Composites in Canada

Andrew Johnston

Group Leader, Composites and Novel Airframe Materials
National Research Council Canada
Institute for Aerospace Research
Ottawa, Ontario
Presentation Outline

• Some Canadian innovations in history
• Canadian aerospace sector and strategic importance of composites
• Aerospace composites innovators in Canada
• Canadian innovation system
• Innovation in action – AFP demonstrator
Canadian Inventions.... Some important ones

- Telephone (1876)
- Standard Time (1878)
- Variable-pitch Propeller (1922)
- Insulin (1923)
- Electron Microscope (1937)
- Heart Pacemaker (1950)
- IMAX Movie System (1968)
- JAVA (1994)
- Blackberry (1999)
Canadian Inventions…
Some less prominent ones

• Zipper (1913)
• Wonderbra (1935)
• Jolly Jumper (1959)
• Abdominizer (1984)
• Poutine (?)
Canadian Inventions.... Some very “Canadian” ones

- Rotary Railroad Snowplow (1869)
- Electric Car Heater (1890)
- Snowblower (1925)
- Retractable Beer Carton Handle (1957)
- Snowmobile (J-A Bombardier, 1958)
- Hockey Goalie Mask (1960)
Some early composites applications in Canada

1974: Momentum Wheel Rim – carbon fibre / epoxy for satellite attitude control

1970s Satcom Antenna - Kevlar fibre composite

Bristol Aerospace - Winnipeg

1981: Canadarm1 - Graphite fibre composite

2001: Canadarm2 (SSRMS) – Carbon fibre / PEEK (not early but I like it...)
Canada’s aerospace industry is a key economic driver...

- Civil and defence sales of $23.6 billion in 2008.
- Well-integrated into the global aerospace industry, 82% output exported.
- 11% of all Canadian industrial R&D spending; $1.2 billion in 2006.
- Over 400 firms with over 83,000 employees. 32,000 prof/tech
5th in world aerospace sales and employment after US, UK, France and Germany.

3rd in world civil aircraft production after US and France.

Highly oriented to commercial markets – 78% of industry output for civil use, cf. 44% in USA.

Several major foreign firms established in Canada.

Has 5% share of both global aerospace sales and employment.

... and a Strong International Competitor

Canada's Aerospace Products (2008)

- Aircraft Engines & Parts 15%
- Avionics 6%
- Space 2%
- Training & Simulation 4%
- MRO 18%
- Aircraft, Parts & Components/Other Industry Related Products & Services 55%

Source: Aerospace Industries Association of Canada

Global Leadership (% of global market share)

- Regional Aircraft 47%
- Small gas turbine engines 34%
- Visual simulation equipment 70%
- Aircraft environmental control systems 60%
- New large aircraft landing gear 60%
- Civil helicopters 14%

Source: Aerospace Industries Association of Canada, Teal Group, 2006
Composites are a High Priority for Canadian Aerospace

- Canadian activities in advanced composites have grown steadily, but relatively slowly over the years
- Significant acceleration since 2000 mirroring growth of composite structures in civil aviation
- Several industry reviews have identified strategic importance of composites to the Canadian aerospace industry
  - 2003 Industry Canada / NRC Competitive Technology Intelligence project undertaken to develop roadmap for aerospace composites technology
  - Industry review of NRC Aerospace programs in 2004 identified Composites as the number 1 strategic technology for the sector (for 2005 – 2010)
  - On-going Future Major Platforms initiative has identified composite materials and related manufacturing processes as critical strategic technologies
- Significant on-going investments by Canadian and provincial governments since 2000 in composites-related infrastructure, research and technology development (R&TD) programs
Growth in Composites Usage in Aircraft Structures

- Civilian
- Military

% Structural Weight Composites

Canadian composites innovators - industry

OEMS
Pennsylvania-based parent now selling Seawind kit aircraft
Development of FAR 23 certified Seawind 300C Amphibian being undertaken just outside Montreal
All composite (Glass/Vinyl ester, undergoing flight testing at NRC)
Target certification date: June 2010
Diamond Aircraft Industries
London, Ontario

- Subsidiary of Diamond Aircraft Industries GmbH of Austria
- Founded in 1992 as Dimona, became Diamond Aircraft in 1996
- Produces several models of all-composite small aircraft out of 250,000 ft² production facility in London

DA42 Twin Star
- Light twin-engine utility and trainer aircraft
- Introduced 2004

D-Jet
- 5-seat, single-engine jet aircraft
- Carbon fibre composite structure
- Now undergoing certification out of London facility
Bell Helicopter Textron Canada
Montreal, Quebec

- Canadian division of Bell Helicopter Textron
- Plant opened in 1986, now 2200 employees in Quebec
- As BHT’s commercial helicopters division is major producer of civilian helicopters, with 7 different models
- Major user of BMI matrix carbon fibre composites
- Long been sophisticated producer of composites for own use
- Recently been increasing composite technology development investments (example later in presentation)
Bombardier Aerospace
Montreal, Quebec

- Canada’s largest aerospace company, 3rd largest OEM in world
- Global express empennage was first primary composite structure certified by Canadian OEM
- Significant recent investments in composites R&D in Montreal

Bombardier C-series
- Will include 46% composite materials
- Al/Li fuselage
- Wings, empennage composite
- Entry into service in 2013

Learjet 85
- First all-composite FAR 25 business jet
- Developed in Montreal, wing and fuselage to be made in Mexico, assembly in Wichita
- Material system for the overall airframe is a low-pressure oven-cured "out-of-autoclave"
- Entry into service in 2013
Company was founded in 1987 in Lunenburg, Nova Scotia.

Now a subsidiary of EADS Sogerma Services with production and test facilities in Nova Scotia and Montreal.

Is a leader in the design, analysis and development of advanced composite structures for the aeronautics, defence and space markets.

Facilities for manufacturing, testing and prototyping.

Integrated capabilities from design & analysis, manufacturing & assembly, to NDI and testing.
Wide range of processes, including:
- Hand lay-up with autoclave/oven curing
- Liquid Composites Moulding (LCM)
- Filament / tape winding
- Compression moulding
- Thermoforming
- Automated Fibre Placement

Invest heavily in product and process development

Large customer base including Airbus, Boeing, Bombardier, Cessna, Honeywell, MDA, Northrop-Grumman, Goodrich and Spirit.
• Subsidiary of Avcorp Industries (Vancouver, BC)
• Specializes in design, manufacture and maintenance of advanced composite structures for regional and business aircraft
• Extensive experience in design-build programs
• Maintains an active and innovative technology development program
• Notable capabilities in certification, manufacturing & process development, reverse engineering, materials engineering, material & component testing

A380 evacuation system components

Honeycomb sandwich floors
High Temperature Composites – Engine Inner Bypass Fairing

- Used unique modified cyanate ester resins to achieve both high Tg and toughness, along with a proprietary low cost VARTM type process
- Comtek built prototype composite fairings using low cost UD carbon fabric and two different resin mixes, were manufactured by Comtek
- High-temperature engine tests by well-known aero-engine company gave excellent results
- Fairings resulted in large weight reduction while being cost competitive with aluminum parts
Bristol Aerospace (Magellan)
Winnipeg, Manitoba

- Tier 1 and 2 manufacturer producing aircraft structures since 1930s
- Long history in composite materials and structures for aircraft and space structures - first began working with composites in 1960s
- About 100,000 ft² dedicated space in Winnipeg producing composite components for Boeing, Rolls Royce, Augusta Westland
- Contracted supplier to Lockheed and BAE Systems for epoxy and BMI parts and structures for JSF
  - First qualified international JSF partner for composites
Boeing Canada
Technology Winnipeg
(Manitoba) Division

- Part of Boeing Commercial Airplane’s Fabrication Division, supporting all current airplane models
- Canada’s largest producer of advanced composites for aircraft, with about 1400 people and 747,000 ft² of fabrication and assembly space.
- Started operations in 1971, making low-complexity fibreglass panels.
  - Expanded operations and complexity of structures to primary and complex secondary structures
  - Now Tier 1 supplier for 787-8
- Some Boeing Winnipeg processes:
  - Autoclave processing, core forming, complex structure assembly
  - Machine-assisted lamination and hot drape forming
Boeing Winnipeg
Product Walk Around

- 787 Vertical Fin Fairing
- 787 Shear Ties
- 787 APS/APU Doors
- Wing to Body Fairing 737, 747, 787
- Main Landing Gear Doors 777, 787
- Nose Gear Door 737, 767
- Engine Strut Fwd Fairing 737, 777
- Engine Strut Aft Fairing 737, 747, 767, 777, 787

Misc Ducts 747, 767, 777, 787

787 Main Landing Gear Door
787 Wing to Body Fairing
• Highly innovative small company, designing, developing and producing composite products for several industry sectors

• Technologies and Capabilities
  – Out-of-autoclave
  – Liquid (closed) moulding, RTM and VARTM
  – Hot-tool press and bladder molding
  – In-house complex metal RTM tooling design and fabrication

• Major Partners
  – A&P Technologies; NCMS; Bayer; Toray Carbon Fibers; Camosun College; University of Victoria; NASA White Sands; NRC/HIA
Current development activities

- Ultra-light, all composite UAVs
- Accelerated manufacturing of wind-turbine blade components
- High-rate production of hydrogen/natural gas storage tanks
  - 20 minute cycle times, with in-situ cure and health monitoring
- High-volume production for 17x15-m radio antenna reflectors

RTM High-Pressure COPV
Profile Composites Technology Lead
Winner 2009 JEC-Paris Composites Innovation Award for Transportation
Rapid Manufacturing of High-Pressure Carbon Composite Storage Tanks
Partners: A&P, Bayer, NASA, NCMS, Toray CFA

35-foot Hi-Precision Radio Antenna
NRC – DRAO Lead Organization
Winner 2009 JEC-Asia Composites Innovation Award for Aerospace
Cost-effective infusion Manufacturing of Kevlar/Carbon Composite Structures for Very Large One-Piece Reflectors
Antenna Reflectors for the Square Kilometre Array

- Composite radio telescope development has been ongoing at NRC/HIA Dominion Radio Observatory (DRAO) since 2006
- DRAO contributing to Square Kilometer Array (SKA) radio telescope project, developing Composite Antenna Reflectors, up to 15 m dia.
  - More than 1000 of these structures would be required for SKA!
- Composites offer high stiffness and high thermal stability.
- Liquid moulding offers a cost-effective approach for mass-production
- A 10m demonstrator (Mk1) showed the potential of materials, design and fabrication method, but had problems with dimensional control
- Profile Composites worked with DRAO to develop MkII design / process
- Now working on design / process development for high-volume production of 15 m reflector version
Composite Antenna Reflectors: Process Improvement with Profile Composites

Significant improvement in dimensional tolerances and ease of fabrication of MkII (right) versus MkI (left). All objectives achieved.
Canadian composites innovators - industry

Other Innovators
Virtek
Waterloo, Ontario

• Founded in 1986 in Waterloo
• Owned by Gerber Technology, a Gerber Scientific company
• Core competency is driving a laser beam quickly and accurately
• Have developed a broad portfolio of patents and wide range of products for several sectors including aerospace
• World leaders in laser projection for composite ply alignment and assembly processes
Specialty inspection services

Developed Backscatter Computed Tomography technology

- Portable device
- Single-side access

Industrial composite application: Fiberglass Reinforced Plastic (FRP) structures in chemical plants

BCT Scanner

Inspection of FRP Pipe

CT Image

Wall thickness degradation
Example Aerospace Application: Fluid Ingress in Honeycomb

- Carbon/epoxy face-sheet section bonded to aluminum honeycomb with various volumes of oil and water
- Single-side and portable inspection through carbon/epoxy face-sheet
- BCT can distinguish oil (yellow) from water (red)
- Provides fluid volume and location measurement
High-performance metallic coatings for composites

- Nanovate™ NS metallic coating protects composites with low weight penalty
- Increases impact damage tolerance, improves erosion protection and reduces wear/abrasion

**Impact Resistance**

- Stone Chips ruptured raw CFRP tube
- No chipping or cracking on Nanovate™ coating

**Erosion Protection**

- Badly eroded unprotected composite edge
- Well protected Nanovate™ NS coated edge

CFRP Cylinder
- Nanovate Coating on wear surfaces
- CFRP Rod (as substrate)
When applied to tooling, Nanovate™ NS metallic coating…
  – Increases durability of by adding hard, low CTE surface coating
  – This reduces manufacturing wear and tear and vacuum leaks
  – Lower thermal mass and lower cost than Invar tools

• Undergoing joint development with ACG (UK) to complete validation
• UBC spin-off (1998)
• World leader in efficient process design support tools
• International clientele and partnerships
• Extensive applications experience
  – New product development support
  – New material development support
  – New process development support

Created to bridge the gap between fundamentals and application in a still-maturing technology area

Gave process modelling seminar at SAMPE 2010
RAVEN3 software

Temperature profile during cure

Process-induced deformations

REDDUCING RISK IN COMPOSITES PROCESSING

• SOFTWARE
  – Easy to use: RAVEN3
  – FEM: COMPRO/CCA
  – Customer specific modules

• SERVICES
  – Full program support
  – Training and technical consulting
  – Materials, process, and facilities characterization
  – Proprietary R&D

SAMPE Booth 222
Some Canadian Universities with Composites Programs

Those with papers at SAMPE 2010 in red
Canadian investment in university-based R&D is high compared to international norms.

Investment in university research in advanced composites has grown rapidly in recent years.
Canadian Universities and Composites

- Canada has world-class university research programs in advanced composites from coast-to-coast.
- Many universities have excellent linkages with the Canadian and international aerospace and automotive industries, including those in British Columbia and, especially, in Montreal.
- Canada is very active in organizing international composites-related conferences, including SAMPE 2010, for which SAMPE Eastern Canada is the co-sponsor.
Canadian Universities at SAMPE 2010

• Some of the areas of research being presented at SAMPE 2010 include (by session name):
  – Process modelling
  – Nanocomposites
  – Liquid moulding
  – Space Applications
  – Structural Health Monitoring and Nondestructive Characterization
  – Design and Analysis
  – Novel Architectures, Hybrids, & Coatings
  – Out-of-autoclave
  – Thermoplastic Composites
  – Automated Fiber Placement

• Wednesday, Featured Lecture 2:00 – 2:50 PM, Room 307-308, “Natural Materials”, Mohini Sain, U of Toronto
The Canadian innovation system provides support from basic research (low TRL) through to product development and productionization (high TRL).

Increasing levels of funding have been made available in recent years aimed at the strategic aerospace sector, including composite materials and manufacturing.

Support for composites R&D has also come from various “green” programs, including those aimed at bio-based materials.

Also key to the composites innovation system are government-funded organizations with the mandate to “bridge the gap” between low TRL and high TRL activities.
Aerospace Innovation in Canada

**University Research**
- CRIAQ (25% Industry funding)

**NRC Aerospace**
- GARDN (50% Industry funding)
- NRC Aerospace (50% Industry funding)

**Industry R&TD**
- 100% Industry funding

**Road Maps:**
- Canadian Aerospace Environmental Technologies RM
- Diagnostic and Prognostic Health Monitoring RM
- Unmanned Aerial Vehicle RM
- Aircraft Cabin Management Systems Integration
- Aerospace Composites

**Future Major Platforms (FMP)**
- Joint Strike Fighter (JSF), other

**INCREASING INDUSTRY INVOLVEMENT / FUNDING**

**FUNDING**
- NSERC (Natural Sciences and Engineering Research Council of Canada)
- CFI (Canada Foundation for Innovation)
- CRIAQ (Consortium for Research and Innovation in Aerospace in Quebec)
- IRC (Industrial Research Chairs)
- Universities
- NRC (National Research Council Canada)
- NRC Aerospace
- SDTC (Sustainable Development Technology Canada)
- GARDN (Green Aviation Research and Development Network)
- BL-NCE (Business-Led Networks of Centres of Excellence)
- NRC-IRAP (Industrial Research Assistance Program)
- Regional Funds
- IC-SADI (IC - Strategic Aerospace and Defence Initiative)
- IRB (Industrial and Regional Benefits)
- SR&ED (Scientific Research and Experimental Development Tax Incentive)
- BDC (Business Development Bank of Canada)
- EDC (Export Development Canada)
- DFAIT (Department of Foreign Affairs and International Trade Canada)
- IC (Industry Canada)
Innovation at Lower TRLs

- **NSERC** – Federal funding for University Research $400M invested annually in Discovery Grants, $300M in “innovation”

- **Canada Foundation for Innovation** - $600M annual funding primarily for innovation infrastructure in universities

- **CRIAQ** – Quebec-based innovation fund for pre-competitive generic-based industrial research (>25% industry contribution). $15M public funds invested over 6 years. Thrusts are:
  - Composites
  - Acoustics
  - DPHM
  - Environmental Issues
  - Manufacturing
  - MDO
  - Avionics
  - Life-Cycle Management
Aerospace Innovation in Canada

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**INCREASING INDUSTRY INVOLVEMENT / FUNDING**

**PROJECTS**
- University Research
- NRC Aerospace
- Industry R&TD

**TRL 1**

**FUTURE MAJOR PLATFORMS (FMP)**
- Joint Strike Fighter (JSF), other
Government Support for Industry R&D (high TRL)

- **Direct** Canadian government support for Industry R&D is modest
- **Total** support, including incentives such as tax credits, is substantial

**Figure 8:** Direct and Indirect Government Funding of Business R&D and Tax Incentives for R&D (2005 or Latest Available Year)

Source: OECD, based on national estimates (NESTI R&D tax incentives questionnaire), some of which may be preliminary.
• **Strategic Aerospace and Defence Initiative (SADI)**
  - Launched April 2, 2007 under Industry Canada
  - Provided $900 million over 5 years to Canadian aerospace and defence industries in repayable contributions for strategic R&D projects (up to 30% of total eligible costs)
  - Additional $200 million funding was announced in 2009.

• **Industrial Regional Benefits Policy (IRB)**
  - Leverages federal government procurement to generate long-term industrial and regional development
  - Contractual commitment by prime contractors to place work in Canada equal to 100% of contract value
  - Includes over 50 major procurements and >$20 billion CND in offset obligations
  - Recent policy changes have increased flexibility, including providing significant leverage for R&D investments in Canada
Aerospace Innovation in Canada

PROJECT STRATEGIC DEVELOPMENT

Project Execution

COMMERCIALIZATION

COMMERCIALIZATION

University Research

NRC Aerospace

Industry R&T&D

CRIAQ 25% Industry funding

GARDN 50% Industry funding

NRC Aerospace 50% Industry funding

Industry R&T&D 100% Industry funding

ROAD MAPS:

Canadian Aerospace Environmental Technologies RM
Diagnostic and Prognostic Health Monitoring RM
Unmanned Aerial Vehicle RM
Aircraft Cabin Management Systems Integration
Aerospace Composites

INCREASING INDUSTRY INVOLVEMENT / FUNDING

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Mid TRL Support

NRC Industrial Research Assistance Program
- Program supporting R&D for small-to-medium enterprises (SMEs)
- Large network of Industrial Technology Advisors (ITAs) across Canada
- Provide a wide range of technical and business advisory services

Green Aviation Research and Development Network (GARDN)
- A business-led Network Centre of Excellence
- $12M funding over 4 years
- 50% industry contributions

Government-supported R&TD Organizations
- Composites Innovation Centre
- National Research Council Canada - Research Programs
Composites Innovation Centre
Winnipeg, Manitoba

• Industry-led Not-For-Profit corporation, established in 2003
• Assist industry in development & commercialization of composite applications & technologies
• Catalyst for attracting new composite industry & start up companies in Manitoba & Western Canada. Very active on national and international level.
• Sectors supported: Aerospace, Ground Transportation, Civil Infrastructure and Industrial Applications
• Specialize in planning & coordinating collaborative projects of all sizes
International Collaborations (Non-client)

- MOUs/Pending Agreements: RRC, University of Manitoba, Industrial Technology Centre
- Boeing Supported Aerospace Consortium Development – St Louis
- MOU National Research Council – IAR, IMI, AMTC
- Technology Partnership Discussions – AMRC Sheffield, UK
- Okanagan Composite Manufacturing Group – Programs / Collaborations
- University of British Columbia - Research Collaboration
- MOU National Composite Center – Ohio, USA
- Biocomposites International Research Network Member
- MOU – CRC-ACS Composite Centre - Melbourne
- SCION Research Collaboration
- Research Centre of China Hemp Materials Discussions
- MOU University of Hong Kong Science and Technology
- Queensland Universities – Professor sabbaticals
National Research Council Canada: A National Institution

- Federal government agency
- Provides essential elements of national S&T infrastructure
- Labs and facilities across the country
  - 20 research institutes
  - Industrial Research Assistance Program
  - Industrial Partnership Facilities
  - CISTI (National Technical Library)

Staff: Approx. 4,300 employees; 1,500 visiting / guest workers
Total expenditures 2009-10: $840 M
Total Income 2009-10: $160 M
NRC role in the R&TD continuum

Research and Technology (R&T)
- Breakthrough Research
- Development of Critical Technologies
- Technology Validation
- Demonstrators
- Prototypes
- Product Definition
- Product Design and Development
- Product Qualification
- Production
- Industrial R&T
- NRC Aerospace
- Universities

TRL
- Fundamental Research: 0
- Applied Research: 3
- Advanced Technology Demonstration: 6
- Product / Process-Specific Technology Development: 9
NRC Composites Activities
SAMPE Booth 635

• Canada’s largest and most comprehensive composites R&TD program
• Major composites activities within Institute for Aerospace Research (Ottawa, Montreal) and Industrial Materials Institute (Montreal).
• Key areas of activity include:
  – Process automation, including automated fibre placement
  – Joining technologies (bonding and welding)
  – Conductive heating technologies
  – Liquid moulding technologies
  – Forming processes
  – Composites life-cycle management
  – Bio-derived and nano-modified polymers and composites
• Serve aerospace, defence, ground transportation and industrial sectors
NRC Activities in Bio-based Polymers and Composites

- Polymers and bio-based composites
  - Natural fiber composites
  - Thermoplastic starch
  - PLA nanocomposites

**Platform**
- Technologies and materials
  - Project Wood-PP

**Industrial Sectors**
- Ground transportation
- Construction

**Timeline**
- 2000
- 2005
- 2006-10

**National Bioproducts Program**
- Technology Group
  - Packaging
  - Biomedical
  - Transportation
    - Energy
    - Sport
    - Aerospace
ADC Machine
- Equipped with thermoset (1” band width) and thermoplastic (0.25” and 0.5” band width) heads
- Thermoset placement head for 8 tows of 0.125”
- Thermoplastic placement head for 1 tow of 0.25” or 0.5”
- Fiber placement programming system

Cincinnati Machine Viper 4000,
- Equipped with a thermoset head
- Placement head for 32 tows of 0.125”
- Capable of handling IML and OML tools
- Fiber placement programming and simulation
- System commissioned in Montreal mid-2008
- NRC machine located at Composite Atlantic
AFP (Automated Fiber Placement) Demonstrator Project

- Collaborative Automated Fibre Placement technology demonstration project
- Partnership involving an SME (Composites Atlantic), OEMs (Bombardier and Bell Helicopter) and government (NRC)
- By far the largest composites demonstrator project ever conducted in Canada
Initial collaboration on all-composite helicopter tailboom demonstrator involved Bell Helicopter, Bombardier and NRC, using NRC’s Automated Dynamics AFP machine.

Follow-on collaboration on composite fuselage section, added Composites Atlantic and used NRC’s Viper 4000 AFP machine (support from Development Economic Canada - DEC).

Both demonstration projects functioned using an IPT approach with members from all participating organizations.
Key Project Outcomes

- Both phases of activity were excellent technical successes and proved an excellent case study for collaborative technology development.
- The knowledge and competencies developed by the participants will be foundational for the future of aerospace composites in Canada.
- New phases of activity already being initiated.

Sandwich fuselage shell with AFP slit tape material from Cytec

Out-of-autoclave radial adhesive joining of barrel sections using NRC heating technology
Wrap-up and Conclusion

• Canada has a long history of innovation and a world-class aerospace industry

• Canada started a bit slow in composites, but innovation across the spectrum has greatly accelerated in recent years
  – Driven by technology maturation, market forces and development of critical competencies across the country
  – Supported by accelerating government and industry investment, university research programs and a strong innovation infrastructure

• There are numerous mechanisms to support international involvement in the rapidly emerging composites sector. The NRC and our partners are eager and willing to engage with you – talk to us!
Go Canada, Go!
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