finally, suppliers of raw materials are becoming more demanding during negotiations, particularly with regard to volume.

In this context, practices in the supply chain are changing. Tier 1 suppliers want to share the risk with their suppliers, resulting in the development of a partnership.

Internationalization is becoming mandatory. Companies must be present at the international level. Local markets are no longer sufficient. SMEs must work on reducing costs and be more innovative. To achieve these objectives, it is necessary to improve cost structures, invest in technology and innovation, develop relationships with Tier 1 suppliers, stay close to prime contractors and keep abreast of market needs.

For SMEs, all these structural changes in the aerospace industry mean that they must develop an international differentiation strategy and thus be the "benchmark." These requirements are real challenges because many SMEs do not have the means to deploy internationally, and support programs are not always suited to their needs.

SECTION 3. CHANGES IN COMMERCIAL AND FINANCIAL TARGETS AND RISK-TAKING

3.1 CHANGES IN MARKET AND PRODUCT NEEDS: SUSTAINABLE DEVELOPMENT'S LONG-TERM VISION

The aerospace industry has undergone waves of major and sustained change in supply and demand, stimulating the development of new products, all in a context of persistent economic uncertainty and in which corporate social responsibility is increasingly restrictive. Innovation must be effective and sustainable.

Development planning and the launching of new products need to integrate multiple parameters which meet economic and regulatory requirements, as well as the imperatives of sustainable development in terms of pollution, noise, and end of life management. Trends in research and product development are now increasingly influenced by the customer needs of airline operators ("market pull" approach). They are also strongly affected by environmental trends stemming from an increasingly strict regulatory context. It is clear that commercial and environmental pressures are converging towards greener aircraft in all their components, and taking into account the entire life cycle management, including end of life.

New commercial targets are guiding the development of products and aerospace components towards respect for the environment and sustainable development requirements on a world-wide basis. And this is increasing over time: cleaner engines, aircraft whose architecture and propulsion system make them less noisy, the use of new materials to make lighter equipment, reduced rejects and waste during production activities (see Figure 8).

Figure 8: Industry commitments regarding CO_2 emissions

3.2 BUSINESS, FINANCING AND REVENUE MODELS:

The global market is dictating many changes in the aerospace industry. Strategies and business models are evolving locally and globally: local and global supply chains are relocating and/or reconfiguring depending on supply and demand as well as socio-economic factors. Deployment strategies and business and revenue models are based on efficiency, reliability and development speed at reasonable and shared costs.

Changing markets, new commercialization and revenue models

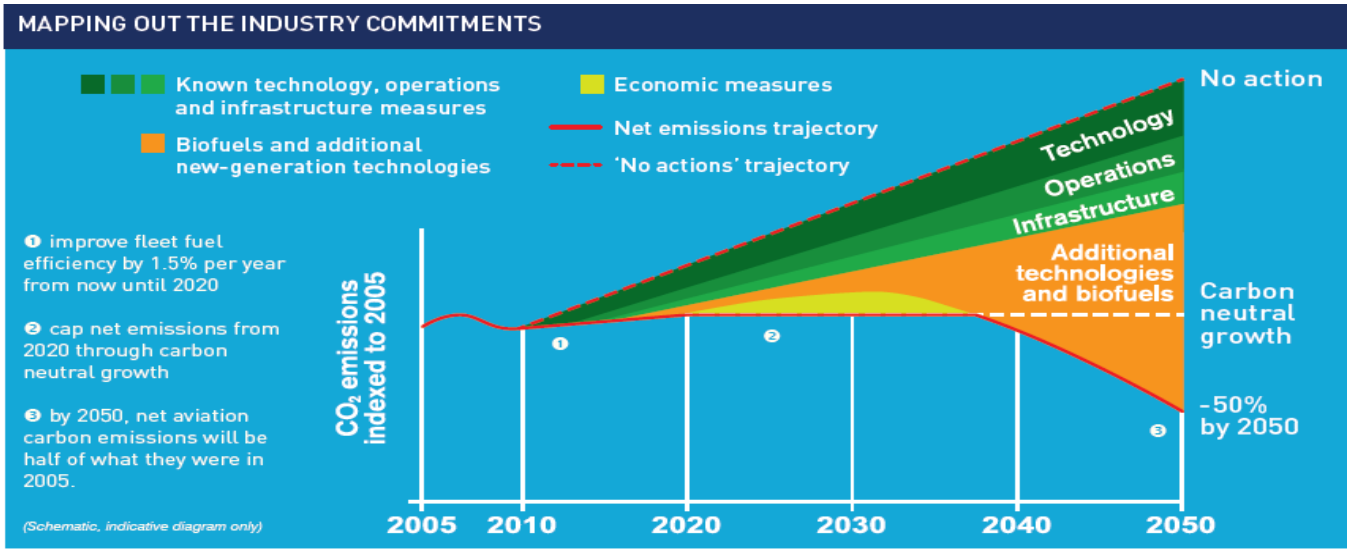
The plenary presentations of the Forum confirmed that aircraft manufacturers' vision is, more than ever, to look at the long term. The life duration of aircraft, which is 20 to 30 years, involves a long amortization of investments – for aircraft designers and manufacturers, for users and for those who maintain them.

Globalization is resulting in many changes in ways of conducting business:

- First, new airlines are emerging: supply and demand is shifting, demand is growing faster in emerging countries and the requirements of these foreign customers may differ.

- Second, it is becoming easier and cheaper to buy new aircraft than to maintain the old ones, which are also considered too polluting: this is offering an opportunity for a more rapid increase than in the past in demand for aircraft fleet renewal.

- Third, airlines and major clients in the aerospace industry now want to reduce their initial investments as well as their financial risk. They have adopted a different business model: they are paying to buy flight hours. Aircraft manufacturers are having to sell and guarantee a service, not a plane. This approach is similar to that adopted long ago in the automotive industry.



Source: Hélène V. Gagnon, Bombardier Aerospace

SECTION 4. CHANGES IN THE ROLES OF INDUSTRY PLAYERS: RESEARCH INFRASTRUCTURES, CLUSTERS AND GOVERNMENTS

The major challenge for the Canadian industry as a whole will be to determine the role and responsibilities of the various stakeholders, and to move them forward together. All players, private and public, must fully engage together and for the long term.

4.1 RESEARCH INFRASTRUCTURES

A favourable context

The strength of Québec's aerospace sector lies in its infrastructure ecosystem. Québec's aerospace industry has a research infrastructure that is unique in the world, with educational institutions, research centres and associations that ensure a constant dialogue and cooperation among all stakeholders in the industry. In addition, a favourable climate and a dynamic of collaboration in "open innovation" have been created and promoted within the Québec aerospace sector. This ecosystem is unique in the world and its collaboration dynamic is becoming fertile ground for the implementation of new work methods and leading-edge practices across the entire aerospace supply chain.

Numerous existing infrastructures

The innovation ecosystem is based on a network of educational institutions, four university aerospace institutes, two aerospace technical schools, and highly-regarded private and public research centres (e.g. CDCQ: Centre de composites du Québec, CTA: Centre technologique en aérospatiale, NRC: National Research Council Canada, CIFA: Centre international de formation aérospatiale). It also includes liaison partners that play a strategic and mobilizing role, such as CRIAQ, Aéro Montréal, the GARDN network and the SA²GE initiative.

New resource management practices

This network has for over 10 years driven excellence to new heights through the development of collaborative research. Today, this ecosystem is positioned for a second wave of collaborative projects aimed at enhancing collaboration and interaction among research teams through new work practices and methods (social innovations). Pilot projects such as the Pooling and Automation of Resources in Communities (PARC) or the Collaboration for research resources, equipment, and expertise (CRÉER) project are helping to establish new management techniques to optimize use of the cluster's capabilities (human capital, infrastructure and equipment). The idea is to maximize the integration of these resources, which is increasingly considered to be the new innovation system of the 21st century.

PARC

The PARC Pooling and Automation of Resources in Communities project proposed by JMJ Aerospace – originally selected as part of the 5th catalyst project of the Quebec Strategy for Research and Innovation (QRIS) 2010-2013 – became part of the National Research and Innovation Policy (PNRI) in 2012. This three-year, $2.9M catalyst project received funding of up to $1.2M from the Quebec Ministry of Higher Education, Research, Science and Technology (MESRST). Launched in October 2013, PARC aims to test new ways of working and industrial collaborations, and systematize them on a transactional technology platform. The PARC project is a multi-sectoral initiative supported by large companies in the aeronautical field such as Bombardier Aerospace, Pratt & Whitney Canada and Bell Helicopter Textron, and by Aluminerie Alouette in the metallurgy sector. They are collaborating with leading academic institutions including École Polytechnique, McGill University, HEC and ETS.
In addition, several umbrella organizations are supporting PARC, including Aéro Montreal, CRIAQ, FCCQ and STIQ. The principle of sharing is the leading objective of PARC. The idea is to experiment with new ways of working to mitigate the cyclical effects experienced by the industrial sectors and their workers. Giving workers more security through these cycles, reducing job dislocations, and encouraging organizations to stay connected with their employees will result in better retention and more knowledge. A second major objective of the project is to facilitate access to leading-edge equipment, optimize the use of existing infrastructure and support industrial cooperation in terms of research and development. This will spur collaboration among industry-universities/research centres.

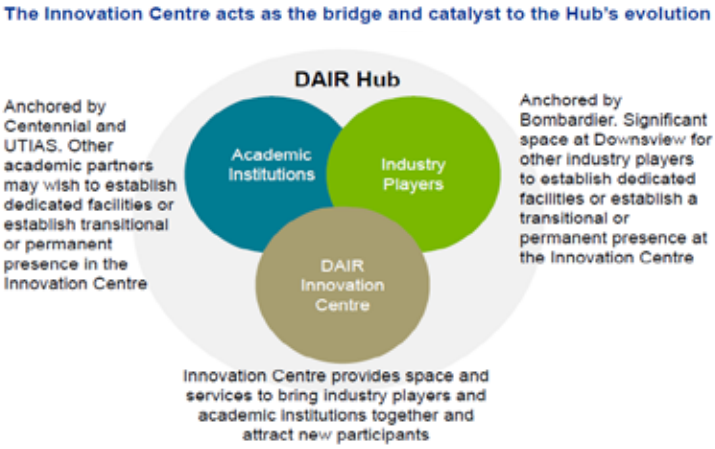
CRÉER

The CREÉR project (collaboration for research resources, equipment and expertise), in which are involved JMJ Aerospace, Aéro Montreal and HEC Mosaic, is a sub-project of the PARC catalyst project. The one-year CRÉER project was launched on January 31, 2014. This project is taking place in a context where all aerospace players increasingly recognize the importance of joining forces, and therefore sharing, their research infrastructure as well as related resources and expertise. More than ever, they recognize the importance of collaborative research. However, neither the aerospace players nor the resources are currently managed for this purpose. The project aims to assist aerospace players to meet the challenges of managing knowledge and skills, organizations, intellectual property and creativity/innovation. This will enable them to optimize the sharing of research infrastructures.
The CRÉER project is valued at $259k ($131k cash and $128k in kind) and operates as part of the "Plan C" of CRIAQ in collaboration with Bombardier Aerospace, Pratt & Whitney Canada and Bell Helicopter Textron under the guidance of a university research team from École Polytechnique, McGill University, the ETS and HEC.

Canadian and foreign models of novel infrastructures

In order for Canada to capture its share of the global, and growing, aerospace industry, it will be necessary to have access to a sufficient number of qualified personnel as well as increased R&D efforts through innovation and collaboration. This is the vision of the Downsview Aerospace - Innovation and Research (DAIR) project. DAIR aims to build a centralized and collaborative aerospace hub based on assets present in Ontario and complementary to the Québec and Winnipeg clusters (see Figure 9). The NRC is also actively discussing mechanisms recommended in the Emerson Report regarding strategic aerospace hubs. These centres, located near equipment, expertise and organizations are helping to improve the development of the value chain. This brings additional opportunities for SMEs, whose projects are often outside of traditional financing programs.

Figure 9: The DAIR Matrix



Source: Andrew Petrou, DAIR

This trend of collaborative investment in innovation infrastructures is not unique to Canada. The Northern Ireland Advanced Composites and Engineering Centre (NIACE) acts as a liaison between government, industry and academic organizations by focusing its activities at TRL 4-6 (see Figure 10). The Forum also highlighted initiatives that are seeking to bring together innovation players through incubators of technology companies. This is the case in Russia with Skolkovo, which is looking to reduce the gap typically found between technological development and market needs. The idea is to combine the key ingredients of a successful innovation ecosystem: financial incentives, entrepreneurial projects, technological universities, research infrastructures, industrial partners and government support, as well as services and mentoring for SMEs. Skolkovo therefore aims to go beyond the simple framework of research infrastructure by subscribing to the broader concept of open innovation and the "innovative city."

Figure 10: NIACE

Source: Scott King, NIACE

Key success factors for efficient research infrastructures

The efficiency of research infrastructures depends on a number of factors outlined below:

- all infrastructure models should focus on the industry and have its support;
- their activities do not focus on product development but rather to the demonstration of technologies;
- they are mainly located on industrial sites or parks;
- they dedicate themselves fully to a sector or on a strong sector;
- they benefit from a major involvement of OEMs;
- they are heavily funded by governments (up to 100% in some cases);
- they can even be established directly within OEMs.

The following key success factors regarding the functioning of an infrastructure ecosystem are also worth noting:

- launch projects on the basis of stronger knowledge: work smarter (making it right the first time), perform more analyses and simulation in early design;
- manage and transfer knowledge: during development projects, ensure a better transfer of knowledge from one stage to the other internally, and a better transfer of knowledge from one organization to another, externally;
- share scarce resources such as manpower, expertise and know-how. This will promote multidisciplinary teams.

Given the importance and complexity of the issues surrounding research and innovation infrastructures, all of the above points are elaborated on in separate briefs.

4.2 STRUCTURAL INNOVATIONS: THE ROLE OF INNOVATION CLUSTERS

Evolution of the Aéro Montréal cluster's structure

Players in the global aerospace industry are geographically dispersed, yet integrated with each other more than ever. They should coordinate more upstream (innovation) and downstream (manufacturing). The trend is to decentralize a portion of the innovation towards Tier 1 suppliers and thereby cascade this to other subcontractors. Innovation modes are more collaborative (with the development of collaborative research), with an increased role played by innovative SMEs to revitalize and strengthen the competitiveness of the supply chain. We are witnessing a restructuring of the industry and a reconfiguration of roles in innovation: new chains of players, new innovation chains and therefore new investment chains in innovation. The presentation by Louis Bouchard, Supply Chain Manager at Bombardier Aerospace, summarized the issues (text box below).

> ***BOMBARDIER AEROSPACE – Supply chain***
>
> *Bombardier Aerospace is a company focused on innovation. It needs to master many fundamental technologies since it is the integrator that designs and manufactures aircraft. It is constantly innovating with, for example, many projects on the use of biofuels.*
>
> *For a large group, the role of suppliers is very important. Therefore, Bombardier Aerospace is committed to create a close relationship with them by sharing all information regarding its customers' needs. Bombardier Aerospace's entire supply chain can then work together to achieve its customers' objectives.*
>
> *This approach could not be more relevant when one considers that 82% of Bombardier Aerospace's activities fall under the responsibility of its suppliers.*

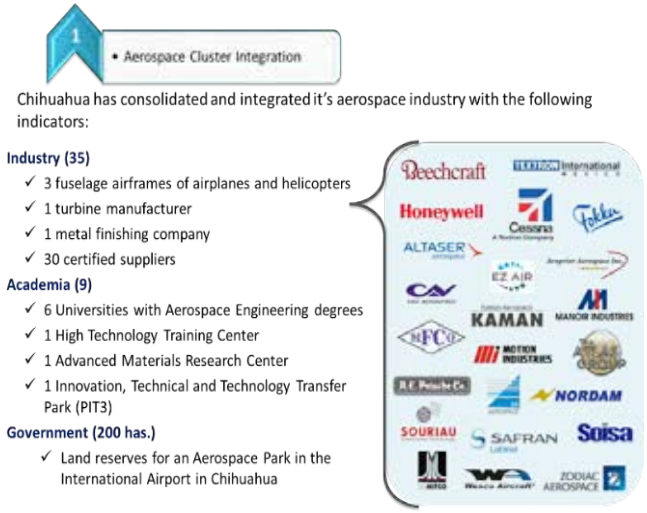
The consensus reflected in several presentations by leaders of major groups and SMEs is as follows: the traditional approach that "opposes" prime contractors on the one hand, and their subcontractors on the other hand, must change: communications and the exchange of new ideas need to be more interactive and bilateral. Subcontractors will then transition from a "*Build to Print*" role (Top-Down innovation approach) to a more prominent role in innovation (Bottom-Up approach). Thus, in addition to prime contractors, Tier 1, 2, 3 become catalysts for change. However, given their limited resources, all suppliers will benefit from government support to meet the challenges of these changes in the industry's supply chain, particularly those related to innovation, in order to successfully position themselves properly on the world stage.

> ***BOMBARDIER AEROSPACE – Innovation chain***
>
> *As presented by Mathieu Boisclair of the Office of Strategic Technology at Bombardier Aerospace, the company also seeks to develop partnerships through collaborative research projects. Universities have been recognized as being very good partners for the development of new technologies requiring research and development at a very early stage of the innovation process.*
>
> *Bombardier Aerospace currently has over ten collaborative projects under technology demonstration platforms, such as the SA²GE and GARDN projects. These programs allow Bombardier Aerospace to understand how all the new technologies being developed work in practice before incorporating them in its aircraft. Note also the involvement of Bombardier in CRIAQ and CANNAPE.*

Examples of successes of clusters in emerging countries

The case of the Chihuahua, Mexico, aerospace cluster, presented by its Director General José Luiz Rodriguez, is an excellent illustration of how various involvements by the private and public sectors can build a strong supply chain and lead to a competitive and prosperous aerospace industry (see Figure 11 and text box).

Figure 11 : Chihuahua cluster



Source: José Luiz Rodriguez, Chihuahua Aerospace Cluster

Chihuahua Cluster, Mexico

The Chihuahua aerospace cluster was established in 2009 with a mission to provide MRO services and fill existing "gaps" to ensure Tier 2 and Tier 3 are better integrated throughout the supply chain so that they can better serve the needs of Tier 1. Four major manufacturers have joined the cluster to date, as well as a major company resulting from a collaboration between Bell Helicopter, Zodiac and Safran. The Chihuahua cluster also has a network of 31 other certified suppliers , mainly specialized SMEs. José Luiz Rodriguez believes that changes in the supply chain are providing an opportunity for Tier 2 and Tier 3. However, to ensure a successful integration of these suppliers, it is necessary to view the Tier 2 and Tier 3 as partners rather than mere suppliers. He therefore recommends that Tier 1 and prime contractors become involved in the supervision and transfer of knowledge and expertise to Tier 2 and Tier 3 because they have a responsibility to support smaller suppliers and the development of a competitive supply chain. Based on successes to date in the cluster, it appears that if the relationship between Tier 2 and 3 on one side, and Tier 1 and prime contractors and the other, develops in a context of partnership, then the Tier 2 and 3 will increase their productivity, leading to an increase in the competitiveness of the supply chain as a whole. These relationships should be balanced and bilateral. Also, constraints and prerogatives of each party must be respected in a spirit of "win-win."

4.3 GOVERNMENT FINANCING AND PROGRAMS

Government role in supporting the industry

The role of government in support of the Canadian aerospace industry is essential on numerous levels. It should focus on the following key areas mentioned in the Emerson report:

- *support research and development (R&D) which is susceptible to not show commercial results for several years but would greatly serve the public interest, in part because of risk sharing;*

- *improve the functioning of markets and company performance by facilitating communication between companies whose needs and capabilities may be complementary – in Canada and abroad and between industry and higher education and research institutions;*

- *make decisions in procurement that strengthen domestic industries and, by extension, the country's economy while respecting international trade rules and acquiring the best product at a reasonable cost;*

- *protect the population - and industry – by ensuring that Canadian products are safe and that strategic technology does not fall into the hands of hostile states or interests;*

- *improve the efficiency of the labour market by supporting dynamic higher education institutions that understand the needs of the industry and facilitate the recruitment of qualified people from abroad in areas where the country is facing a serious skills shortage;*

- *enable Canadian companies to compete on an equal footing with their competitors on the world stage by negotiating fair rules of the game, ensuring that these rules are respected in practice, and by communicating information on foreign markets with companies;*

- *provide funding to support the purchase of Canadian products, provided that funding arrangements are beneficial to taxpayers and the economy, and that they fall within the framework of international agreements.*

The waves of significant changes in the aerospace industry are affecting the role of governments. The global context, the environmental requirements of sustainable development, as well as increased competition mean that Québec's aerospace industry is aware of the challenges and the required investments. It has also developed specific expectations with regard to government support for many major and mobilizing projects,

which are long-term and collaborative.

Once again, the Emerson Report, for its part, has recognized these needs:

"But policies and judicious public programs, targeted and implemented appropriately, can play a crucial role in facilitating success by encouraging aerospace innovations that involve a huge financial risk and a long lead time,

- *by improving industry access to supply chains and global markets,*
- *by leveraging public procurement to support industrial development*
- *by helping to ensure a skilled and flexible workforce."*

Government support programs

During the Forum, various existing programs, including some which have been modified, were presented.

The Natural Sciences and Engineering Research Council (NSERC) has expanded its range of support programs to better support not only university researchers, but also companies that collaborate with universities and welcome their students. The NSERC now offers a wide range of partnership programs oriented towards technology development in an industry setting, but is also investing in skills development. There are several of these programs in the form of scholarships for undergraduate students or graduate students. Regardless of the approach, the goal remains to provide additional financial leverage and complementary skills to accelerate technology development and eventually generate business and financial success.

Industry Canada's Strategic Aerospace and Defence Initiative (SADI) program provides repayable financing equivalent to 40% of eligible project costs. The program's objective is to support research and development in Canada related to aerospace, defence, space and security. This program covers all TRL (1-9). The recipient must be able to demonstrate that the financial support will be invested in research and development and that it will generate economic benefits for Canada.

For its part, SDTC (Sustainable Development Technology Canada) seeks to further act as a catalyst for sustainable technological development. Its funding reduces the risk of demonstration projects of green technologies in order to accelerate their adoption and commercialization. SDTC funds projects that aim to reduce the environmental impact of the aerospace industry, such as the elimination of chromium plating curing, de-icing wings with tempered steam, or biofuels.

In terms of specific support to SMEs, governments have already implemented various programs such as IRAP-NRC or research and development tax credits. However, these programs are barely enough. Over time, budgetary envelopes need to be increased and award criteria expanded. Governments now understand the industrial issues, which go well beyond simple research and development within a company. Henceforth, government action must touch all aspects of innovation, with an emphasis on collaborative research and innovation.

In addition, the new support programs for SMEs anticipated in the coming years will, among others, be more oriented towards the downstream phases of the innovation process and to investments in projects in public-private partnership to enable the national aerospace industry to take a place in the international arena.

Financing low TRL towards high TRL and commercialization

To fully support the industry, and in particular to reduce the risks surrounding new challenges being faced by SMEs, the government should continue its funding for SME capacity development that go beyond the mere financing of research and development, and which extends to high TRL close to commercialization. This should also be tailored to the specific needs of each SME.

According to presentations made by government officials, it is clear that governments are listening to these needs. The SADI program, the organization of Sustainable Development Technology Canada (SDTC), NRC's Industrial Research Assistance Program (IRAP), or partnership programs of the Natural Sciences and Engineering Research Council (NSERC) are all programs that have relatively broad eligibility criteria in

order to include a maximum number of eligible organizations and projects while being geared towards the commercial success of various technologies. For example, IRAP offers a flexible and personalized approach where you can receive appropriate coaching from an industrial technology advisor. The IRAP advisor brings a wide range of techno-commercial support which seeks to complement the capabilities of the partner company. (see Figure 12).

Figure 12 : IRAP-NRC model

Source: Claude Attendu, IRAP-CNRC

4.4 CHANGE IN PARADIGM AND TOOLS FOR MANAGING AND SHARING KNOWLEDGE IN A MORE OPEN INNOVATION PROCESS

Catalyst projects more focused on sustainable development

The SA²GE catalyst project is proving to be an outstanding accomplishment of the local aviation industry. It consists of a regrouping to develop a greener aircraft that aims to maintain the competitive position of Québec in a global aviation market in full transformation, in the context of the fight against climate change and new environmental regulations.

This four-year catalyst project has a total budget of $150M, including $70M from the provincial government and $80M from industry.

The project's five sub-projects in research and development are: aircraft fuselage structures made of composite materials, integrated avionics for cockpit applications, next generation landing gear, next generation engine, and integrated modular avionics for critical systems. SMEs are active in the program, accounting for 7.2% of the budget, with a minimum of 5% initially assigned to them.

Cases of successful collaborative research in Québec

Initiatives such as SA²GE are facilitated by the climate of cooperation that has strengthened over the years in Québec. In fact, Québec has been a pioneer in creating a culture of collaboration in research and development in the aerospace industry, with the establishment and growth of CRIAQ.

CRIAQ, founded in 2002, brings together 56 member companies, 26 universities, and 16 associate members. It hosts 19 international projects and manages $127M invested in 125 projects, involving 60 universities and 660 students.

For CRIAQ leaders, such as CEO Clément Fortin, collaborative research and sustainable development should be integrated. This requires a deep understanding of all the issues and ramifications of their respective objectives and of the tradeoffs to be made. There is a fragile balance between economic performance and sustainable development. Under the aegis of CRIAQ, many projects are under way to reconcile these objectives. For example, in biofuels and recycling of aircraft, 14 projects have been started and six are in preparation for a total investment of $22M in green technologies.

In addition, in order to advance innovative companies (including SMEs) towards the commercialization of new technologies stemming from research and development, CRIAQ has developed analysis tools to properly assess and supervise work projects downstream of TRL 4. Finally, to promote collaboration and collaborative research, CRIAQ organizes forums and moderates an online open innovation platform.

Collective projects and funding technology demonstrations

Even though the Canadian aerospace industry is more competitive than ever, it is important that its leaders remain alert and more vigilant because the context in which the aerospace industry operates is increasingly uncertain and changing. The collective dynamism of industrial clusters need to battle against inertia and push for more innovation: *"In a global economic environment where change is occurring at a dizzying pace, the greatest risk comes from an attitude of complacency and inability to adapt (...) the inertia would jeopardize one of the country's most important industrial sectors and, in turn, crucial benefits in terms of the economy, technology and security arising from a strong and competitive aerospace industry."* (Source: Emerson Report)

The current environment requires, as a prerequisite, a change in vision and perception. Industry must develop a comprehensive and systemic view of all the components of an aircraft, as well as the integration of all phases of its life cycle, from design to decommissioning.

Funding for technology demonstration is a great way to support this need for a systemic view of all the components of an airplane while increasing the chances of quick and successful commercialization of innovative new technologies.

The various programs in place are generally intended to fund initiatives located between the phases of research and development and commercialization, namely at median TRL (TRL 4-5-6). These stages of development are very costly and difficult, but essential to carry forward a technological invention to market entry. Among programs that are available to support organizations through these phases (often called the "valley of death"), are the following two:

Industry Canada's Technology Demonstration Program

This program will fund large-scale technology demonstration projects that typically require the integration of several different technologies and the coordination of activities of many partners.

Demonstration activities involve moving new technologies out of the laboratory and testing them in real-world settings to ensure they fulfill their intended use in a safe and efficient manner. Companies often find it difficult to finance this step in the technology development process, limiting the speed and scale with which innovation is advanced.

While the criteria for targeted projects are those that will create jobs in research and development, the emphasis will be principally on those that generate sustainable economic value for Canada. The projects covered are up to TRL 6. This program aims to support between one and three projects for a total value of $108M, assuming a 50% participation from the recipient.

The French Council for Civil Aviation Research (CORAC)

CORAC is part of an effort to ensure the consistency of research and innovation efforts in the field of aviation, including the preservation of the environment and sustainable development. CORAC has six technology demonstration platforms: the composite plane; extended modular avionics; the cockpit of the future; propulsion systems; optimized energy management; and the helicopter of the future. This research council includes research facilities and industry organizations, including many SMEs. Members are responsible for collaborative development. The first phase of funding (over five years) is $500M in public money and $500M from the private sector.

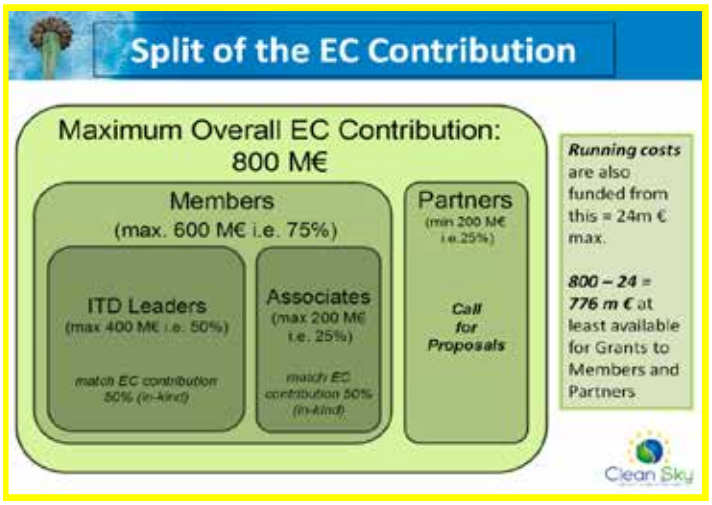
International programs

The European Clean Sky project is an ideal example of a systemic and mobilizing initiative. This ambitious research program aims to develop breakthrough technologies to significantly improve the environmental impact of aircraft and air transportation. The program has six major research areas arranged in a matrix as shown in the following figure. The program's goal is to reach TRL 6 for various technologies developed before the end of the seven-year program. This program has a total budget of €800M which comes from both the public and private sectors.

Figure 13 : The Clean Sky project

Source: Giuseppe Pagnano, Clean Sky

Figure 14 : Clean Sky financial framework



Source: Giuseppe Pagnano, Clean Sky

Canadian Networking Aeronautics Project for Europe (CANNAPE)

More than ever, given the context of globalization, the major players need to come together to share resources and reduce their respective risks in order to undertake extensive work in research and development. This work is necessary to develop innovations that will respond to market needs. The CANNAPE program aims to support Canadian businesses and enable them to participate in major European programs. There is currently a joint Canada-Europe initiative to identify research themes and priorities in order to plan future efforts and ensure they are coordinated.

The box below provides information on the objectives and the approach used at the last workshop in December 2013, and the results in terms of the priorities of the industry and the research community. It is clear from the table below that the priorities are geared towards environmental aspects, as well as the need for the integration of components, technologies and systems.

The CANNAPE (Canadian Networking Aeronautics Program for Europe) program *was a two year FP7- funded Coordinated and Support Action (CSA). It aims to improve and increase engagement between the aeronautics R&D communities and networks within the EU and Canada.*

The strategic aims of the CANNAPE program are:

1. To increase contact between the Canadian and European research community

2. Raise awareness of opportunities for aeronautics and air transport research collaboration between Europe and Canada;

3. Involve Canadian companies, organizations and universities in FP7 and Horizon 2020 projects.

4. Develop a technology road map outlining capabilities and technology priorities for Canada-EU collaboration.

These targets have been hit through operational activities, which included four workshops aimed to identify strategic technology themes ready for collaborative programs between the EU and Canada and project ideas rising – called "CANNAPE Babies".

The 4th CANNAPE Workshop held in London in April 2013 was officially the last under the FP7 funded action, but the Canadian and European CANNAPE stakeholders confirmed their commitment to build on the very successful work achieved through the first phase of CANNAPE.

During this meeting, the Government of Canada officially announced its support of a coordinated call to be managed through the soon to be formed national aerospace research collaboration network. This workshop thus laid the foundation for Canada's participation in such a call between EU and Canada under Horizon2020 research program.

The EU-Canada preparation process requires the key themes under the 2015 call for Horizon 2020 projects to be confirmed in March 2014. The objective of the December 4th workshop was to gain consensus on key themes for discussions with the EU for a Coordinated Call Horizon 2020 in order to be in a position to anticipate potential projects in the spring 2014 timeframe.

CANNAPE Round table sessions – December 2014

As a way forward, the results of previous road mapping exercises done under CANNAPE between Canada and Europe through which an initial 10 potential areas for consideration, were used, as well as the 1 0 priority themes developed by the AIAC Technology and Innovation Committee.

The participants in the workshop (including 10 Europeans) participated in the identification of topics for an EU-Canada coordinated call. To achieve this, the workshop attendees participated in concurrent round tables on three broad themes: 1. Structures, materials and manufacturing, 2. Aircraft systems, 3. Aircraft configurations (Aerodynamics, MDO, Advanced design)

The results of this exercise will provide guidance in determining the priority areas to be proposed for a coordinated call between Europe and Canada. As anticipated in CANNAPE support action, the final formulation of areas may need to be rather open, in line with common challenges in EU and Canada, but inclusive of topics expressed as preferential on both sides.

4.6 COMMERCIAL INNOVATIONS: MULTIPLE OPPORTUNITIES AND PARALLEL MARKETS: MILITARY AND SPACE.

New opportunities

The aerospace industry is changing and new horizons are opening up. Some aerospace technologies can now be used in space-related and defence applications, not to mention the many development opportunities in emerging market countries.

According to Emerson:

"1- As the North is being opened to increased resource transportation and extraction, there is a need for aircraft to travel long distances in harsh and icy conditions to help identify and develop natural resources, protect the environment, supply communities and installations far from population centers in the South, and to intervene in case of emergency.

2- And as safety concerns are evolving to focus on unconventional threats, there is a demand for air technologies to perform increasingly complex monitoring with very precise strike capabilities."

Differentiation and added value

For prime contractors and Tier 1, brand management has become a key factor in the management of innovation. It is essential for companies who want to become partners of these prime contractors to fully understand the needs of these companies and to present an offering that demonstrates beyond any doubt that this collaboraton would add value.

Certification

It is important that certifications evolve alongside technology to protect public safety and the environment. Above all, delays in obtaining certifications that could slow technological and commercial development should be avoided. There is no better guarantee of future sales than a certified product delivered on time and offering the required performance.

According to Malcolm D. Imray, Airworthiness Engineer at NRC, there are some challenges faced by manufacturers regarding the certification process:

- new technologies little known to the authorities represent an obstacle to certification given the lack of reference and knowledge about the subject;

- the authorities have limited budgets, which limits the re sources dedicated to the certification process;

- knowledge of the certification process is limited, particularly in the small business community;

- discussions with certification authorities often occur too late in the development process, which often forces additional and expensive developments.

Government support downstream of the innovation process

NRC is a research partner at low TRL and works with Transport Canada to ensure that new technologies, fuels and manufacturing processes offer viable opportunities for the Canadian aerospace industry. A partnership with regulatory authorities earlier in the development cycle is the key to ensuring a healthy future for the aerospace industry in general.

An alternative to a partnership with the authorities could be a partnership with an experienced organization in order to learn from it. Companies still face a huge risk exposure even if they are financially strong. Transport Canada's approach, in addition to establishing the regulatory framework and ensuring compliance, is to support and assist companies in technical and regulatory capacity issues.

Support for commercialization and international expansion

The Forum provided an update on support programs for international commercialization, which have become crucial in the context of globalization. Some financial support mechanisms

are available for the commercialization and expansion stages. Organizations such as the Canadian Commercial Corporation (CCC) and the Export Credit Agency of Export Development Canada (EDC) are liaisons between Canadian firms and foreign organizations.

The aerospace industry is becoming increasingly global, making it necessary to have organizations to support and facilitate business efforts outside of Canada. With its export guarantee program (EGP), EDC covers part of the financial risk related to international business. EDC can also directly fund, as co-lender with the customer's bank, a commercialization project. This may include the expansion of a new factory outside the country or a foreign acquisition. Once the agreement between governments is completed (G-2-G agreement) the CCC becomes a select government partner to facilitate and strengthen long-term bilateral trade with a foreign country. Adding a government partner that accompanies the execution of the agreement – namely beyond the initial signature – can reassure foreign buyers and also reduce payment risks with these foreign buyers. In addition, conventional financial institutions also offer financing services of various kinds, including loans for the acquisition of assets to help companies to invest in specialized equipment. This was noted by Ghassan Deko, Vice President, Commercial Financial Services at RBC- Royal Bank. Its asset acquisition loan program provides access to approximately 23% more capital since a greater percentage of the acquisition and inventory is eligible for funding.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, we can summarize the major waves of change and innovation that are driving the aerospace industry to rethink its activities and to innovate in all areas. The Forum demonstrated that changes in the aerospace industry are profound and ongoing. Four major waves of change are emerging. They result in the following eight recommendations to implement sustainable success factors and facilitate the adaptation, resilience and performance of the Canadian aerospace industry over the coming years.

Change No. 1: Profound and sustained transformations in supply and demand, stimulating the development of new products. The aerospace industry is global, emerging countries are now having a significant impact, both on supply and demand, economic uncertainty is continuing, and the trend towards an industry that is more respectful of sustainable development is clear. Development planning and the launch of new products need to integrate multiple parameters which meet economic and regulatory requirements, as well as the imperatives of sustainable development in terms of pollution, noise, recycling and waste reduction.

Change No. 2: Rapid, and more integrated, technological innovation. System engineering is becoming key, technologies are systemic and more intelligent, therefore interconnected. Teams are multi-disciplinary, design and manufacturing are integrated with more simulation. New aircraft architectures are required and demand new materials and manufacturing and assembly processes.

Change No. 3: Industry players are more international and geographically dispersed, as well as increasingly integrated amongst themselves, and need to enhance coordination upstream (innovation) and downstream (manufacturing). Innovation is being decentralized towards Tier 1 suppliers and is therefore cascading to other subcontractors. Innovation modes are more collaborative, giving a bigger role to innovative SMEs to revitalize and strengthen the competitiveness of the industry.

Change No. 4: Business strategies and models are evolving locally and globally. Local and global supply chains are relocating and/or reconfiguring according to supply and demand, as well as socio-economic factors. Deployment strategies of factories, as well as business and revenue models, are based on complex and multi-criteria analyses in terms of efficiency, reliability, and speed of development at reasonable and shared costs.

KEY SUCCESS FACTORS

Overall plan: We need a systemic vision of all phases of design, manufacturing, operation and end of life management, and an inclusive approach that integrates all players in the supply chain, orienting them towards clear and common goals.

Globalization and risk management: The North American industry faces high costs compared to emerging countries, as well as long delays before receiving the expected new product revenue. It has to reduce operational costs and financial risks associated with the investments required through subsidies, levers, tax credits, government procurement, etc.

Mobilization of stakeholders: Players need to work together and coordinate upstream and downstream through mobilizing projects, technology demonstration initiatives, etc. Collaboration and partnerships in all forms, both locally and internationally (such as the CANNAPE initiative), should be encouraged.

Acquiring world-class resources: Differentiation and specialization essential to competitiveness require quality expertise, in the right amount, at the right time and the right price. Human resources and knowledge management should be further optimized.

Increase SMEs' chances of success: SMEs' operational and innovative capabilities should be capitalized on, giving them easier access to financial markets and programs as well as support in finding qualified work force, the protection of intellectual property, improved management practices and international marketing.

Support for exports: Canadian companies should be allowed to better take advantage of opportunities in the global market by accelerating and extending the scope of various mechanisms such as free trade agreements, grants and tax credits, international framework programs, trade and diplomacy missions with emerging countries, etc.

Recommendation 1: Continue to apply recommendations of the Emerson Report to strengthen the government's strategic and financial support for the aerospace industry

The government can play a central role to prioritize, target, coordinate and reduce risks while accelerating the development and commercialization of innovative products and processes that will increase the global competitiveness of the Canadian aerospace industry. Among other things, the Emerson Report recommends that:

- the list of strategic sectors in the government's science and technology strategy be expanded to include aerospace and space;

- the government establish a list of priority technologies to guide policies and programs related to aerospace;

- the government created a program to support the large-scale demonstration of space technologies;

- the government maintain its current level of funding for the Strategic Aerospace and Defence Initiative (SADI) – deductions made in recommended volume reallocations - and that it amend the terms of SADI to ensure a more effective program for stimulating the development of aerospace and space technology in the future;

- the government helps to fund a national initiative to facilitate communication and collaboration among aerospace companies, researchers and higher education institutions.

Globalization is sparking change and "forcing" international groupings and closer ties between the research community and industry. In this regard, two specific recommendations are made so that the government improves existing or creates new programs:

1) Canada-Europe collaboration in order to prioritize innovation development by the industry: It is critical to strengthen support for programs such as CAN NAPE, which aims to support Canadian companies and enable them to participate in major European programs.

Under the current joint Canada-Europe approach, research themes and priorities are identified in order to plan future efforts together. It would be important that government funding be aligned with these priorities and oriented towards environmental aspects, as well as with the need to integrate components, technologies and systems.

2) Closer research and development ties carried out in collaboration between universities and aerospace companies:

To meet the industry's need for manpower that is skilled and adapted to industry requirements, and to fill the "gap" between the upstream and downstream aspects of the innovation

process, the government should aim to establish programs and mechanisms that will support and encourage closer collaboration and smoother transfer of knowledge between research and industry. For example, this approach may include measures such as:

- post-doctorate researchers in companies;
- academic researchers on sabbatical sent to companies;
- research funds subsidizing professional researchers after their post-doctorate.

All elements of the industry, all its resources and stakeholders, need to increase their ability to grow, to specialize, to be open to alliances and adapt to change. As noted in the Emerson Report: *"Without reacting and adapting to the changing global environment, it is not the status quo that awaits the country, but a steady decline, significant missed opportunities, a decrease in its industrial capacity and innovation, a loss of quality jobs in advanced manufacturing, and the gradual disappearance of an industry that greatly contributes to its wellbeing."*

Beyond funding, several improvements and enhancements are required to equip the aerospace industry with the best management practices, more effective coordination and collaboration tools, more advanced technologies, stronger commercial and international trade links, and a more qualified labour force, led by more experienced managers.

By taking various elements of the findings confirmed during the Forum, and by drawing on recommendations of the Emerson Report, we propose the following additional recommendations.

Recommendation 2: Increase the capacity and competitiveness of the industrial supply chain and strengthen dynamic ties among its players (OEMs, Tier 1 and subcontractors)

More support is needed for SMEs that are performing well and qualify as suppliers to local prime contractors and which are often growing quickly, so that they can internationalize and be more competitive globally in terms of innovation and costs. This will require the implementation of best management practices, including in strategic management, operations management, management of human resources and the management of innovation, as well as in world-class practices and business networks and investments in advanced technologies:

- continue the MACH Initiative and extend it to a larger number of SMEs;
- implement more effective innovation practices by promoting collaboration and the sharing of resources among SMEs (see Recommendations 4 and 5);
- support assistance programs to improve productivity;
- support technology investments.

Recommendation 3: Increase the innovation capacity and technology absorption of all industrial players (including SMEs) and develop more fluid and interactive links among innovation players.

In addition to improving their operational capability necessary to compete with emerging countries, the "upstream" innovation capacity of SMEs should be increased, namely in the research and development and design phases, as well as their ability to commercialize internationally. This would be designed to increase their overall strategic autonomy and global competitiveness in a globalized industry that requires parallel improvements in costs, new products, and adaptation to new customers. For example:

- we need to encourage and accelerate the introduction of more intelligent and better connected information and design-manufacturing technologies;
- we should financially support the development (training) or hiring of more qualified and versatile personnel;
- SMEs should continue to be supported financially and by consulting organizations such as PAR-CNRC to capitalize on digital technologies to maximize their overall productivity;
- financial support and expertise will be needed to improve the research and development and production processes as well as to systematize and integrate their supply chains and the logistics of their distribution networks. Financial and technical support will be required to increase their presence and visibility worldwide via digital and social networks, such as RFID-type traceability systems, automated monitoring systems, or multilingual translation systems.

Recommendation 4: Reduce risks and delays in innovation through collaborative innovation at all levels of the aerospace innovation chain.

The era of open and collaborative innovation is well under way, and is here to stay. We should encourage and support more collaboration and the sharing of resources and infrastructures in research, demonstration and manufacturing.

a) Collaboration within vertical supply chains:
The evolution of the relationship between prime contractors, Tier 1 and SMEs, which is notable within the aerospace supply chain, necessarily entails a decentralization of innovation activities across multiple organizations which must work together to ensure the integration of all the different elements of innovation. We should therefore support these collaborative and integration projects in a more systematic way than in the past.

b) Horizontal collaboration between players in the industry who have complementary skills:
The requirements of the global market are making it necessary to develop more efficient products by merging numerous skills and technological specialties. These are frequently held by several suppliers, often SMEs. We should therefore support this linking among complementary companies by facilitating their cooperation and helping them to effectively manage their expertise and intellectual property to better coordinate multidisciplinary teams composed of internal and external experts.

Recommendation 5: Maximize the use and exchange of resources and leverage shared infrastructures

Vertical (in the supply chain) and horizontal (among complementary players) collaborations promote cooperation and foster major catalyst projects. For facilitate them, we should support the establishment of various mechanisms and facilities that encourage and financially support the pooling, sharing and mobility of equipment, tools and machinery among players, research centres, universities and companies. More specifically, government agencies active in helping companies and research organizations need to promote and fund the acquisition of specialized resources that will be shared:

a) Sharing of human resources: We should continue projects such as PARC and CRÉER and encourage others through the sharing of various kinds of resources between companies.

b) Sharing and exchanges of highly qualified personnel among firms and universities. For example, in addition to scholarship programs in the workplace for graduate students, we should have grant programs that enable a university researcher to be "loaned" (shared) by a university to a company when the company needs one for a specific project. Conversely, one could also envision company engineers or specialists being funded by government to perform internships in research environments.

c) Sharing of research equipment: Research, design and simulation facilities, which would be shared by several universities and made available to the industry (similar to what is already being done in the field of nanotechnology infrastructure in Québec).

d) Sharing of specialized research tools: Shared supercomputers accelerating research and facilitating the simulation of complex systems, etc.

Recommendation 6: Ensure a constant supply of qualified manpower and the upgrading of technical, operational and managerial skills of industry players having to constantly adjust to new ways of working and managing

Supporting knowledge transfer, technical and managerial training, and the continuous improvement of employee expertise are more than ever key pillars of successful aerospace companies. Therefore, we need to:

- support the development of university training programs through the form of continuous training for the industry;

- support and encourage the joint development of new university training programs aligned with the needs of industry which would be offered jointly in several university institutions.

Recommendation 7: Support through public-private partnerships, as well as local programs and international initiatives, the achievement of various sustainable development objectives of the industry

In order to meet the commercial, social and environmental imperatives of the industry and their customers, while reducing the financial and technical risks of the efforts required, aerospace companies should integrate all aspects of sustainable development and ecological footprint from the very start of any innovation project.

To support them, and share the risks and financial levers, various avenues are possible which require either direct intervention or indirect support from various levels of government: government procurement, subsidies, tax credits, international relations.

Recommendation 8: Continue alignment of university research at high TRL with initiatives stemming from the Emerson Report

So much progress has been in the last 20 years in the dialogue between universities and aerospace companies that it could serve as a model.

We should encourage new joint initiatives, such as the joint master's degree in aerospace engineering or the recent bachelor of aerospace engineering at École Polytechnique de Montréal, which have increased the quality of the training courses offered.

In particular, we should encourage the involvement of industry members as course lecturers.

To support students and companies involved in this kind of industry-oriented training program, we should continue the parallel progress made at the university research level through programs such as Bourses en Milieu Pratique (BMP), as well as MITACS internships that allow direct contact and facilitate the transfer and introduction of better technologies and knowledge stemming from research in an industrial environment.

The ever-growing need for industry to develop innovative technologies can only be met by an increasingly skilled workforce, ready to be employed. The establishment of major national projects stemming from the Emerson Report, such as technology demonstration, target medium-term impacts in this regard since qualified personnel of the future would be trained on equipment and systems that are similar to industrial systems.

In support of physical infrastructures allowing for the demonstration of technological innovations at TRL levels further downstream, the role of post-doctoral students as well as academic and institutional researchers must be aligned in the context of higher TRL projects (5-6).

It follows that efforts should be made to build on the excellent range of training programs currently available. These should include not only the training of researchers, but also the training of highly qualified personnel who will work seamlessly and in complementary fashion, at upstream research and downstream phases of the innovation process.

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