Thrust Area Working Group # 3 – Composites

Product and Technology Roadmap Overview

Oct 29, 2013

Composite Product and Technology Roadmap

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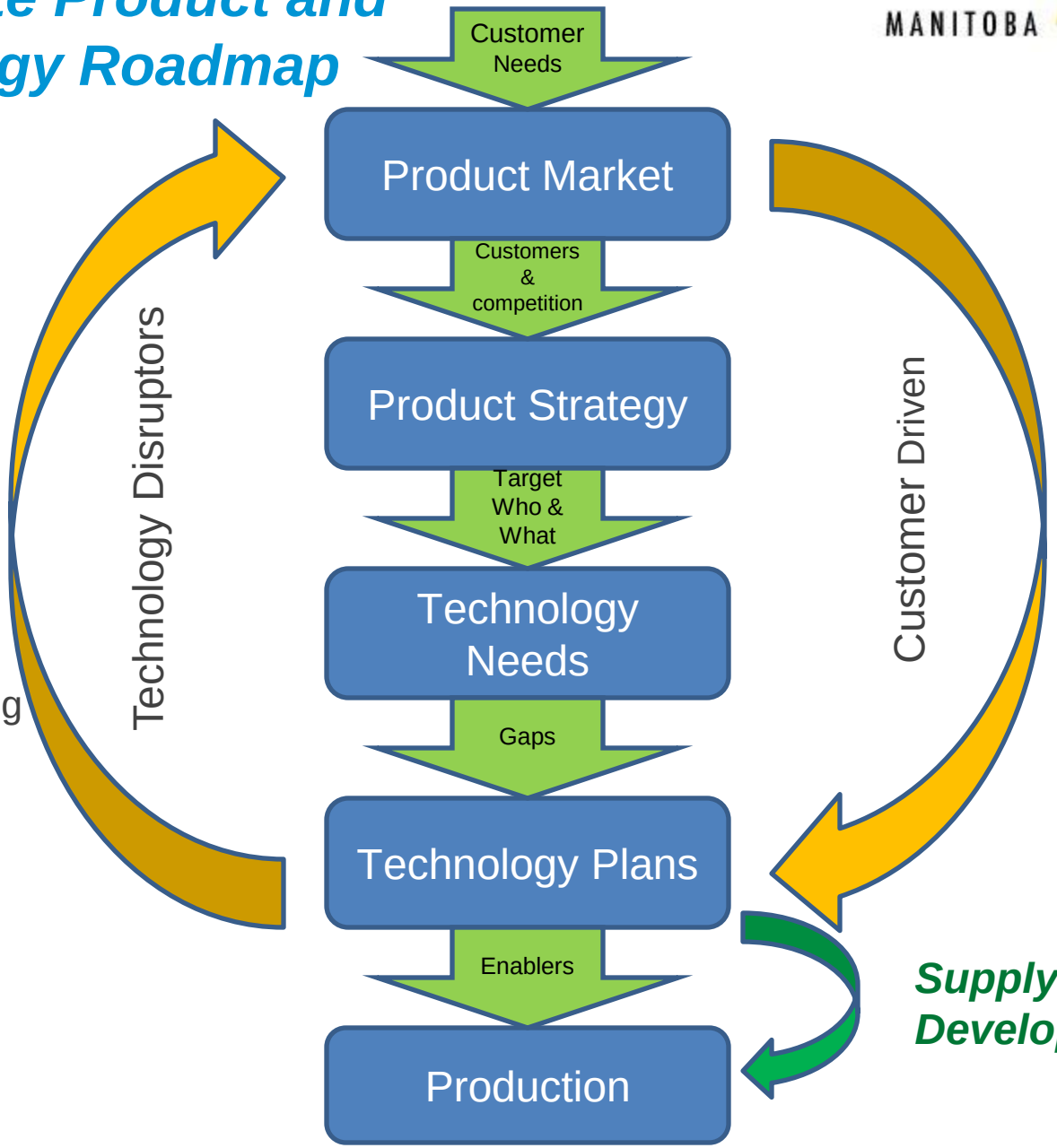

Push

- CMC
- Automated lamination
- Additive Manufacturing with fibres

Pull

- OOA
- RI
- PI & BMI
- Pre-Forms
- Automated Inspections

Supply Chain Development

Composite Product and Technology Roadmap

Global Customer Needs 2028-2033

Efficient Manufacturing
- Lower cost
- Integrated structures
- Higher complexity
- Larger sized structures

Increased product performance
- Higher temperatures
- Lighter weight
- Intelligent structures
- Integrated systems
- Passenger comfort & connectivity
- Safety

Environmental Improvements
- Lower noise levels
- Reduced operating & MRO costs

Tier I capabilities
- Design
- Certification
- Rapid design & development cycles

New Airplane configurations
- Faster cruise
- Higher altitude
- Blending Wing Body
- Higher efficiency
- Autonomous vehicles

Legislative and Regulatory
- Security
- Environmental

Product Market

- OEM
- Tier I
- Commercial
- Military
- Space

- Primary structure
- Secondary structures
- Interiors

MB Product Strategy

Structures
- Nacelles
  - Pylon Heat Shields
  - Cowls
  - Inner barrels
  - Thrust Reversers
- Acoustic treated structures
- Wing-to-Body Fairings
- Landing Gear Doors
- Winglets
- Movable LE and TE
- UAS
- Space components
- High Temp regions

Engines
- High temp core
- Exhaust Nozzle

Interiors
- Panels
- Seats
- Assemblies

Technology Thrusts

MB Composite TRM Technical Opportunity Rating Matrix		
Oct 29/13		
Composite Workgroup #3		
Technology Thrust	**Description**	**Disposition**
OOA	Out-Of-Autoclave: prepreg, Vacuum Bag Only (VBO)	keep and evaluate
Hi Temp Composites	Hi Temp 2500F+ Ceramic Matrix Composites (CMC): braided preforms, pyrolysis fabrication, feature machining, joining Mid Temp 600F Polyimides (PI): prepregs, infusion Mid Temp 350F Bismaleimide (BMI): prepregs, infusion	keep and evaluate Note: added BMI and PI classes Oct 29/13
RI	Resin Infusion: preforms, RTM and its variants, tooling	keep and evaluate
TP	Thermoplastics: infusion, sheet forming, joining, bonding	keep and evaluate
Drape Forming	Drape Forming of prepreg materials, laminate and sandwich panels	keep and evaluate - fits into Auto Fab composites
Auto Fab - composites	Automated fabrication of composites, preforming, lamination, reticulation (pre-cure operations)	keep and evaluate
Auto Fab - machining	Automated processing of composites, drill and trim, finishing (post-cure operations)	keep and evaluate
Auto Fab - inspection	Automated inspection of composites, lamination, NDI, dimensional	add and evaluate
~~Novel Mfg~~	~~Novel Manufacturing: innovative competitive advantages~~	remove unless pre-competitive element defined
Bio Composites	Bio-Fibres, bio-resins	keep and evaluate
Additive Mfg - composites	Additive Manufacturing for reinforced composites through incorporation of reinforcing fibres into a polymeric AM system	keep and evaluate
~~Tooling~~	~~Tooling:~~	remove as each application is specific, to be investigated within each technology thrust
~~Material Eqiv~~	~~Material Equivalency: low Cert cost and short timeline approval methodology~~	remove as each material is specific and FAA and TC constraints limiting
Pre-forms	Design, analysis and fabrication of 3D fibre pre-forms, braided, woven, stitched	keep and evaluate
~~Multi-function materials~~	~~intelligent, nano, multi-purpose materials and coatings~~	remove as each application is specific, to be investigated within each technology thrust

Thrusts and application breadth

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MB Composite TRM Technical Opportunity Rating Matrix											
Oct 29/13	Y - applicable or high potential										
Composite Workgroup #3	P - possibility of application										
	Technology thrust										
Product and applicability - Indicates breadth of technology thrust application potential	**OOA**	**Hi Temp Composites**	**RI**	**TP**	**Drape Forming**	**Auto Fab - composites**	**Auto Fab - machining**	**Auto Fab - inspection**	**Bio Composites**	**Additive Mfg - composites**	**Pre-forms**
Structures											
• Nacelles											
• Pylon Heat Shields		y				p	y	y			y
• Cowls	y	p	p	p	y	y	y	p		p	y
• Inner barrels	p		p	p	y	y	y	p		p	y
• Acoustic treated structures	p		p	p	p	y	y	p		p	
• Thrust Reversers	p		p	p	p	y	y	p		p	
• Winglets	y		y	y	y	y	y	p		p	y
• Movable LE and TE	y		y	y	y	y	y	p		p	y
• UAS	y		y	y	y	y	y	p	p	p	y
• Space components	p	y	y	p	p	p	p	p		p	y
• Wing to Body Fairings (WBF)	y		p	p	p	y	y	p	p	p	
• Landing Gear Doors	y		p	p	p	y	y	p		p	
• extended temperature regions 350F+	p	y	y		p	y	y	y			y
Engines											
• High temp core		y				p	p	p			y
• Exhaust Nozzle		y				p	p	p			y
Interiors											
• Panels	y		y	p	y	y	p	p	p	p	p
• Seats	y		y	y	y	p	y	p	p	p	y
• Assemblies			y				y	p		p	

Thrust Opportunity Ratings

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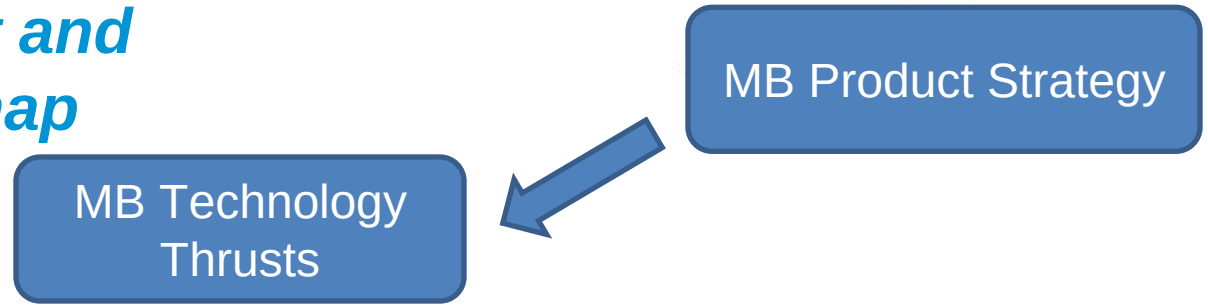
MB Composite TRM Technical Opportunity Rating Matrix											
Oct 29/13	Key Thrusts - invest and lead										
Composite Workgroup #3	Partner Technologies - contribute and participate in a larger Tech Demo										
	Technology thrust										
Criteria: rating 1=low and 5=hi	**OOA**	**Hi Temp Composites**	**RI**	**TP**	**Drape Forming**	**Auto Fab - composites**	**Auto Fab - machining**	**Auto Fab - inspection**	**Bio Composites**	**Additive Mfg - composites**	**Pre-forms**
Total score	**54**	**52**	**49**	47	45	**54**	48	50	44	50	**59**
Ranking 1 = first	**2**	**4**	**7**	9	10	**2**	7	5	11	5	**1**
Efficient Manufacturing enabler											
• Lower total product cost	**4**	**1**	**3**	3	4	**4**	3	3	4	4	**3**
• Integrated structures	**3**	**4**	**5**	3	3	**5**	5	5	2	5	**5**
• Higher complexity	**3**	**4**	**5**	4	4	**4**	4	4	3	5	**5**
• Larger sized structures (monolithic, sections)	**5**	**3**	**4**	4	3	**5**	5	5	3	2	**4**
Increased product performance											
• Higher temperatures 650F	**2**	**4**	**2**	2	2	**2**	2	2	1	2	**5**
• Higher temperatures 2000F+	**1**	**5**	**1**	1	1	**1**	1	1	1	1	**5**
• Lighter weight	**4**	**5**	**4**	3	3	**4**	3	3	3	4	**4**
• Intelligent structures	**3**	**3**	**3**	3	3	**3**	3	3	3	3	**4**
Breadth of Application											
• Platform applications, niche=1, widespread=5	**5**	**1**	**3**	3	4	**5**	3	4	2	2	**4**
• Adaptable to New or Current Airplane configurations	**5**	**4**	**3**	3	3	**3**	3	3	3	3	**3**
• Multiple Platform capabilities (GA, MIL, COM, UAS)	**5**	**1**	**4**	3	3	**3**	3	3	4	3	**3**
Provides competitive advantage											
• Economic growth to Industry	**4**	**3**	**3**	4	3	**4**	3	3	4	3	**4**
Direct links to market needs	**4**	**4**	**3**	4	3	**4**	4	4	4	3	**3**
TRL advancement potential (from now to reach TRL9)	**3**	**5**	**3**	4	3	**4**	3	4	4	5	**4**
Disruptor technology (push, replaces current workstatemer	**3**	**5**	**3**	3	3	**3**	3	3	3	5	**3**

Composite Product and Technology Roadmap



Key Thrusts - Technology investment and leadership

- Out-Of-Autoclave (OOA): prepreg, Vacuum Bag Only (VBO)
- Hi Temp Composites: 2500F+ Ceramic Matrix Composites (CMC) braided preforms, pyrolysis fabrication, feature machining, joining; Mid Temp 600F Polyimides (PI) prepregs, infusion; Mid Temp 350F Bismaleimide (BMI) prepregs, infusion
- Resin Infusion (RI): braided preforms, RTM and its variants
- Automated Fabrication - composites: (pre-cure operations) preforming, lamination, reticulation, drape forming, consolidation
- Pre-Forms: Design, analysis and fabrication of 3D fibre pre-forms, braided, woven, stitched

Partner Technologies - Thrust contributors and participants in a larger Tech Demo

- Additive Manufacturing - Composites: Additive Manufacturing for reinforced composites through incorporation of reinforcing fibres into a polymer AM system
- Automated Fabrication - inspection of composites, lamination, NDI, dimensional

Key Technology Thrust
Out-of-Autoclave processing (OOA)

Description

• OOA technology enables a fundamental shift in the manufacturing approach by allowing aerospace grade parts to be fabricated at reduced pressures, eliminating the need for an autoclave

Timeline for Technologies

• baseline technology will be required in 2015 to capture potential OEM markets for airplane derivatives already in post-launch development

• advanced knowledge in processing, scale-up and complexity must be gained to enable application in new designs prior to the next generation of derivatives and new airplane launches, approximately 2018-2023

Key Technology Thrust
Out-of-Autoclave processing (OOA)

Strategy

• establish an OOA Technology Development Centre to conduct collaborative pre-production technology demonstrator projects and subsequent improvement evaluations, build on CCMRD efforts

• could be a joint effort with the Automated Lamination Centre

Cost to Implement

• a very ROM estimate to develop the technologies is $4M over a 4 year period.

Risks if not implemented in Manitoba

• a wider global supply base of potential competitors will emerge as this technology is implemented. Manitoba's composite aerospace industry will only compete and maintain market share for these structures in 2018 if the engineering design and advanced processing knowledge remains superior to the emerging competition.

Key Technology Thrust
High Temperature Composites (CMC, PI, BMI)

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Description

• Ceramic Matrix Composites (CMC) are created from carbon fibre braided preforms and a pyrolysis fabrication method in a high temperature oven. The fabricated products are suitable for very high temperature environments, capable of 2500+F.

• Polyimides (PI) are a class of matrix materials capable of 600F+

• Bismaleimides (BMI) are a class of matrix materials capable of 350F+

Timeline for Technologies

• first CMC commercial applications will be on the GE LEAP engine 1st Stage Shroud with an EIS of 2016

• use of CMC's will expand into other engine applications such as combustors and 2nd Stage airfoils in the 2020 timeframe

• BMI and PI applications are expanding to mid temperature regions

Key Technology Thrust
High Temperature Composites (CMC, PI, BMI)

Cost to Implement

• a very ROM estimate of the total funding required to develop High Temperature Composite technologies would be $12M over 5 years

Strategy

• establish a High Temperature Composite Technology Development Centre for collaborative pre-production fabrication, inspection and repair technology demonstrator projects and subsequent improvement evaluations. Build on existing industry capabilities and development activities in research entities such as CIC, CCMRD, NRC, UBC, UM

Risks if not implemented in Manitoba

• super-alloys are being used in the MRO of high temperature products. As CMC materials are adopted, the fabrication and MRO industry in Manitoba will be affected. The workstatement for these industries will gradually shift from the metallic components to more BMI, PI and CMC and therefore revenues could be negatively impacted

Key Technology Thrust
Resin Infusion (RI)

Description

• Resin Infusion (RI) is a broad-based term covering a number of technologies whereby dry fibres are impregnated with a liquid resin in-situ, resulting in near net shape composite products

Timeline for Technologies

• a number of composite manufacturers are currently using Resin Infusion processes and materials

• advanced knowledge in design, analysis and processing of larger and higher complexity structures must be gained to enable application to the next generation of derivatives and new airplane launches occur, approximately 2018-2023

Key Technology Thrust
Resin Infusion (RI)

Cost to Implement

• a rough cost estimate for developing the basic RI knowledge and capability would be $3M over 4 years. This would set the infrastructure and knowledge to extend into the next generation of materials and processes which would be an additional $3M over 3 years.

Strategy

• partner with either an existing RI fabricator or with a RI tooling/material supplier that could provide the expertise required to establish basic capability with an existing Manitoba stakeholder. This could be driven in support of an OEM or Tier 1 planning on a new product introduction. A long term commitment for the next generation of product designs, requiring a new RI technology, would be an advancement driver

•***Risks if not implemented in Manitoba***

• the next generation of RI materials and processes will likely enable products with high economic revenue generating potential

Key Technology Thrust
Automated Lamination

Description

• Automated lamination a broad-based term covering a number of technologies whereby prepreg materials are laminated, reticulated, drape formed and/or consolidated in the pre-cured state using specialized manufacturing equipment.

Timeline for Technologies

• a number of equipment suppliers and composite manufacturers are currently using Fibre Placement, Tape Layers and Filament Winding machines for Commercial and Military products

• the need for higher laydown/processing rates currently exists

Key Technology Thrust
Automated Lamination

Cost to Implement

• automated lamination process development will require equipment and specialized knowledge

• a very ROM estimate is $8M over 4 years

Strategy

• establish a Technology Development Centre with a focus on innovative composite fabrication manufacturing techniques that do not require capital intensive investment. The goal is to develop novel means to accomplish lamination, reticulation, drape forming, consolidation and/or other specialized processing in a highly competitive manner

• this could be a joint effort with the OOA Centre

Risks if not implemented in Manitoba

• aerospace demands for cost reduction will drive manual production to global suppliers with lower labour costs

Key Technology Thrust
Pre-Forms

Description

• Pre-forming is a broad-based term covering a number of technologies whereby dry fibres are woven, stitched or braided into a reinforcement charge that is subsequently impregnated with a polymer matrix to form a highly controlled composite structure

Timeline for Technologies

• 2D pre-forms are currently available commercially and 3D pre-forms to a lesser degree

• the next generation of 3D product designs, requiring a new pre-forming technology will be based on OEM and Tier 1 needs for the next generation of Derivatives or new platforms (est 2018 to 2023)

Key Technology Thrust
Pre-Forms

Cost to Implement

• Entry into the 3D pre-forming industry will be capital extensive and require specialized knowledge

• Estimate $5M over 4 years

Strategy

• partner with an existing braiding or weaving supplier looking to expand their capabilities or increase their production capacity. This could be driven in support of an OEM or Tier 1 planning on a new product introduction

Risks if not implemented in Manitoba

• A non-technological alternative would be to purchase the pre-forms from existing suppliers. This would reduce revenue potential and global competitiveness for advanced design, analysis and fabrication knowledge of complex products.