CRN
Composites Research Network

UBC
a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

# Composites Research Network:

## A Sustainable Approach to Design and Manufacturing

UTIAS National Colloquium on Sustainable Aviation

Toronto, June 2013

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Team-Lead: Modelling

# Composites Research Network: Background

- UBC Composites Group has been active since late 1970's
- CRN established in 2012
- Started with funding from Western Economic Diversification Canada
- The Boeing Company joined as founding Tier I member in January 2013
- **Vision:** A vibrant leading-edge composites industry, supported by the CRN and partner organizations.
- **Mission:** To create knowledge in practice documents that enable effective and low-risk knowledge-based composites manufacturing and design.

# CRN Nodes


UBC Vancouver
UBC Okanagan
Future node
Future node
Composites Innovation Centre, Winnipeg
University of Victoria
University of the Fraser Valley / City of Abbotsford

Composites Research Network

Director

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Network Manager

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Vancouver Node Coordinator

Reza Vaziri

Kelowna Node Coordinator

Abbas Milani

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Winnipeg Node Coordinator

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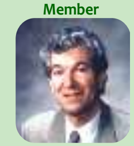
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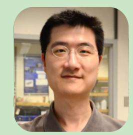
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# Facilities

## Manufacturing and Repair

**Manufacturing:**
- Autoclave
- RTM System
- Ovens
- Lay-up Room

**Machine Shop:**
- Waterjet Cutter
- CNC Router
- RoboDrill

**Repair:**
- Composite Repair System

## Material Characterization

**Material Characterization:**
- Dynamic Mechanical Analyzer (DMA)
- Differential Scanning Calorimeter (DSC)
- Thermomechanical Analyzer (TMA)
- Thermogravimetric Analyzer (TGA)
- Rheometer
- 3D Digital Microscope
- FTIR Spectrometer
- UPLC Mass Spectrometer

## Mechanical Characterization and Non-Destructive Testing

**Mechanical Characterization:**
- Static Testing
- Impact & Ballistic Testing
- Digital Image Correlation System
- High Speed Camera

**Non-Destructive Testing:**
- Ultrasonic Testing Equipment
- CMM 3D Laser Scanner

## Design and Simulation

**Hardware:**
- 192 Computational Cores
- GPU Enabled Computing
- Infiniband Interconnect
- Advanced Job Scheduling and Cluster Management Software

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# Industrial Partners

- Canadian and international companies can join CRN
  - Actively engaging in discussions with prospective members
- The Boeing Company joined CRN as the founding Tier I member in January 2013
  - Active involvement going beyond simple funding
- Strong and effective linkages with other Canadian initiatives such as CCMRD, CIC, as well as international centres
- Numerous Western Canadian companies are interacting with CRN, actively engaged in programs and projects

| | |
|---|---|
| **TIER I** | **Large international aerospace, automotive, and other companies** |
| **TIER II** | **Mid-size companies in the supply chain – product manufacturers, materials suppliers, …** |
| **TIER III** | **Small local industrial, marine and aerospace manufacturers** |

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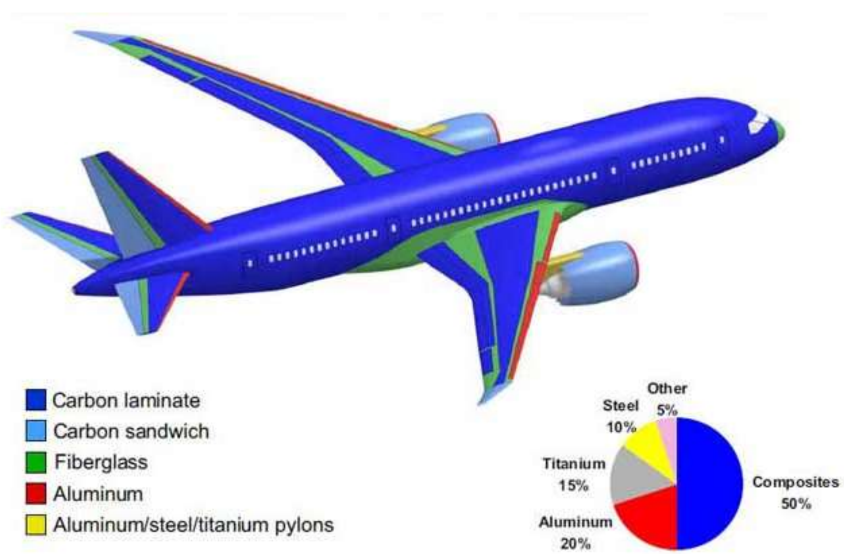
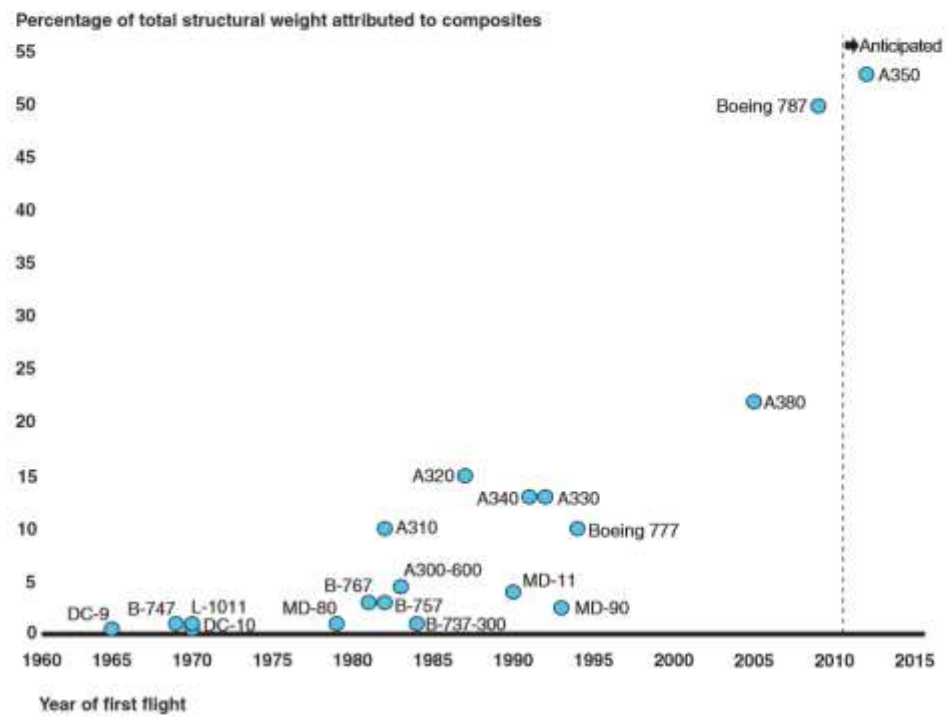
# COMPOSITES IN AEROSPACE INDUSTRY: OPPORTUNITIES AND CHALLENGES

# Composites in Aviation Industry

- Fibreglass was introduced during WWII by Royal Air Force
- Carbon fibre was developed in 1960’s and since then has been used in military and civilian aviation industries
- All major aircraft manufacturers are moving towards employing CFRP composites as the material of choice for significant components (empennage, wing, fuselage, …)




Sources: GAO analysis of information from FAA, NASA, Boeing Company, *Jane's All the World's Aircraft*, and *Jane's Aircraft Upgrades*.

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http://www.gao.gov/assets/590/585341.pdf
http://www.carbonfibergear.com/wp-content/uploads/2009/05/carbonmarket3.jpg

# Advantages of Composites

- High Specific Stiffness and Strength:
  - Lighter Structures
  - Better Fuel Efficiency
  - Boeing 787 is 20% more fuel efficient compared to similar sized airplanes[1]
- Highly Tailorable
- Integrated Manufacturing
  - The structure can be made from far fewer pieces
- Allows more flexible designs and better aerodynamics
  - Possibility of creating complex surfaces and shapes
- Longer maintenance cycles

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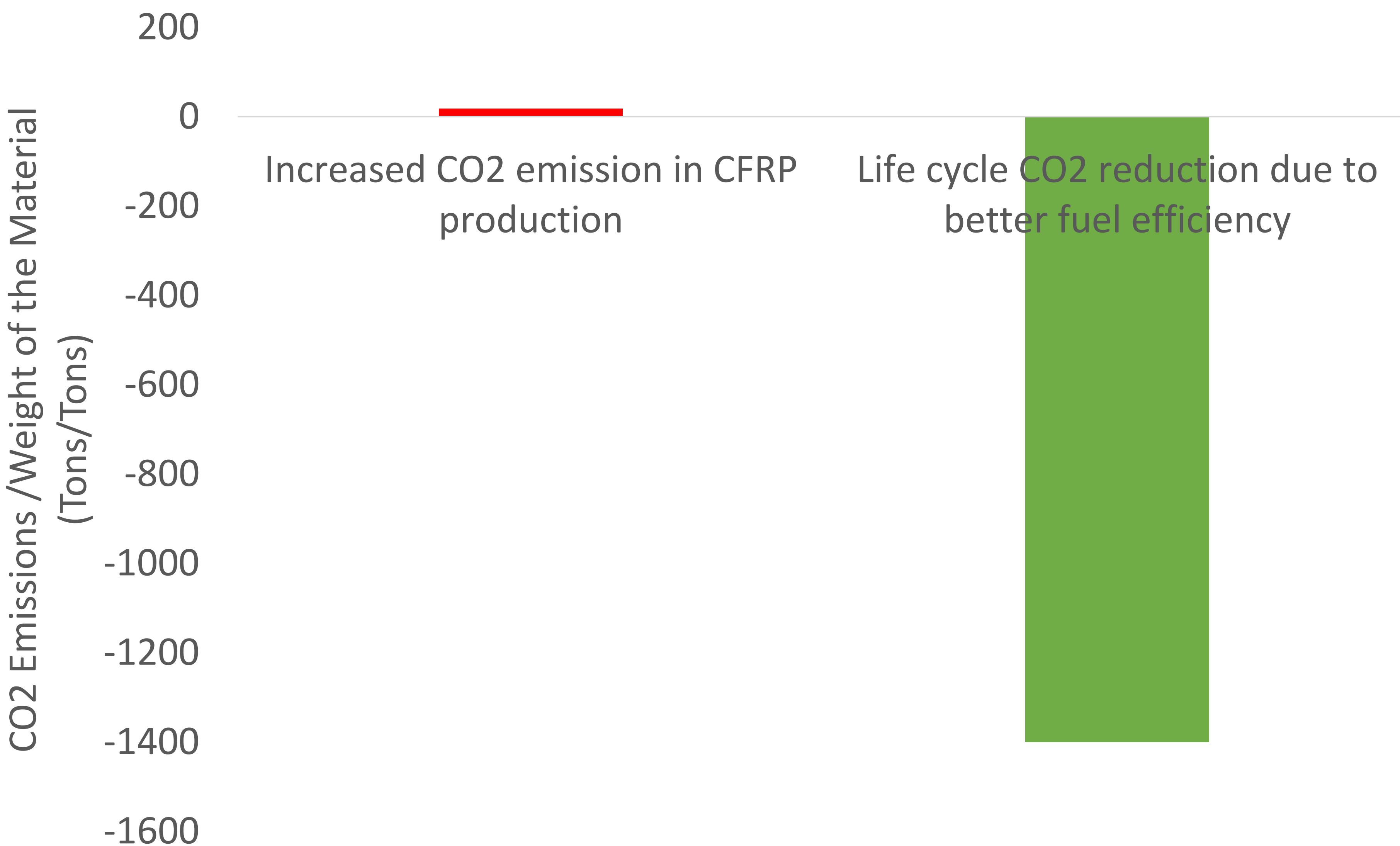
1. Boeing 787 Program Fact Sheet: http://www.boeing.com/boeing/commercial/787family/programfacts.page

# Challenges

- Complex design
- Material formation happens at the same time as structural fabrication
  - Introduction of variability and defects in the material (voids, wrinkles, micro-cracks, residual stresses, warpage, etc.)
  - More advanced inspection and quality control required
- Require significant initial investment
- Higher $CO_2$ emission in production of CFRP compared to aluminum
- Recycling
- Demographics: Average age in aerospace industry is ~48, and many knowledgeable composites experts are retiring

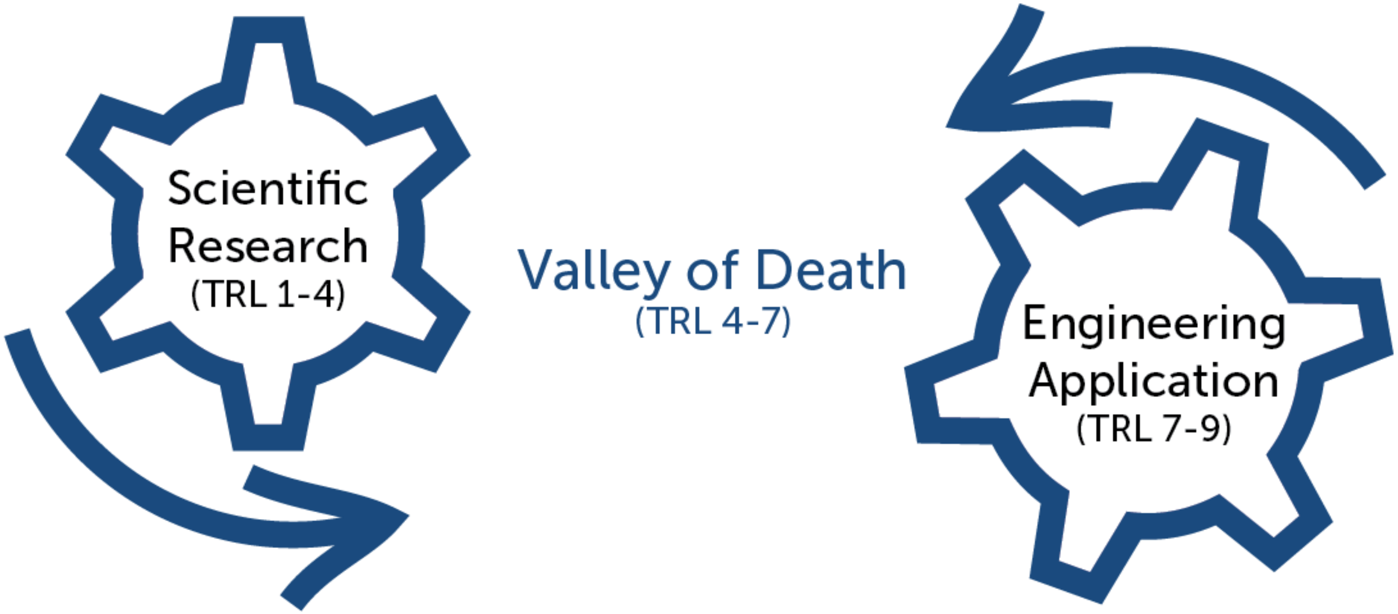
# $CO_2$ Emission: Switching from Aluminum to CFRP




Sources: Toray company: http://www.toray.com/ir/pdf/lib/lib_a136.pdf
http://www.lcmp.eng.cam.ac.uk/wp-content/uploads/W1-Steel-and-aluminium-facts.pdf

# HOW WILL CRN HELP?

# The Existing Disconnect between Academic Science and Engineering Practice




- **Basic Research**
- **Narrow focus, great detail**
- **Little attention to integration**
- **Academic papers**
- **Hands-off interest in use of knowledge**
- **Slow and methodical**

- **Wide focus**
- **Integration is critical**
- **Often get the desired result without knowing why**
- **Fast and results-oriented**

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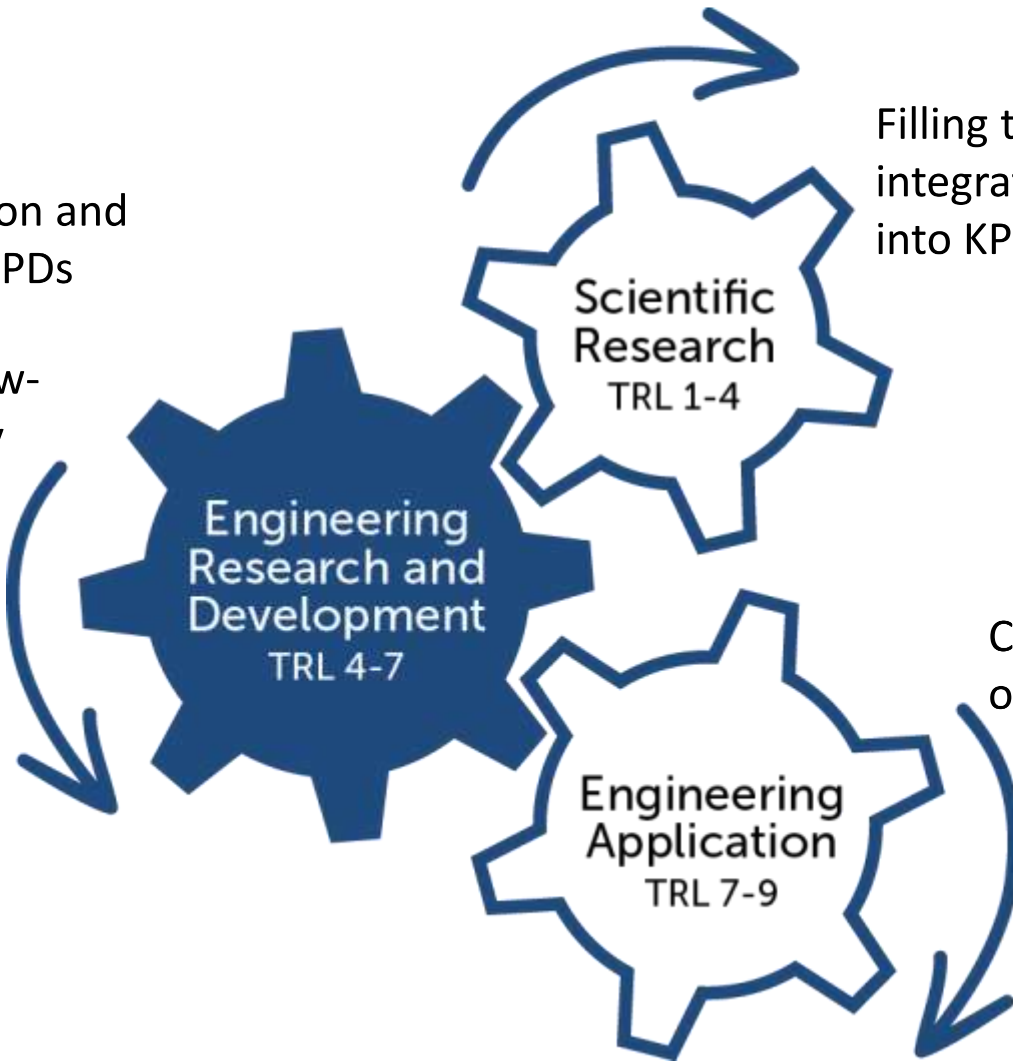
# CRN Approach to Manage the Disconnect

Continuous creation and improvement of KPDs

KPDs capture know-how supported by know-why

KPDs are immediately recognizable as practice documents but tie back to the fundamentals




Filling the gaps in the integration of knowledge into KPDs

Customizing KPDs to own products

Provide direction and feedback to KPDs

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# Know How versus Know Why

- Composites manufacturing and design is today largely based on *know how*
  - E.g. “processing recipes” largely developed based on trial-and-error
  - Results in large risk when tackling size and product scaling
- The *know why* partially exists
  - “Hidden” in academic journals
  - Very compartmentalized
  - Not available in useful form for a practitioner

# Knowledge in Practice

- KPDs are an example of the missing link between academic journal papers, and industrial protocols, standards and regulations
- They are the precursor and support for industry led initiatives such as CMH-17, standardization efforts such as SAE, ASTM, and others
- They are the precursors for the development of customized company documents that can include further proprietary company technology
- They are excellent training materials

# CRN Activity Matrix

**ENGINEERING APPLICATION**

**KNOWLEDGE**

| | **Science** | **Practice** |
|---|---|---|
| **Integration** | **Basic Program Activity**<br>*Core (Shared) Funding*<br>• Focus on integration and completion of existing knowledge in an easily usable form in KPD<br>*"Helping you do better what you do already"* | **Basic Project Activity**<br>*Partially Core Funding*<br>• Application of KPDs to real problems – evaluation and feedback into KPDs<br>*"making it work for your problem"* |
| **Creation** | **Advanced Program Activity**<br>*Focused (Individual) Funding*<br>• Focus on creation of next generation knowledge of particular interest to one Company, made more efficient and effective by building on existing knowledge and KPD structure<br>*"helping you do it better in the future"* | **Advanced Project Activity**<br>*External to CRN*<br>• Typically performed at Company (or Company contractor) – protects Company proprietary and other data needs<br>*"making it work for your problem"* |

# KPD Details

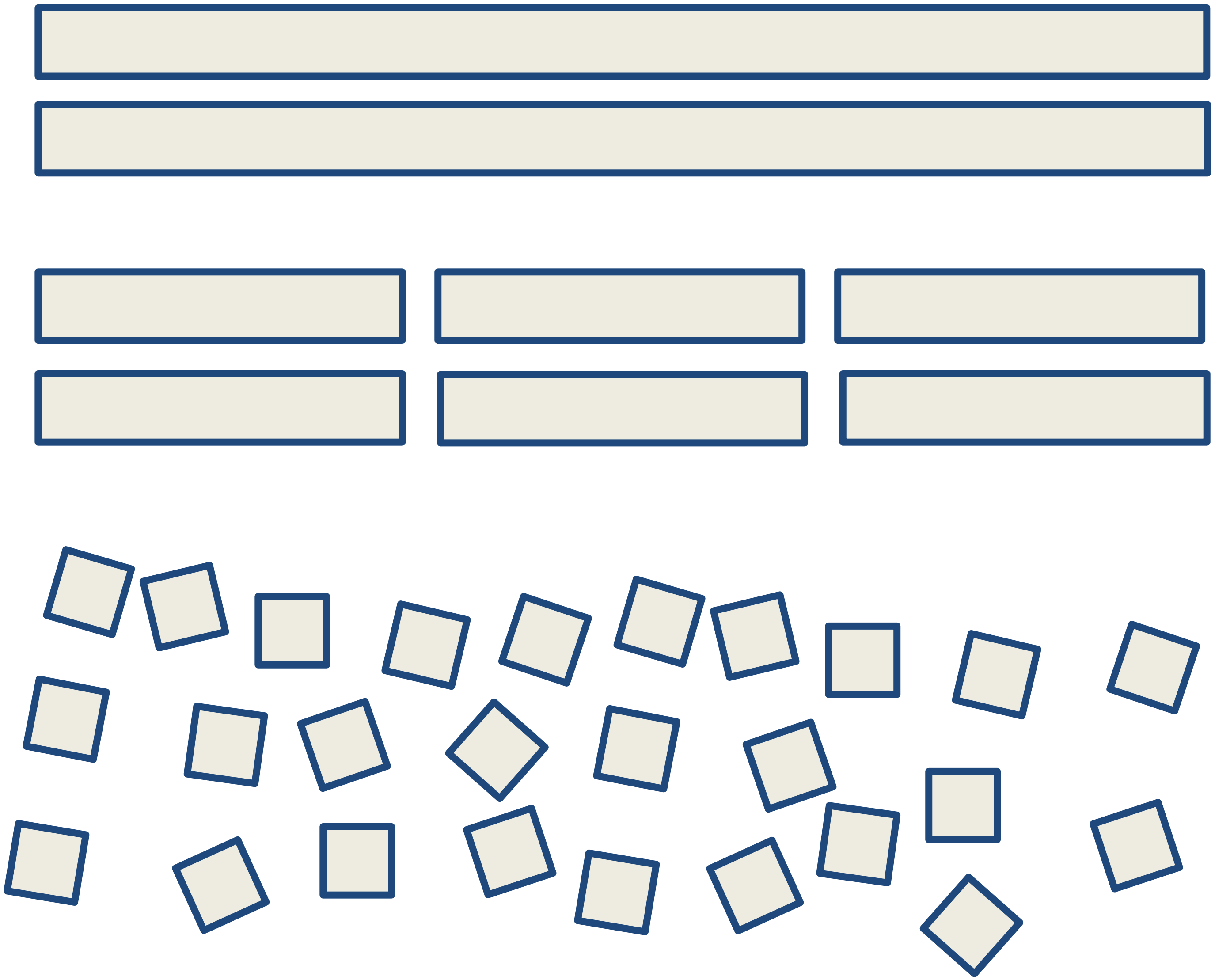
- A *Knowledge in Practice Document* (KPD) is a technical document focused on an aspect of design or manufacturing of composite structures
  - Requires deep understanding of industry needs as well as the foundational knowledge
  - Provides a platform for sharing knowledge in a structure relevant to industrial workflows
  - Identifies gaps in knowledge where they exist and is updated to reflect new knowledge and needs as it emerges

# KPD Hierarchy

**Workflow KPDs**
closest to industrial practice

**Theme Level KPDs**
Integration activity – weaving together knowledge into usable assemblies

**Building Block KPDs**
closest to academic publications



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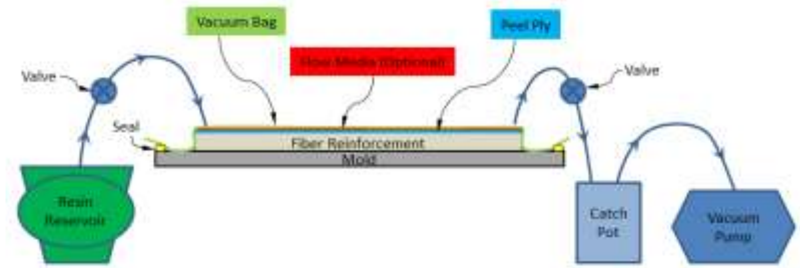
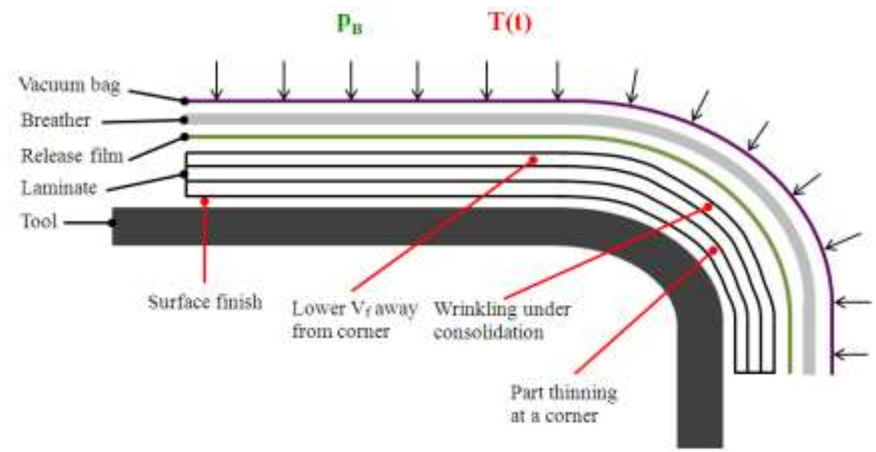
# KPD Website

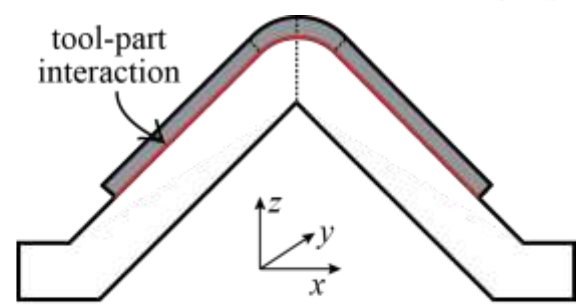
- KPDs are rich content documents presented in the form of a website:
  - Multimedia
  - Interactive tools such as calculators
  - Various entry points (such as FAQs, tables of contents, etc.)
  - Advanced search
  - Forums

# KPD Themes

- Material Deposition
- Thermal Management
- Quality Management
- Porosity Management
- Residual Stresses and Dimensional Control
- Repair Management
- Structural Design
- Impact and Ballistics

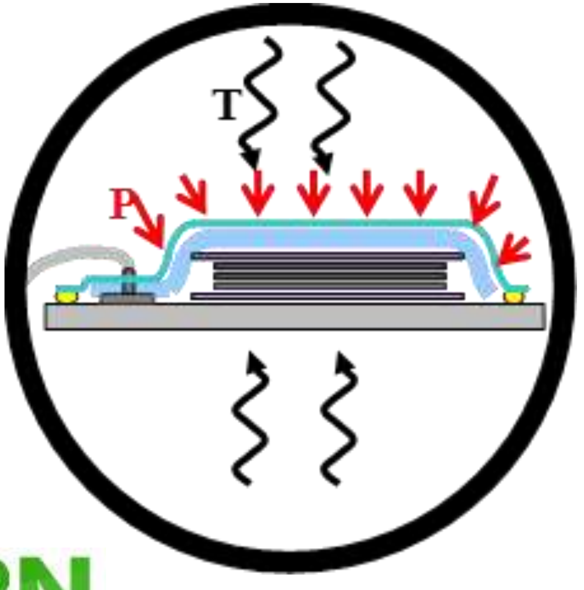


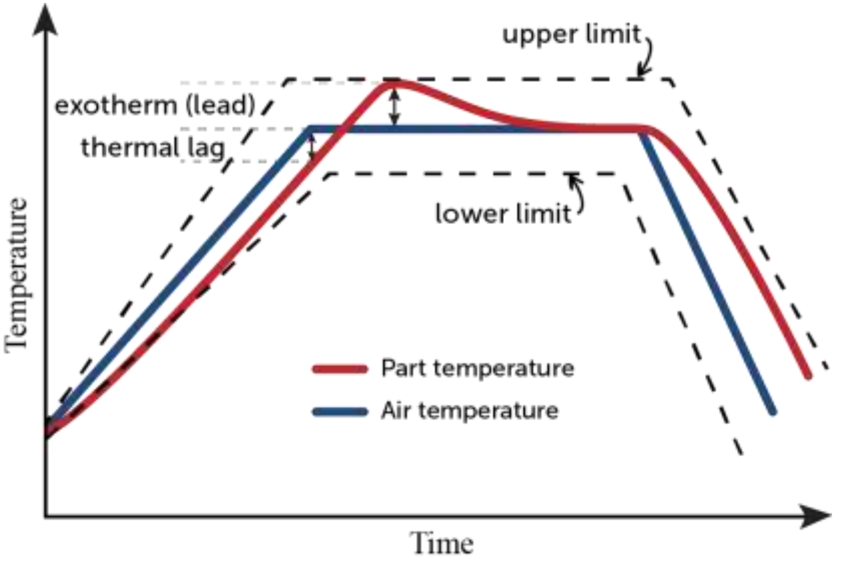



# KPD Theme: Thermal Management

- Composites have to go through a pre-defined temperature cycle to ensure the quality of the manufactured part.
- Part, tool and the cure environment are the main players.
- Thermal Management KPDs focus on understanding and management of the thermal response of the system.

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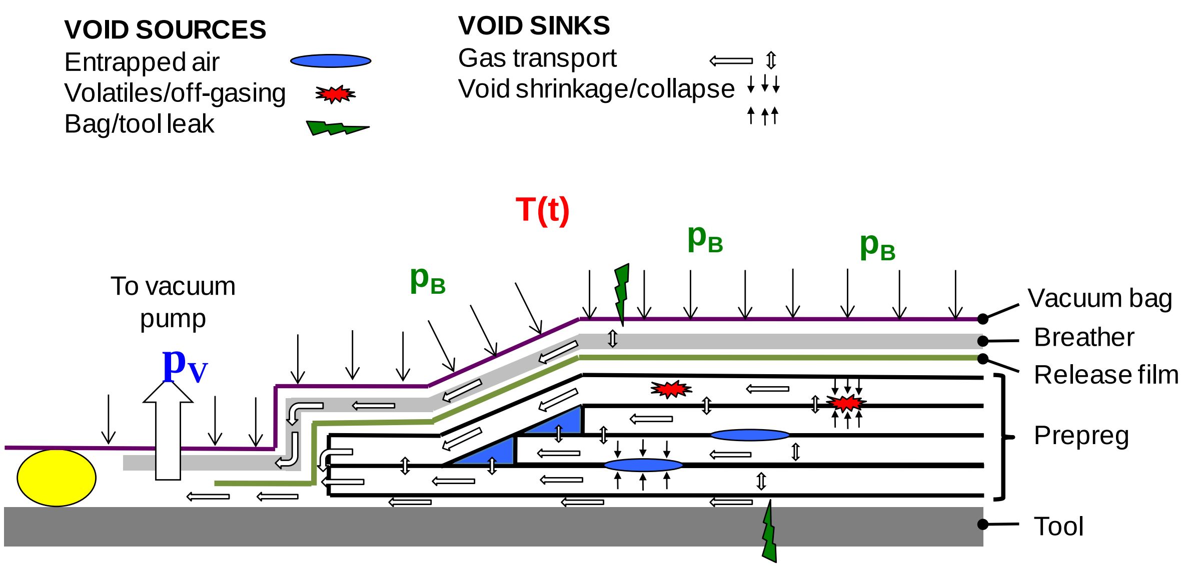
# KPD Theme: Porosity Management

- Voids and porosity are a significant and recurring defect found in composite parts, source of much rejection and rework
- Aerospace industry has very tight limits on the void ratio in the composite parts.
- Goal is to help industry minimize the void content in their products by developing an understanding of how void sources and void sinks can be managed at each stage of the manufacturing process.




Courtesy of Goran Fernlund

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# Summary: CRN and Sustainable Aviation

- A more efficient and effective use of current knowledge and generation of new knowledge is needed
  - The KPD model aims to provide a means to do so
- The KPD model provides a platform for equal attention to both the creation and use of knowledge
- CRN is a strategic and long-term model for academic-industry interaction and partnership applicable to engineering research

# Acknowledgements

Canada

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Diversification de l'économie de l'Ouest Canada

BOEING®

UBC a place of mind

University of Victoria

NRC·CNRC Canada

NSERC CRSNG

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CONVERGENT

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