NRC Aerospace Manufacturing Technology
Overview for NDIA

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Since April 1st, NRC's R&TD organizational structure is based around 3 divisions, under which fall various portfolios, and programs.

A portfolio is a collection of programs and/or projects (both current and planned initiatives) that are grouped together within a research division to facilitate effective project management to meet strategic business objectives.
NRC Portfolios

- Engineering
  - Aerospace
  - Coastal and Ocean Engineering
  - Construction
  - Energy, Mining and Environment
  - Surface Transportation
  - Communications Technologies
  - Automotive

- Frontier Science
  - National Science Infrastructure
  - Nano and Emerging Technologies
  - Information and Security
  - Measurement Science and Standards

- Life Sciences
  - Aquatic and Crop Resource Development
  - Human Health Therapeutics
  - Medical Devices
Aerospace Portfolio Programs

• A number of Programs that are in various stages of development:

- Aeronautics for the 21st Century
  - Includes a Competitive A/C Manufacturing sub-program
- Aeronautical Product Development
- Working and Travelling on Aircraft
- Reduction of Aviation Icing Risks
- Unmanned Aircraft Systems
- Air Defense and Space
Our role in the R&TD continuum*

Research and Technology (R&T)

Breakthrough Research

Development of Critical Technologies

Technology Validation

Demosntrators

Prototypes

Product Definition

Product Design and Development

Product Qualification

Production

Universities

NRC Aerospace

Industrial R&T

TRL
0 3 6 9

Fundamental Research

Applied Research

Advanced Technology Demonstration

Product / Process-Specific Technology Development

years

National Research Council Canada

Conseil national de recherches Canada

Canada

* after EADS
## NRC Aerospace Portfolio: Technology Capability areas and Client/partner interactions

<table>
<thead>
<tr>
<th>Avionics Systems</th>
<th>Simulators</th>
<th>Airframes &amp; Components</th>
<th>Engines &amp; Controls</th>
<th>Space Structures</th>
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</thead>
<tbody>
<tr>
<td><strong>Flight Research</strong></td>
<td><strong>Aerodynamics</strong></td>
<td><strong>Aerospace Manufacturing</strong></td>
<td><strong>Gas Turbine</strong></td>
<td><strong>Structures &amp; Materials Performance</strong></td>
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<tr>
<td>Flight mechanics, avionics, airborne research, accident diagnostics</td>
<td>Fixed- &amp; rotary wing aerodynamics, bluff-body aerodynamics</td>
<td>Automation &amp; robotics, metal forming &amp; joining, composites fabrication &amp; joining, machining</td>
<td>Combustion research, testing &amp; evaluation, engine performance &amp; certification testing, tribology</td>
<td>Computational &amp; experimental structural analysis, aeroacoustics, applied mechanics, materials engineering</td>
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**Civilian & Military Operators**

**Regulators, Users**

**Manufacturers, MRO**

**Universities**
NRC Aerospace Manufacturing
A Critical Resource in Support of Leading Edge Manufacturing Technology Insertion

- New building opening: May 04
- Located downtown Montreal (Université de Montréal campus)
- 65,000 sq.ft.
- 45 employees
- 20-30 guest workers
NRC Manufacturing
Mission

• **Help industry assess, demonstrate, adapt and implement** manufacturing technologies that have the potential to:
  – decrease the life cycle cost of aerospace products
  – make them globally competitive

• **Develop, adapt and improve** innovative aerospace manufacturing technologies to provide a competitive edge to Canadian industry (i.e. fill selected *technology gaps*)

• **Target significant efforts at Canadian SMEs** to strengthen their capabilities and competitiveness

• **Contribute to the education and training of highly qualified engineering personnel** for the benefit of Canadian industry
Four technology thrusts:

- Automation, robotics and IMS
- Forming and joining of **metallic** products
- Forming and joining of **composite** products
- Material removal technologies
For needed Cycle-time and Cost Reduction: Automation!

- Automated Laser US Inspection (composites and FSW)
- FSW and Robotic FSW (replacing drilling/riverting)
- ATL and AFP for automated composite lay-up
- Automated composite Isogrid (Isogrid Canada/NRC Mfg)
- Nano-composites
- Robotic assembly
- Automated laser processing of composites (cut, drill, trim)
- Welding of TP Composites
- DM/ALM (EB and laser-based, for improved buy-to-fly ratio)
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Robotic Assembly and Surface Preparation

• Robotic assembly
  – Riveting
  – Friction Stir Welding

• Robotic surface preparation
  – Polishing of LG Casings
  – Peen forming of wing planks
  – Painting of components with real-time part recognition

• Collaborating Robots for accurate positioning of large component

• Virtual Manufacturing
  – Metrology Workbench (large scale assembly)
  – Robotic cell design scenarios
  – Process and robotic cell equipment simulation (business cases)
Forming and Joining of Metallic Products

- **Laser welding** and repair of fuselage and engine components (YAG and CO$_2$ lasers)
- **EBW** of engine materials and aerospace component
- **FSW** for airframe structural components, including Robotic FSW
- **LFW**
- **Hydroforming**
- **Additive Layer manufacturing** (EB and laser based)
Robotic FSW for Assembly of a Complex A/C Structure

Embedded algorithms correct for vibrations and drifting away from programmed path in r-t
> Workcell layout & component selection for industrialization phase (under development)
> An innovative robotic post-welding surface finishing technique
> Design of an automated production-level fixture
Composite Manufacturing Processes Group

• **Major Group elements**
  - Automated Fibre Placement (AFP)
  - Liquid Composite Moulding (LCM)
  - *Thermoplastic* composite manufacturing and joining
Automated Fibre Placement: ADC AFP Machine

- **Working Envelope:**
  1.0m diameter x 2.0m wide x 4.0m long

- **Six axes** of motion including
  - three linear motions (longitudinal X, lateral Y, and vertical Z)
  - three rotational motion (Yaw, Roll and spindle)

- **Thermoset** Fibre Placement head
  - use 8 tape/tow X 0.125 in width
  - feed and cut control of total 1.00 in band

- **Thermoplastic** Fiber placement head
  - use one tow with 0.25 in or 0.5 in width
Technology Demonstration
Automated Fibre Placement
on Full-Scale Cylindrical and Conical Articles
New Viper 4000 AFP Machine
(Operational Sept. 2008)

- **Working Envelope:**
  - 4m (13ft) diameter (i.e. A-320 diameter)
  - 8m (26ft) long
- **Seven axes** of motion
- 32 X 1/8” tows, total 4” wide
- **IML** *(male mold)* and **OML** *(female mold)* capability
- Components were **received in Montreal** January 2008
- Available to international collaborators and clients for **technology demonstration** projects, or **prototype** manufacturing.
AFP Technology Demonstration: Composite FWD Fuselage
NRC Laser Ultrasonic Inspection System
Robotic Resistance-Welding of Thermoplastic Composites

Progress:

- **End-effector** has been designed, manufactured and is being tested on an AMTC robot.

- **Robot control** program development in progress.

- **Large scale demo** planned for 2013 with a major OEM.
IAR-AMTC
Material Removal Program

- High speed machining of Al alloys
- High performance machining of Ni- and Ti- alloys
- High precision machining
- Tool life improvement and management
- Superabrasive grinding technology
- Machinability of composites
Machining of Composites - An Overview

Characteristics of Polymeric Composites Vs. Metals
- Non-homogeneous Structure
- Anisotropic behavior
- High abrasiveness of reinforcing fibers
- Brittle Fracture rather than plastic deformation

Challenges
- Damage to workpiece
- Finish Requirements
- Rapid Tool Wear
- Environmental and Safety considerations
- Machining Cost

Actions
- Cutting process optimization
- Tool wear resistance and tool geometry
- Cutting Process and Damage modeling
Drilling Process Damages

- Surface Delamination
- Internal Delaminations
- Hole Geometrical Errors
  - Hole Diameter
  - Hole Circularity
- Matrix Overheating/Burning
- Fiber Spalling and Pull out
- Matrix Chip out
- Fiber chip out and breakage
• Use **Machinability Maps** for developing online variable feed rate drilling strategy, for thrust force reduction and damage control.

• Development of **in process NDT** like Ultrasonic C scan and optimize cutting parameter for delamination control

**Good Hole Quality**

**Poor Hole Quality**
Work in Progress: Vibration Assisted Drilling of Composites

Objective
Assist conventional drilling process by superimposing low frequency modulation (0.1-1kHz) with low amplitude (10-100 µm).

Advantages
- Lower cutting forces.
- Reduced delamination, burr formation and micro cracking.
- Lower tool wear and thermal damage (thermal stress relieving).
Questions?