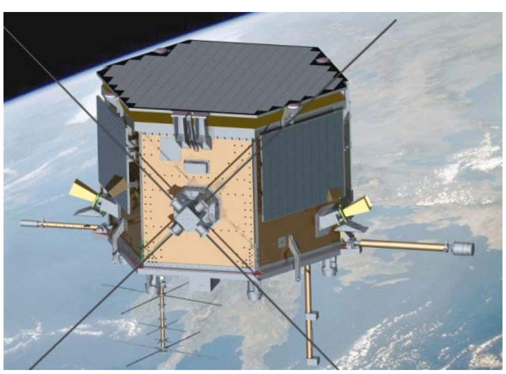

Manitoba Aerospace Technology Road Map - 2017

Manitoba’s Aerospace Research and Technology Committee (MARTC)

MANITOBA AEROSPACE

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Executive Summary

Manitoba's Aerospace industry released its first Technology Road Map in 2014. Since that release several initiatives identified in that report have been implemented. We find ourselves in a unique situation again, in that while our original Technology Road Map has been validated by virtue of its being acted upon, other work needs to be pursued. Two recent national imperatives have motivated a revitalization of our technology roadmap.

Manitoba's aerospace sector has more than 40 business establishments that are anchored by four global companies: Boeing Canada Operations Ltd.; Standard Aero; Magellan Aerospace and B/E Aerospace. These four global concerns' primary focus remains on complex components design and manufacturing (composites and metallic), precision machining, maintenance, repair and overhaul (i.e. MRO), and environmental testing of gas turbine engines.

Manitoba has a vibrant and successful aerospace industry that has been built on entrepreneurship, innovation and productivity. Technology capability and industrial competitiveness are the basis for its continuing success and is a key motivator for continuing this process of preparing a Technology Road Map, followed by a period of technology implementation.

The Impetus

We initially formulated our Technology Road Map as a follow on to the Canada's Aerospace Review and the Emerson Report. In the more recent situation the arrival on the scene of the *Consortium for Aerospace Research and Innovation in Canada (CARIC)* and their combined pursuit with AIAC of a National Technology Roadmap for aerospace, have motivated an update of our earlier work.

One further point is that Manitoba will soon have an investment in an advanced manufacturing technologies facility under the National Research Council. This will be a considerable investment which needs to be aligned with both the national technology roadmap and the regional needs of the Manitoba aerospace industry.

Our intention, with the updating of the Manitoba Technology Roadmap, is to provide industry established technology priorities to the National Aerospace Technology Road Map initiative and to the National Research Council's manufacturing initiative so that both appropriately reflect the priorities of Manitoba's local industry.

The Manitoba Aerospace Inc. (MAI) is the not-for-profit organization whose mission is to support and promote the aerospace industry through business development activities and human resource initiatives. The association encourages industry and government partnering on a variety of issues aimed at growing this sector worldwide. MAI represents a "Network of Excellence" for the delivery of aerospace products, manufacturing, and value-added services by our world-class companies and partners. It is a central point of access to Manitoba's aerospace industry, leading a network for collaboration, growth, and development.

Manitoba Technology Road Map Process - 2017

The Manitoba Aerospace Research and Technology Committee, or MARTC provided the Steering Committee function for the TRM 2017 update. As we had already broken down our sector's interests into six thrust areas, the previous Thrust Area Working Groups (TAWG) were reconvened and membership revitalized. These groups were then charged with the requirement to reconsider their previous work in the context of current circumstances. The MARTC Committee met throughout 2016 where they reviewed the TAWG reports as well as tuning the combination of their decisions with respect to the National Technology Road Map and the NRC manufacturing initiative.

Five of the Thrust Area Working Groups (TAWG) were eventually reformed with participation from over 40 participants from the aerospace and community. As was the case in 2014, each TAWG was chaired by an industrial member with a deputy chair from the Not-For-Profit Organization (NPO) community. These Deputy Chairs were tasked to support their Chair both administratively and technically. Over the period May to September 2016, these TAWGs met to critically review Manitoba's technology needs and to prepare a summary report for these identified critical technologies within their thrust area, based on the format set by the MARTC Committee.

Collectively, these Summary Technology Reports represent Manitoba's revised Aerospace Technology Road Map and are included in this Technology Road Map Summary Report (as Appendix C). The earlier report is not considered to be obsolete in that it forms the basis for the current work and positioning of certain technology development needs.

To maintain momentum on implementing the recommendations from this report, potential Implementation Strategies are included in the Discussion section of this report. Finally, a series of conclusions are presented to provide a mobilization and immediacy to implementing this Technology Road Map (TRM).

We also note here, that during this process of the TRM-2014 review and revision, Manitoba's aerospace industry association merged with their human resource development partner, to become a renamed **"Manitoba Aerospace Inc.",** or MAI for short. References are made to MAI in this report.

The TRM 2017 update activities included significant SME participation. The TRM 2014 activities did include the SME community, however their engagement was more limited. During this cycle, we found that starting at the Steering Committee Level – MARTC, that the SME's were far more interested in participating to ensure their requirements were tabled and included. At the working level – the TAWG groups, the SME's often dominated the discussion and overall contributed significantly to the contents of this report.

Manitoba Aerospace Technology Road Map Report - 2017

Background

Discussions began in the spring of 2015 on the need to merge Manitoba's Technology Roadmap with more recent national developments to ensure that investments which were forthcoming for the aerospace sector would also support Manitoba's aerospace community.

To explore this further, an early concept paper was produced which outlined how the recommendations from the Technology Road Map (2014) could be implemented through integration with CARIC resources made available to the region. This concept paper was accepted and the CARIC Regional Director became the technology leader within the MARTC (Manitoba Aerospace Research and Technology Committee).

MARTC was established in late 2014 to oversee the implementation of the TRM 2014 recommendations. It met for the first time in early 2015 and then frequently to address the coordination of efforts to implement TRM 2014 recommendations. A total of seven meetings were held from the period of November 2015 to September 2016. In the course of time the burden of work shifted from organizing to directing the TAWG committees to re-examine their previous reports and to submit a document which reflected their considerations.

Of the six committees, which were re-tasked, four decided that enough had changed from the previous work that a re-examination was indeed appropriate and thus proceeded to do so. Two committees decided that not enough had changed and they advised MARTC of their decision to stay with the previous work. One new committee was however also struck from various aerospace participants which re-examined the previous TAWG6 work. This committee assembled like minded people and decided that enough of a difference existed between their vision and previous work, that a new TAWG group was formed. TAWG7 was therefore formed with the intention of reviewing Unmanned Aerial Vehicles and their opportunities in Manitoba. In the end, five TAWG committees presented their final technology review reports.

These five TAWG committees each had representation from the business, academic and not-for-profit sectors which resulted in a more robust appreciation of the work ahead and provided a better definition of what could be achieved going forward. Assistance and consultation with the National Research Council was also pursued to add validity and feedback to the work undertaken.

It is often claimed that the process of developing roadmaps is more important than the roadmaps themselves, due to the associated communication and consensus -building benefits which are required to assemble the working groups and then complete the related technology review tasks. We can claim this to be true as elsewhere in this report it is noted that a series of projects were completed since our first foray into the TRM area, and that these projects included significant investments.

A key feature to our TRM is that it was led by Manitoba industry with participation from industry, academia, local and federal government and Not for Profit organizations. As such, several partners have participated in past TRM projects and are identified for the projects which flow from this exercise. The overall benefit of this current and previous process is a reinvigorated innovation strategy in the businesses which participated with new opportunities having been identified or potentially better clarified. We have also been able to provide an overall order of magnitude to the work and investment in certain TRM projects going forward.

As a last point on the process and nomenclature, this report is referred to as the Manitoba Aerospace Technology Roadmap – 2017. While the report development process spans now 3 calendar years, the final report will be published and made public in 2017.

Progress Since 2014

The TRM2014 exercise was beneficial and helped stimulate multiple discussions within the Manitoba Aerospace and Education community regarding collaborative project opportunities. A number of these discussions evolved and progressed into formal proposal submissions for funding assistance. By the end of 2016:

- 25 collaborative project opportunities were identified and discussed
- 7 evolved into formal projects that were submitted for funding
- 4 projects were selected for funding support

The 4 projects that were successful in receiving funding support represent a total investment of approximately $15.79M in Manitoba's aerospace community with contributions (for all 4 projects) as noted below:

- $8.4M Western Diversification
- $1.5M Manitoba Government
- $1.46M NRC/NSERC
- $1.69M CARIC
- $2.99M Private Sector

Specific discussion on the details of the approved projects:

Composites: COMP709 / CCM10: Design and Technology Development of Optimized Composite Aircraft Structures Using Knowledge Based Iterations. The Canadian Composite Manufacturing R&D Consortium (CCMRD) launched this collaborative technology demonstrator project in 2015 with CARIC funding support. This $2.55M project is led by Boeing and project partners are Magellan, Convergent Manufacturing Technology, Asco, Avcorp, PCM Innovation, Red River College, UBC Composite Research Network, Composites Innovation Centre and The National Research Council of Canada.

Advanced Manufacturing: DPMH-711 Advanced Fusion Welding technologies for repair of Aluminum and Magnesium alloys is a CARIC project led by Standard Aero with Red River College providing fusion welding evaluation thru the CATT and the UofM providing metallurgical expertise, for repair of aero engine components. The total project is approximately $1.4M.

Space and Rockets: Satellite Integration Facility. Magellan Aerospace teamed with the University of Manitoba to submit a proposal to Western Economic Diversification which would establish a facility large enough to accommodate the simultaneous assembly, integration and testing of three satellite buses. This project anchors the Satellite Integration Facility with an Academic Partner – The University of Manitoba, through the establishment of an Industrial Research Chair in the Engineering Department. Total investment for this project is about $4.4 million.

Advanced Manufacturing: Additive Manufacturing Hub. A submission was made to Western Diversification and the Province of Manitoba for the establishment of an Additive Manufacturing Facility in Manitoba. The focus of this technology is in the metal additive domain and a new SME has been formed to support the transference of this technology to the aerospace, medical device and transportation sectors. Total investment here to date is $7.5 million.

The TRM continues to promote and support collaborative project discussions and project proposals. A summary of project proposals that have been submitted for support along with more detailed information on projects that have been approved for funding support are available at the links indicated on page 49 of this report.

Thrust Area Working Group Report Summaries

Thrust Area 1 – Advanced Manufacturing

TAWG1 was assembled to consider revising their previous work under the Manitoba Aerospace Technology Road Map, which was published in 2014.

This team was to review the assigned key technology thrust areas, validate these, and provide updates as appropriate. To some extent, it was necessary to rebuild this team. Group members who had a grasp of this technical area and who may be able to ultimately benefit from the recommendations of this report were selected from Manitoba Aerospace Inc. membership. SME representation was also deemed to be important to achieve.

Several amalgamations from the former report structure were made and some new topics representing interests of the group were identified. The group also reconsidered its approach to several areas in the TAWG1 report recommendations. Several amalgamations were made and some new titles were selected to represent these new areas of interest

The technology areas of interest to TAWG1 participants were chosen to be the following:

- Inspection
- Adaptive Machining
- Additive Manufacturing
- Machining Strategies
- Nanotechnologies
- Joining
- Post Processing

A brief description of each of these areas and their importance will be presented followed by an order of magnitude investment requirement and timeline.

Inspection

This area of interest combines the former (TRM 2014) areas of 3D Scanning, Automated Scanning, and Non-Destructive Evaluation. These technologies are considered to be necessary for the final inspection step of the manufacturing process. Most importantly these technologies need to be integrated into a combined solution to be effective. This presented a key problem to further development for TAWG1, in that while one company had the capability to pursue one of the technologies, the integration of all of the technologies was a skill found more in the digital domain rather than the manufacturing domain. This technology area of interest was ranked as having the third highest interest, but with no clear path to comprehensive solution from TAWG1. Individual technology elements are discussed below in more detail.

NDT, NDE and NDI are interchangeable terms use to identify as suite of inspection technologies such as ultrasonics, eddy current, x-ray and others used to characterize the condition of a part. The challenge of handling "hard to inspect" items is of interest to TAWG1 participants.

Automated scanning is an advancement on manual scanning techniques. The intent is to integrate inspection with manufacturing so that decisions based on part condition and metrology can be made during the manufacturing process. The current view is that automated scanning needs to be able to work quickly to allow integration with adaptive machining and other similar processes.

Ultrasonic scanning was mentioned in this TAWG's previous report. We note now that Boeing is committed to this technology. The use of water as a coupler to support this technique continues to be a distraction and improved coupling methods need to be developed.

Shape Grabber technology was discussed in this TAWG. This technology offers 1-micron resolution. It has a limitation of being able to support objects which fit into an 8" x 24" cylinder. To be effective this technology needs to interface with CAD systems. Precision ADM has the capability to do this for smaller objects. This size limitation needs to be addressed.

Our team notes that blue light is now in vogue for digital scanning. Blue light supports very fast scan routines. White light has been passed over, as it reflects excessively.

Lastly, Spin Testing was also raised as an opportunity within this area but it is a very expensive process. Spin Testing is often necessary at the end of the production process. Currently this test regime is not being performed in Winnipeg. The absence of this technology results in extra costs and turnaround times that need to be managed.

Adaptive Machining

Adaptive machining is typically used when individual components in a batch have slight geometric differences. Advanced Adaptive Machining technology integrates inspection and scanning systems, special software and an attendant computer integrated with a CNC machine's control to take executive control of the process, automatically modifying programmed tool paths to cope with subtle part-to-part variations. This technology was highly ranked as an opportunity for investment for TAWG1. Industry support is also indicated.

Adaptive Machining is important to the MRO industry, and had the support of both StandardAero and Boeing Canada. This technology was noted to have applicability in both the metals and composites area, where a product rebuilding process starts to take place. CAD is an important element to this rebuilding activity. A view was put forth, that this technology will need the support of an OEM for it to take hold. As such there are now several aerospace OEM's which have operations in Manitoba. Given that Adaptive Machining has applications in metal and composites, both of these materials can be supported through their respective OEM's. Furthermore, it was suggested that Adaptive Machining has a learning and development process which could make it a candidate for the upcoming National Research Council's - Factories of the Future project. It was noted that the CATT Centre model would be particularly helpful for supporting this type of technology. The CATT model allows for research programs to be shrouded with a set of structured rules for usage.

An example was posed was to use Adaptive Machining to enable Additive Manufacturing to be part of a repair of manufacturing process. In this case, 'Additive' steps would lay down a near net shape, with follow-on machining, controlled adaptively, to account for part variations.

Additive Manufacturing

A considerable investment by Manitoba industry in metals based Additive Manufacturing has been made since the TRM 2014 report. This technology is currently being commissioned for the health, transportation and aerospace sectors. Plastic based AM is not being advanced at this time in aerospace and no related production capability is yet found in Manitoba.

As a general comment, AM – Metals offers high precision and high strength products. These parts can be deployed into unique aerospace and medical applications. It was noted in our group that 7 types of AM technologies are now available. Additive Manufacturing is more expensive than traditional casting machining operations and as such it has unique applications. The choice of material substrate only partly influences the total process costs and the entire system needs to be evaluated before starting down one path to create an end product. AM is complemented with either traditional machining or adaptive machining for purposes of finishing the product.

Another challenge to Additive Manufacturing is to keep the heat levels down to avoid materials distortion. An interest in cold metal transfer for certain parts was also indicated, so as to minimize materials distortion. As a result of growing interest in AM in Manitoba, it is noted that Manitoba now participates on certain international standards creating bodies. ASTM Committee F42 on Additive Manufacturing Technologies was formed in 2009 and meets twice a year. This Committee has now also representation from Manitoba. The benefits from joining this Committee are building an appropriate network and building an appropriate knowledge base to support product development.

Heat treating is an important requirement in working with metals-AM. Heat treatment changes the internal metallic structure of the component and this change needs to be explicitly considered during the design process. Unlike traditional manufacturing where many parts are produced and heat treatment produces a known result based on previous experience, AM does not have this history, nor does the operator likely have the depth of experience. To this end a general heat treating capability was noted as being needed in our region.

Challenges presented with AM are that this technology requires an Intellectual Property management regime. As well, OEM support is needed to advance the technology. Other considerations are that developing a user base is of interest to the new local participant in this field. As well, partnership opportunities could also support the development of this technology in the region. Collaborative investment can also be considered to extend the technology.

Machining Strategies

Both Cormer Industries and Magellan Aerospace have interests in High Speed Machining. Magellan's interest is for reasons of providing components for the F35 program, and Cormer for reasons of supporting their international customers. Other areas of interest in this section are cooling approaches, high performance cutting of titanium and nickel alloys, surface enhancement of metallic materials, and toolpath optimization. Some of these areas of interest - particularly high performance cutting and toolpath optimization, would fit into the Factories of the Future technology set.

Nanotechnologies

The Nano-Systems Fabrication Laboratory (NSFL) continues to support the nanotechnology efforts of University of Manitoba researchers and others. While certain elements of the aerospace sector are interested in supporting this technology, our local industry is currently not in a position to do so. Our researchers advise that Nano films present opportunities which have applications for aerospace, such as dispersion of electrostatic charges and shedding ice buildup. The TAWG1 group notes that the Factories of the Future has a high interest in supporting Nanotechnology.

Joining

This topic was added to our report as certain work has become more complex, which, along with light-weighting projects for aerospace parts has resulted in the creation of some components which are very thin and need to be joined.

Joining considers the view that materials have 'skins' which need to be managed in the joining process. This is particularly important in complex parts. The application of heat in many joining processes, creates distortions in the end products which then need to be managed or at least corrected in the post operations cycle. Advanced fusion welding technologies, including continuous wave lasers, micro lasers, laser-arc hybrid and cold metal transfer (CMT) are becoming increasingly attractive for lightweight and low heat input aerospace applications.

The CATT center, which is a partnership between Red River College and StandardAero is one location where significant process development work is currently being conducted. Plans are underway to acquire additional joining and materials processing technologies to the CATT centre.

Post Processing

This technology area is a new addition to the discussion in TAWG1.
Grouped into this topic were heat treating, isostatic pressing, hipping and chemical treatments. Members of TAWG1 noted that these technologies were not available in Manitoba and were needed to sustain certain projects in the industrial base. Consideration for the introduction of these technologies is suggested. Another Post Processing procedure identified was peening, which is typically used to correct distortions in thick pieces. This technology is in itself an art form. It is noted that in certain applications the materials are too light to support such an application so other approaches are needed. Other post-processing alternatives such as using spray on metals and heat treatment itself to improve heat management are posed as opportunities for development. A post processing view of joining is envisaged. This too has a potential application in the upcoming Factories of the Future where the effects of heat treatment and shot peening could be examined in more detail.

Technology Rankings by way of importance to TAWG1 industry representatives indicated the following Rank Order, as presented in Table 2.

Table 2: TAWG1 Technology Rankings

Technology	Rank
Additive Manufacturing	1
Adaptive Machining	2
Inspection (NDT)	3
Machining Strategies	4
Joining	5
Post Processing	6
Nanotechnologies	7

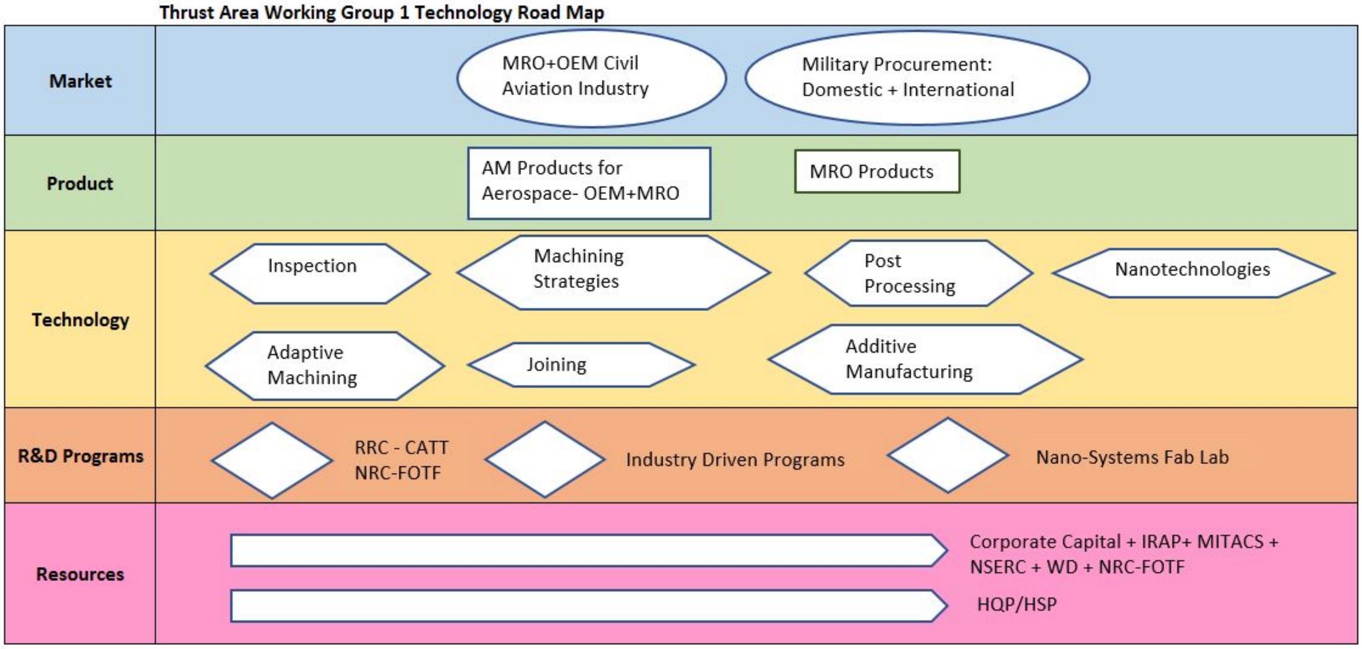
Projects of Interest to TAWG1 are presented in the following table of TAWG1 Projects Identified.

Table 3: TAWG1 Projects Identified

Technology	Cost	Timeline	Description
Additive Manufacturing	$5M	3 Years	Additional AM technologies working with blended materials
Adaptive Machining	$5M	3 Years	Joining in with an OEM to support Adaptive Machining
Joining and Post Processing	$20M	3 Years	Additions are being considered for the CATT Centre to support these new technologies
Heat Treating	$2M	2 Years	Establishment of a capability to support this activity for local industry
Inspection	$5M	3 Years	Development of Large Data and image capture capabilities to support inspection processes
Machining Strategies	$2M	3 Years	New cooling, cutting and surface enhancement approaches
Nanotechnologies	$2M	5 Years	Development of new nano films for the aerospace industry

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG1 identified technologies.

Thrust Area Working Group 1 Technology Road Map



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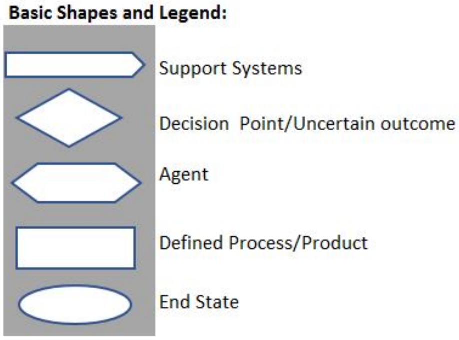


Thrust Area 2 – Robotics and Automation

TAWG2 updated their previous work under the Manitoba Aerospace Technology Road Map, which was published in 2014. This team reviewed the assigned key technology thrust areas, validated these, and provided updates as appropriate. Group members who have a technical background in this emerging area and who may be able to ultimately benefit from the recommendations of this report were selected from Manitoba Aerospace Inc. SME representation was also deemed to be important to achieve.

Several amalgamations from the former report structure were made and some new topics representing interests of the group were identified. The group also reconsidered its approach to several areas as reflected in the attached TAWG2 report (Appendix C).

The technology areas of interest to TAWG2 participants are the following:
Robotic Applications
Robot Integrated Sensing
Robot Communications
Robot Software Systems
Robot Safety Systems

Projects of interest
A brief description of each of these areas and their rank importance are presented followed by an order of magnitude investment requirement and timeline.

Robotic Applications: The use of robotic machines, control systems, and information technologies are used to optimize productivity and quality in aerospace component manufacturing. This includes Robotic Assembly and Robotic Finishing that were identified previously. There are endless possibilities for applications; similar to that of a human.

Robot Integrated Sensing: Various sensing technologies are used to improve task performance. This includes Vision, Force Feedback, Sonar, and Lasers, anything that assists with feature identification, location and validation. In addition, this includes End Effector use and effectivity and Spatial positioning and awareness areas.

Robot Communications: The effective use of information used to support robot associated activities. This includes the Industrial Internet of Things, Machine to Machine Protocols and Analytics. Additional technologies relate to Interconnectivity (wireless, cloud based, Bluetooth, etc.), high speed, high volume data communication and performance measurement and management.

Robot Software Systems: The development and use of systems and tools used to manage resources required to support robotic activity. This includes Environmental Awareness, Real-time/Live Simulation, Machine Learning (AI), Algorithms, OS. Additional technologies of interest include proximity awareness, real-time interconnected systems, data collection towards AI and Controller Operating Systems.

Robot Safety Systems: The development and use of systems (regulatory or other) used to protect collaborative humans from harm, as well as product and environment from damage.

Technology Rankings by way of importance to TAWG2 representatives, indicated the following Rank Order, as presented in Table 4.

Table 4: TAWG2 Technology Rankings

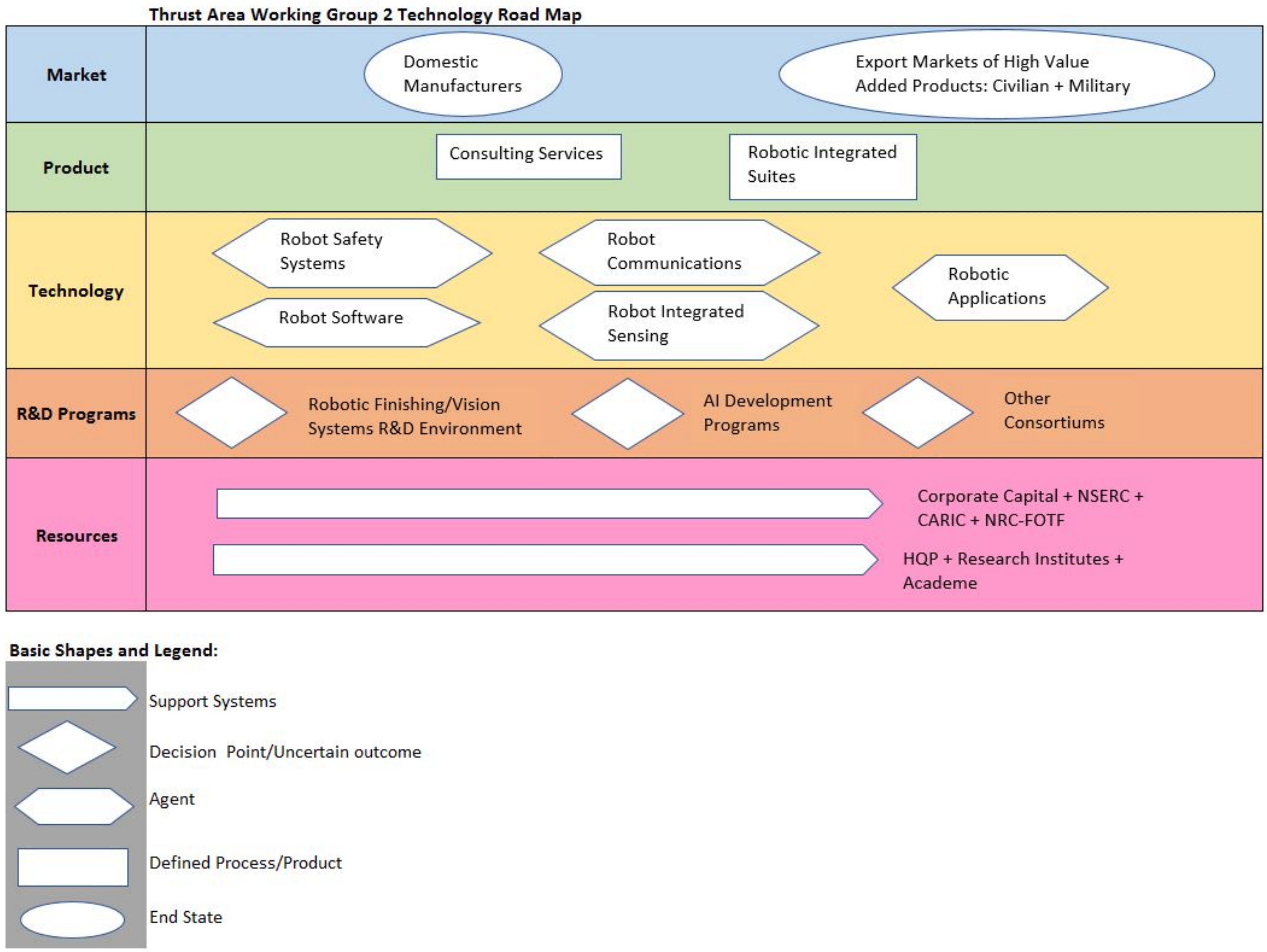
Technology	Rank
Robotic Applications	1
Robot Integrated Sensing	2
Robot Communications	3
Robot Software Systems	4
Robot Safety Systems	5

Projects of Interest to TAWG2 are presented in Table 5.

Table 5: TAWG2 Projects Identified

Technology	Cost	Timeline	Description
Robotic Applications	$1M	2 Years	optimize productivity and quality in aerospace component manufacturing.
Robotic Integrated Sensing	$1M	2 Years	feature identification, location and validation, including end effector use, effectivity, spatial positioning and awareness
Robot Communications	$1M	2 Years	Industrial Internet of Things, Machine to Machine Protocols and Analytics.
Robot Software Systems	$1M	2 Years	systems and tools to manage resources which are required to support robotic activity
Robot Safety Systems	$1M	2 Years	the development and use of systems to protect collaborative humans from harm, as well as protecting the product and manufacturing environment from damage

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG2 identified technologies.



Thrust Area 3 – Composites

TAWG3 updated their previous work under the Manitoba Aerospace Technology Road Map, which was published in 2014.

This team reviewed the assigned key technology thrust areas, validated these, and provided updates as appropriate. In large part this was a continuation of the previous group.

Technologies Considered
Seven priority Composite technologies for Manitoba were identified in 2016. These topics are refined and expanded from the previous set of five. Table 6 is presented to demonstrate the difference between the Key Thrusts of 2014 and 2016.

Table 6: Comparison of the Key Thrust Technologies in 2017 versus 2014

Key Thrust Areas of Interest: (2016)	Key Thrust Areas of Interest: (2014)
Out of Autoclave*	Out of Autoclave
Mid Temp Resin Systems	Previously was High Temp Resins
Resin Infusion*	Resin Infusion
Pre-forms*	Pre-forms
Hybrid Processing	new
Automated Fab – Right sized equipment	Previously was Automated Lamination
Automated Inspection	new

* N/C – No change

A brief description of each of these areas is presented followed by an order of magnitude investment requirement and timeline.

Out of Autoclave: Traditionally aerospace prepreg composites are cured in an autoclave, where the autoclave pressure minimizes voids between plies from air entrapped during the lamination process and from resin off-gassing. Newer prepreg systems that enable equivalent consolidation at lower pressures allow cure without an autoclave. Typically, these are processed with Vacuum Bag Only (VBO) allowing an oven cure only. In addition to eliminating a significant capital expense, there are also processing advantages to reduced pressure cures in terms of avoidance of typically defects such as core crush for sandwich constructions. This also enables production synergies by allowing discrete part flows as part of a dedicated production line vs dedicated or batch processing in a fixed autoclave.
For reference, an autoclave for large composites processing is not only expensive (notionally $10 - $20M for a 15 – 20 ft diameter x 30 – 50 ft long) but is a complex custom installation, built on site to pressure vessel codes and certifications (typically 1 – 2 years) and must be ordered in advance. The combination of this capital cost and lead time act as a significant barrier to both new entrants and growth for existing manufacturing.

Mid Temp Composites: This technology area is a refinement from High Temp Resin systems (focusing on the lower 350F to 600F, Bismaleimide (BMI) and new resins classes PI and CE). This separates it from the very high temperature (2500F+) for Ceramic Matrix Composites, allowing conventional epoxy based composites processing but providing higher temperature capability for new applications with reduced cost.

Resin Infusion: This technology moves away from traditional pre-impregnated materials (prepregs) to the introduction of the resin separate from the reinforcement. This can be via injection into a preform in a closed cavity mold, in adhesive films interleafed with dry fibers or various combinations (e.g. Hybrid Processing entailed above). In addition to the dimensional advantages discussed previously, the separation of fibers and resins provides a cost reduction, particularly at higher production volumes. Additional benefits are available at the other end of the scale with the elimination of out-time restrictions on prepregs on very large structures that inherently take significant layup time.

Preforms: This area of interest includes the design, analysis and fabrication of 3D fibre pre-forms, in braided, woven and stitched configurations. Preforms include the fibre only and work in conjunction with two other technologies identified: Resin Infusion and Hybrid processing. These enable more cost efficient closed mould processing with it's advantages in part geometry (elimination of "bag side" surfaces) and high volume production. Additional structural advantages are inherent in the stitched configuration, increasing the "through-the-thickness" strength, a typical weakness of laminated structures.

Hybrid Processing: This entails SQRTM (Same Qualified Resin Transfer Molding) and its variants where traditional prepregs are processed at the same time as preforms and resin transfer molding. This combines the effectiveness of prepreg for large acreage (minimizing issues with long path resin flows in RTM) with advantages in consolidation and part geometry inherent with cavity molding. The use of the same resin system simplifies both the processing environment and the material allowables utilized in the structural analysis thus significantly enabling the certification process.

Automated Composites Fabrication with Right Sized Equipment: This technology is related to pre-cure operations preforming, lamination, reticulation, drape forming, for composites fabrication. Typically, these are specialized processes without off the shelf solutions and lend themselves to right sized solutions. One exception is lamination where large gantry type machines are commonly available. However, the size and capital expense of those solutions, combined with the process flow advantages of smaller dedicated equipment provides significant impetus for right sized lamination also. The increasing usage and reduced cost of industrial robots is a significant enabler in this area, lending more commonality to the programming and facilitation of an application with a right sized end effector.

Automated Composites Fabrication – Inspection: This technology area covers both the pre-cure and post-cure environments for composites fabrication. Inspections prior to cure during lamination (confirming ply number and orientation) and the detection of FOD (primarily backing not removed from the plies prior to lamination) in a timely fashion allowing errors to be corrected have a significant cost avoidance potential as detection after cure usually results in part scrappage. Additionally, post cure inspections (typically NDI and dimensional) are often bottle necks in the production process so alternate technologies that increase flow (e.g. laser NDI, Blue light scans) are of significant benefit.

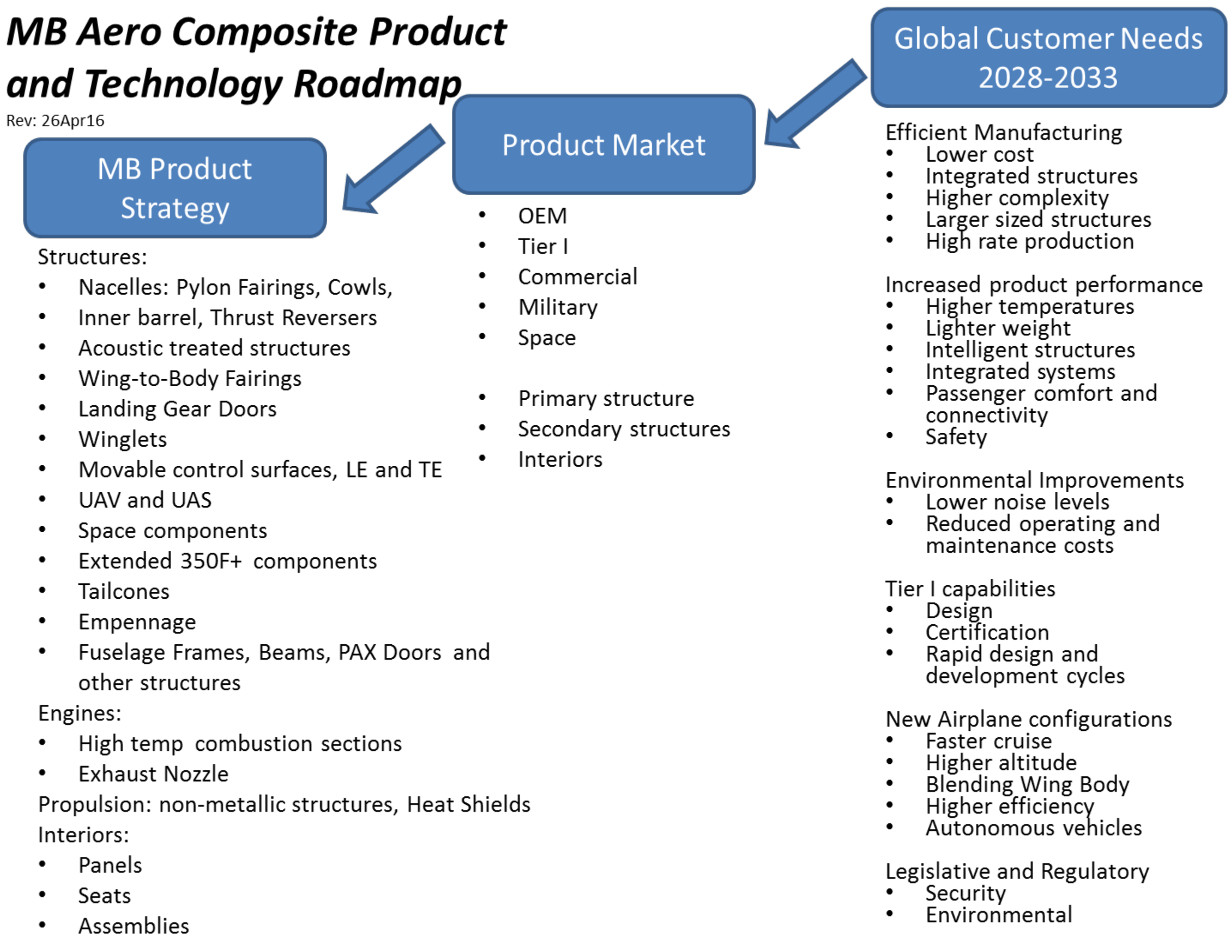
Projects of Interest to TAWG3 are presented in Table 7.

Table 7: TAWG3 Projects Identified

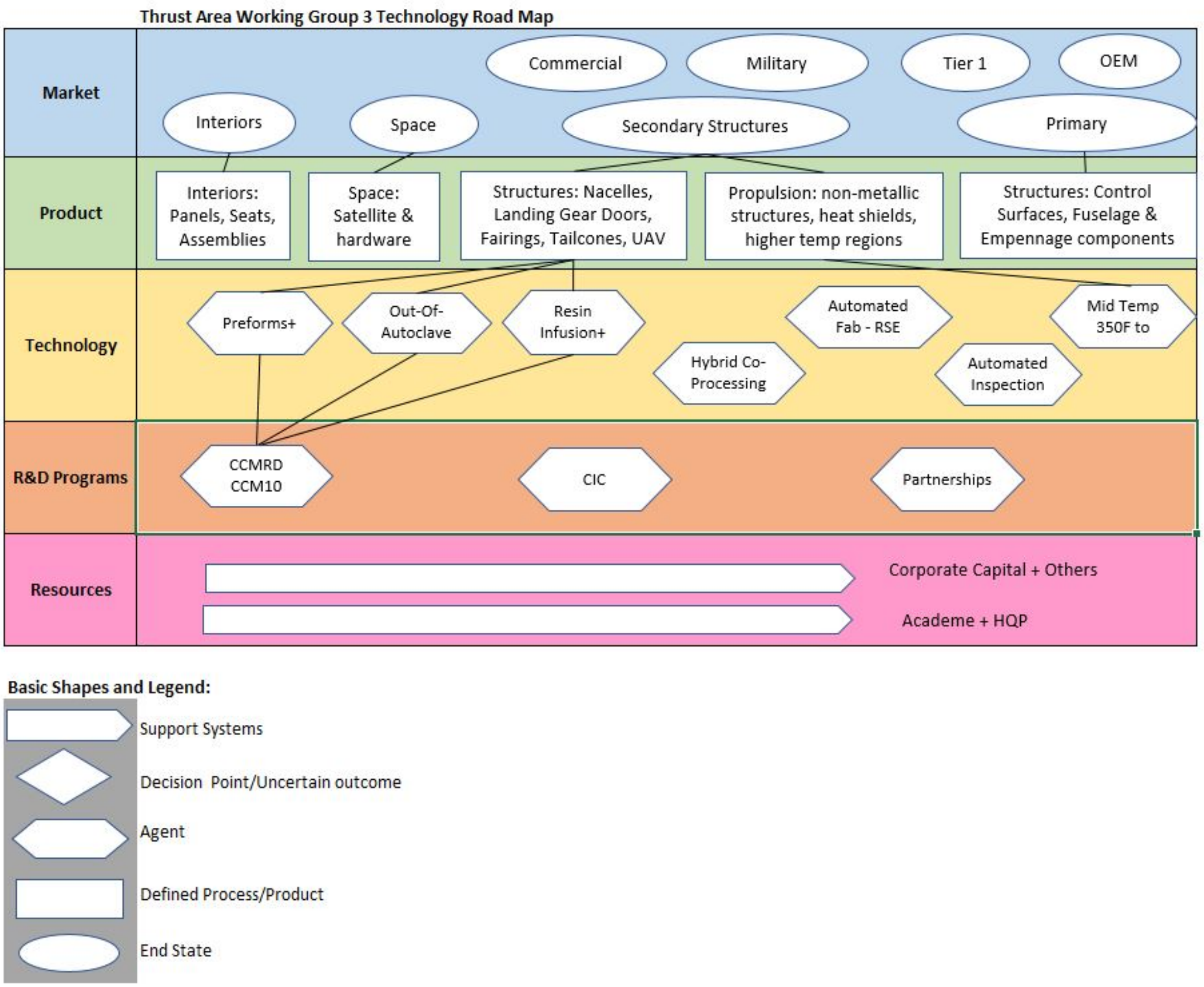
Technology	**Cost**	**Timeline**	**Description**
Out of Autoclave	$1M	2 Years	Design, product development and manufacturing with new prepreg systems using OOA approaches.
Mid Temp Resin Systems	$1M	2 Years	Design, product development and manufacturing of Mid Temp Resin Systems
Resin Infusion	$1M	2 Years	Design, product development and manufacturing of Resin Infusion systems, and in particular -oriented at very large structures.
Pre-forms	$1M	2 Years	Pre-form technology use and capability development to support high volume production schemas.
Hybrid Processing	$1M	2 Years	Design, product development and manufacturing using hybrid processing technologies.
Automated Fab – Right sized equipment	$1M	2 Years	Automated Fab -RSE demonstrators
Automated Inspection	$1M	2 Years	Support the introduction of NDI, Blue Light and others, into the inspection process.

These technologies are now expressed in the following Technology RoadMap which reflects the Composites Thrust Area Working Group deliberations

Figure 1: Technology Road Map for TAWG3 – with minimal graphics



The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG3 identified technologies.



Thrust Area 4 – Simulation Modelling & Analysis

Simulation, Modeling & Analysis is critical for Manitoba's aerospace industry for reasons of reducing engineering and development times that are involved in producing the necessary manufacturing, operation and maintenance instructions and training required to support an aeronautical product design. Additionally, OEM and other customer demands will expect instruction and documentation formats to match the best in the industry. Future training and instructional information will take advantage of 3D design data technologies to improve delivery (VR goggles, tablets, etc.) to reduce errors in manufacturing and operations and to enhance training. This technology can further generate business opportunities for publications, 3D animation, and VR businesses in Manitoba in support of the needs of local aerospace companies. Because of these needs Manitoba Aerospace companies require an increasing number of trained technicians to support our businesses in this area.

Technologies Considered

TAWG4 identified three technologies of interest:

- Enhanced Technical Instructions and VR Training
- Simulation Platform for Complex Interconnected Systems
- Modelling of New and Emerging Composite Materials

Enhanced Technical Instructions and VR Training call for the utilization of the latest hardware and software to enhance delivery of instructions through guided troubleshooting, and enhanced graphical content using 3D models and simulations. A second component - Virtual Reality training offers an immersive environment that more closely simulates aerospace maintenance scenarios. Two strategies are proposed here for development. Strategy 1: VR training -Partner with NGRAIN (Canadian)/ Panametric Corp –Creo/ Silkan to enhance existing or develop new training elements in existing Gas Turbine R&O (GTRO) training in Manitoba. Or consider a Strategy 2: Purpose Made Engine Test Simulator. In this case one would partner with a 3d Software provider (NGrain, Bluedrop, Silkan), StandardAero – Test Cell group and an OEM to develop an engine test cell simulator app

A Simulation Platform for Complex Interconnected Systems recognizes that product complexity comes from the introduction of a higher number of integrated systems. Some systems are currently too complex to effectively analyze with non-interfacing traditional simulation tools, and require multidiscipline system level tools in order to be well understood.

Modelling of New and Emerging Composite Materials refers to the next generation of aerospace designs which will call for the deployment of more and different composite materials. The modelling of these new materials would be performed using software and simulation tools. Of particular and early interest is the development and verification of process modelling software for 3D preforms.

Technology Rankings

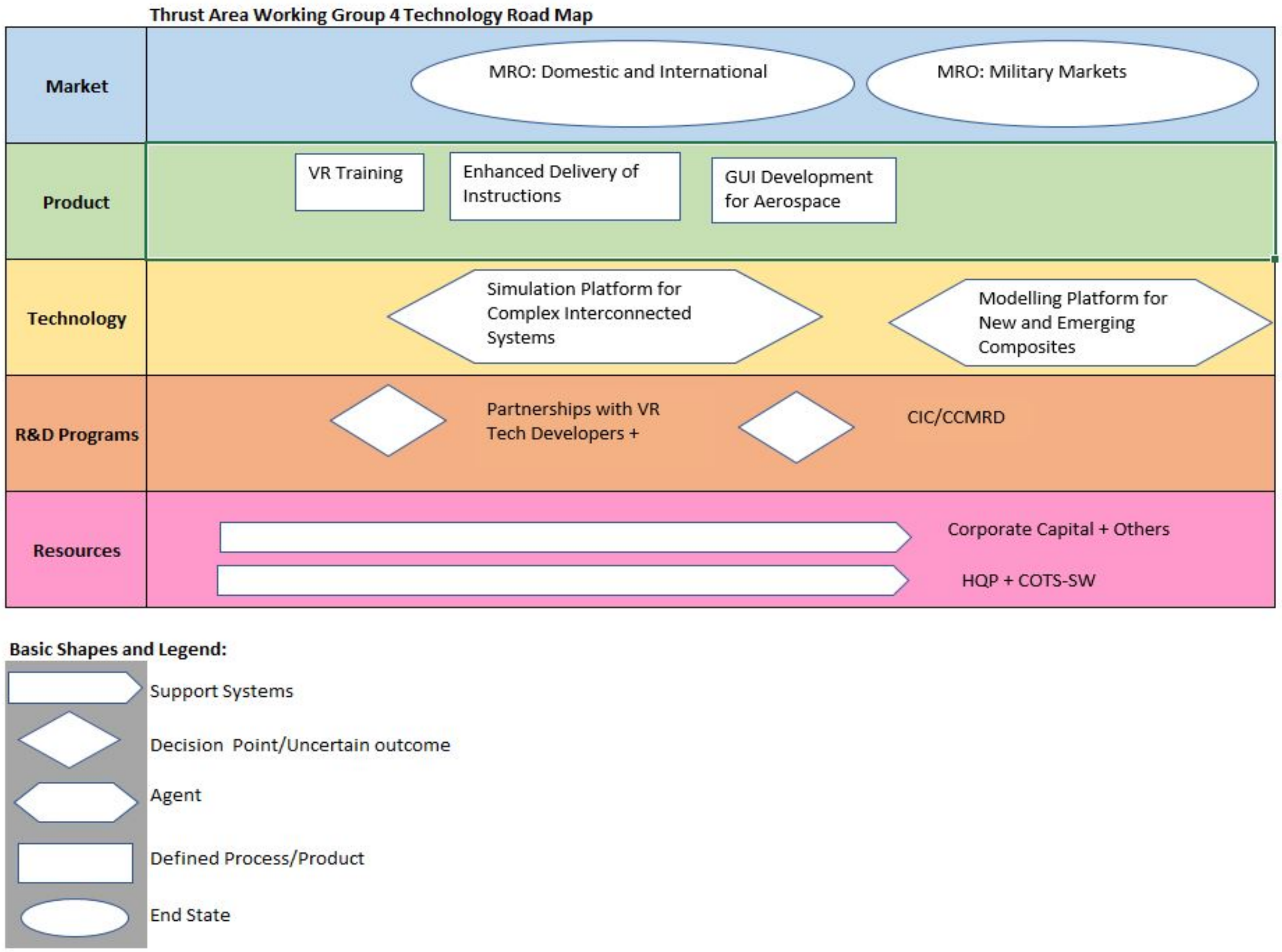
Given that relatively few technologies were chosen from the onset, a ranking approach was not used in this case.

Projects of Interest to TAWG4 are presented in Table 8.

Table 8: TAWG4 Projects Identified

Technology	Cost	Timeline	Description
Enhanced Technical Instructions and VR Training	$10M	5 Years	development of aerospace specific training programs along with turnkey hardware for the VR system.
A Simulation Platform for Complex Interconnected Systems	$5M	5 Years	Development of a high fidelity multi-discipline system simulation platform and developing a proficient local user base
Modelling of New and Emerging Composite Materials	$3M	3 Years	Development requires verification through testing and the ability to access facilities with capable manufacturing systems to validate process models.

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG4 identified technologies.



Thrust Area 5 – Test and Certification

The Manitoba Aerospace Research and Technology Committee (MARTC) of Manitoba Aerospace Inc (MAI) decided that the Manitoba Aerospace Technology RoadMap (TRM), published in 2014, should be revisited by the Thrust Area Working Groups with the following objectives:

- Review the key technology thrust areas developed during the TRM to validate and update these as appropriate, and
- Continue the TRM activities as appropriate, focusing on the definition of specific projects that would stimulate collaboration amongst Manitoba Aerospace stakeholders.

A collateral objective of this process would be to prepare for Manitoba's participation in a National Technology Roadmap.

Key Technologies – Revised Key Technology List

The Test and Certification Thrust Area Working Group (TAWG5) evaluated aero-propulsion technology requirements for development, production, and certification testing for gas turbines that could be furthered through collaboration. The primary motivation for TAWG5 is sourced in the two-large aero-engine test and certification facilities located in Manitoba. The Thompson/GLACIER facility serves the needs of Pratt & Whitney and Rolls-Royce, while the Test Research and Development Centre at Winnipeg International Airport delivers engineering development as well as test and certification requirements of GE Aviation. These facilities are driven by the three largest aircraft engine manufacturers and together, they result in approximately 85% of the world's new commercial aircraft engine fleet, passing through Manitoba as part of their airworthiness certification. This engages Manitoba firms in early phases of technology development and thus offers insight into emerging technologies and systems.

The TAWG5 Technology Review identified and ranked the following technologies as part of their assignment.

A brief description of each of these technology areas is are now presented followed by a series of possible projects.

Ice Crystal Testing Methodology: A discussion was held on how the wind tunnel at U of M could support this methodology. This resulted in a recommendation to not consider ice crystal activities other than for the purposes of academic pursuit/human capital development.

Use of Analytical Evaluation to Demonstrate Equivalency to Regulatory Requirements: It was felt that this technology area would be too restricted by commercial sensitivity issues to enable effective collaboration.

Engine Testing Simulator: this is a large and target-rich domain for collaborative endeavours. TAWG5 will examine the lessons learned from their earlier TRM activities and will continue to pursue modelling and simulation collaboration opportunities.

Ingestion Testing Modelling: This technology was again considered to be restricted by commercial sensitivity issues and was extremely expensive to pursue. As such, no further effort is envisaged for this technology area.

Fuel Testing and Evaluation (Ice, Biofuels): Fuel icing is currently not an issue and Biofuels certification testing is currently being pursued by numerous organizations. There is little opportunity for collaboration that will result in significant outcomes and as such, no further activity is being considered for this technology area.

Development of Emerging Ingestion Tests (Volcanic Ash, Sand Ingestion): Although there are no pressing issues related to ingestion testing, it was decided to maintain a watching brief on this technology area.

Health Monitoring of Test Sites (Infrastructure): Due to design variations between test sites, there is little collaborative potential in this technology area. No further work is planned.

Improvement of Efficiency of Test Sites (Wireless Communication, Robust Instrumentation, Robust High Speed Video): This technology area will not be pursued for the same reasons as the previous technology area - Health Monitoring of Test Sites.

Health Monitoring of Engines to Develop Engine Maintenance Scheduling: This topic addresses a vast area of research, development, test and evaluation which has been under study for several decades. While some specific projects may arise, there are insufficient resources for TAWG5 to pursue this technology area.

Custom Design of Specialized Instrumentation: There are several sensor/instrumentation collaborative activities currently underway, such as the Manitoba Aerospace Sensor Centre of Excellence (MASCoE). Advanced sensors and instrumentation will continue to offer significant collaborative potential; however, this technology area will be re-focused in downstream TAWG5 deliberations.

Table 9: TAWG5 Technology Rankings

Technology	Rank
Ice Crystal Testing Methodology	**1**
Use of Analytical Evaluation to Demonstrate Equivalency to Regulatory Requirements	**2**
Engine Testing Simulator – Development of Data Acquisition Systems for Engine Test Modelling	**3**
Ingestion Testing Modelling	**4**
Fuel Testing and Evaluation (Ice, Biofuels, etc.)	**5**
Development of Emerging Ingestion Tests (Volcanic, Ash, Sand Ingestion)	**6**
Health Monitoring of Test Sites (Infrastructure)	**7**
Improvement of Efficiency of Test Sites (Wireless Communications, Robust Instrumentation, Robust High Speed Video)	**8**
Health Monitoring of Engines to Develop Engine Maintenance Scheduling	**9**
Custom Design of Specialized Instrumentation	**10**

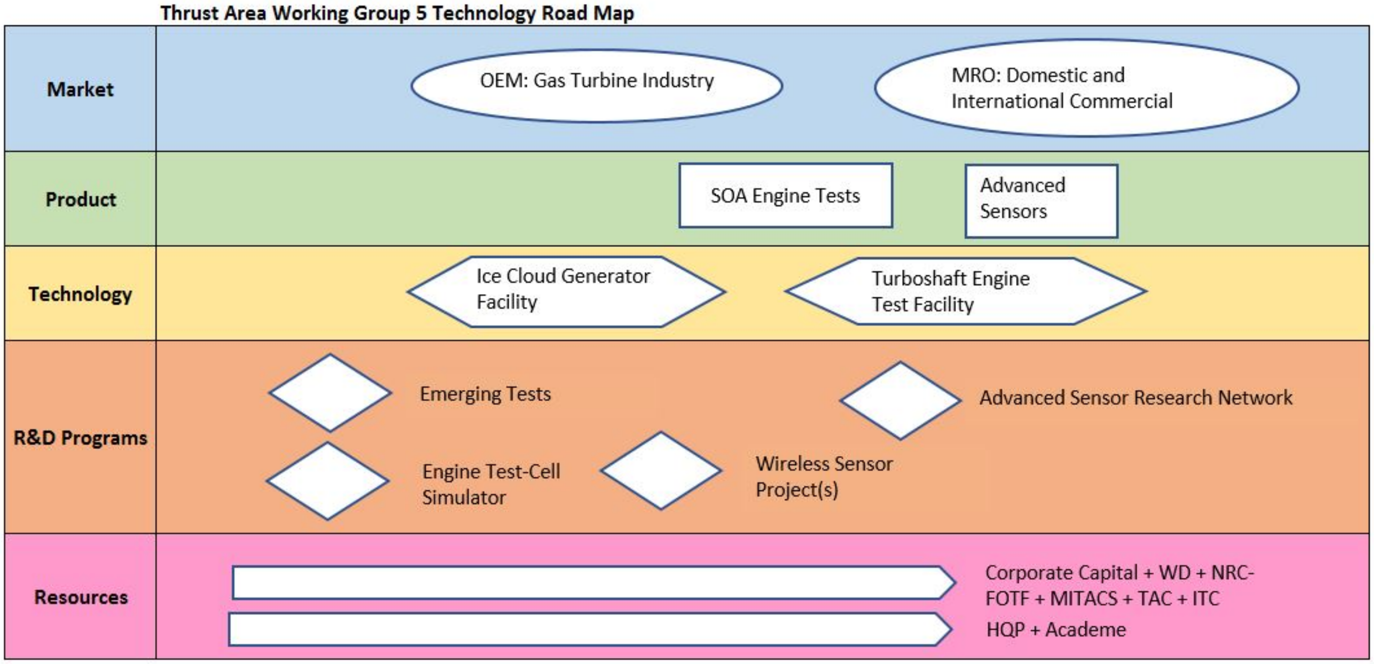
Projects of Interest to TAWG5 are presented in the following table of **TAWG5 Projects Identified**.

Table 10: TAWG5 Projects Identified

Technology	Cost	Timeline	Description
Ice Crystal Cloud Generator at UofM	$1M	2 Years	Support the development of new ice crystal cloud generator to investigate research areas of interest
Turboshaft Engine Test Facility	$10-20M	5 Years	Support the development of novel Turboshaft Engine Test Facility to test new designs in support of Climate Change challenges.
Advances Sensor Research Network	$10M	3 Years	Support the development of MASCoE.

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG5 identified technologies.

Thrust Area Working Group 5 Technology Road Map



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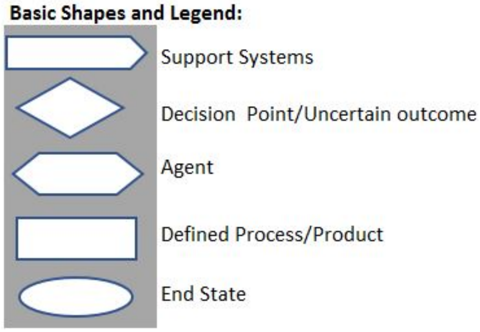


Thrust Area 6 – Rockets and Space

This group evaluated the role of rockets and space for Manitoba's aerospace future and identified Space Autonomy as a technology of interest:

Autonomy permits a spacecraft or other entity, with a control system, such as an aircraft, automobile, or machinery to operate in the absence of human control. Most autonomy is implemented in the form of pre-programmed responses to anticipated desired or undesired input conditions. One of the challenges is to package the autonomy into very small and reliable computer processors that are tolerant of the demanding environment of space.

A significant and somewhat unpredictable portion of the life cycle cost for the space mission can be attributed to the on-orbit operations. The unpredictable portion is associated with the real, vs. planned on-orbit life of the spacecraft. For example – the SCISAT-1 spacecraft has completed 10 years on-orbit compared to a planned lifetime of only 2 years. The actual operation costs are typically outside of the control of the product supplier; however, additional autonomy allows for more efficient management of the anomalies onboard the satellite and undoubtedly reduces those costs.

Nominal condition autonomy includes concepts such as sensor fusion (combining the inputs from various sensors to determine the current "state" of the system), and prediction of future states. From a spacecraft or aircraft perspective, this might include tolerance for sensor unavailability or variable sensor accuracy, selection of less-costly/accurate sensors, and using mathematical algorithms to improve the accuracy of the measurement.

Off-nominal (or anomaly) autonomy includes failure detection, isolation, and recovery to either a "safe-hold" state or a fully operational state. This technology area includes both development of the autonomy methods themselves, as well as verification of the effectiveness, robustness, and safety of the autonomous responses.

Satellite technology is generally characterized by long dedicated mission cycles, in orbits ranging from 1,000 km to high orbits of 35,800 km (geostationary orbits). Technology purposed to these missions need to survive the hostile space environment consisting of in part, orbital debris and x-rays.
Most spacecraft being designed today have significantly higher levels of autonomy. In order to continue to compete in this market, Magellan Aerospace Winnipeg will have to catch up, keep up, and ideally lead in this technology area.

Technology Performance Goals:
Nominal Mission: (satellites)

- Algorithms (for use onboard): this software needs to be developed which will combine a variety of low cost sensors to provide attitude accuracy on a par with a commercial star tracker.
- Algorithms (for use onboard): this software needs to be developed which will combine a variety of low cost sensors to provide positional accuracy on a par with GPS.
- Algorithms (for use onboard): this software needs to be developed to maximize the output of the mission in the context of a number of competing observers with conflicting resource

demands. An example of this would be when nine science experiments all want to look in a different direction at different times throughout the orbit. Priority would be defined in these cases as a response to the concurrent measurements.

- Algorithms for managing the anomalies onboard satellites. The outcome of such systems is the lifetime extension of the host satellites.
- Failure detection algorithms that can assess the state of the satellite and take appropriate actions. Algorithms need to be developed which monitor the health of the satellite and to correct for, or compensate for, orbital debris events.

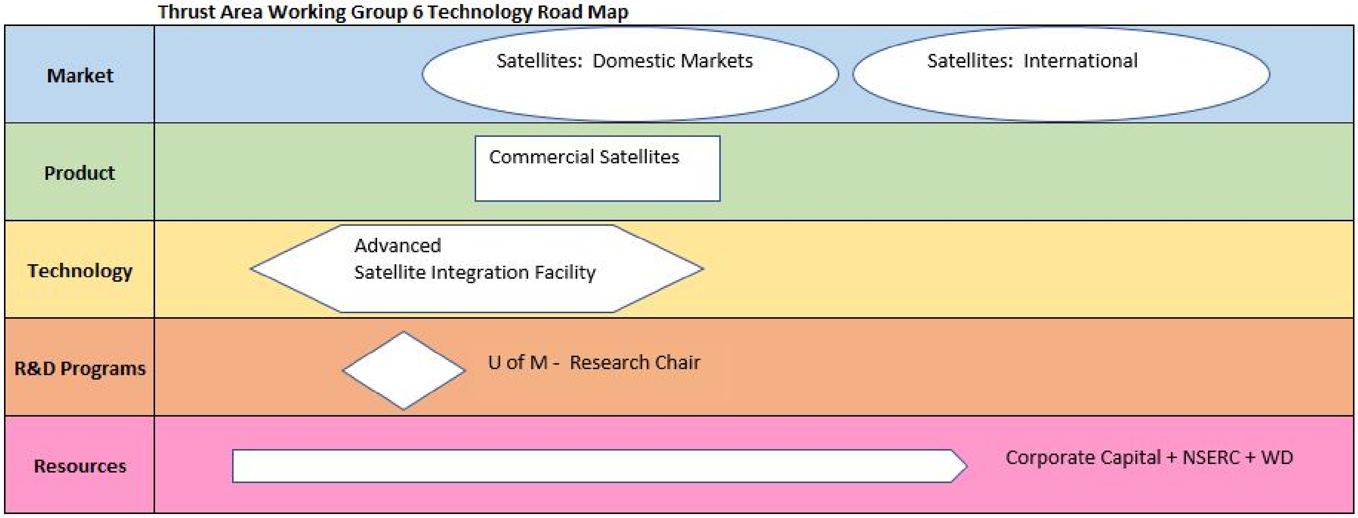
Importance and Breadth of Application:
Satellite technologies are required within the next 2 years as the satellite industry is growing at a rate of 7% annually, with a current market size of $190B. Satellites are sold on a contractual basis to telco's and governments as special purpose projects. There are few similarities between satellite contracts as technology has generally advanced between orders such that each configuration is unique.

Implementation Strategy:
Satellite collaboration can be conducted in partnership with firms such as MDA and others, wherein Magellan is responsible for key components which are integrated elsewhere. A key trend in satellite development at this time is satellite miniaturization with the purpose of developing smaller devices, which produce the same results. Magellan has developmental experience in this design and development area. This is highly dependent on the scale of the satellite project. Smaller projects are completed on site, and larger ones may be partnered.
The role of the Canadian Space Agency (CSA) to support and collaborate with this industry is recognized and is an important stakeholder.

Projects of Interest to TAWG6 are currently in hiatus, principally since the principals to this section have achieved their intended outcome of financing an Advanced Satellite Integration Facility at Magellan Aerospace. Additionally, an Industrial Research Chair was recently financed by two parties (NSERC and Magellan) which will continue to lead and develop technologies of interest to this group as well are developing HQP.

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG6 identified technologies.

Thrust Area Working Group 6 Technology Road Map



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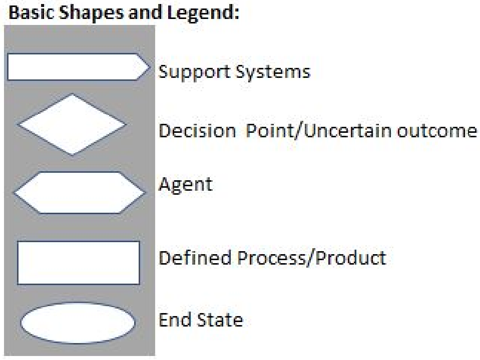


Thrust Area 7 – Unmanned Aerial Vehicles

TAWG7 was created following a decision by industry members with an interest and capability to respond and support MARTC in their efforts. The group decided that it should consider creating a new working group, called Thrust Area Working Group 7 or TAWG7. In the former TAWG6, some related concerns to this group were addressed.

Permission to proceed was obtained from the MARTC Chairman. A Chair and Deputy Chair were then selected to support the development of this new TAWG report. Industry members from within Manitoba were selected from those whom were known to have an interest and capability to respond to this area of interest. A professor from the University of Manitoba Faculty of Engineering was also approached, and indicated a willingness to participate. An additional member was selected from the local IRAP contingent, based on their willingness and interest in this area of technology development.

The reasons for assembling this team was so that participants were aware that this is a quickly growing aerospace segment, and that the previous social, political, etc. constraints are changing while the underlying technology opportunities are escalating.

The area of concern to the TAWG7 group, was UAV's, or Unmanned Aerial Vehicles. A key distinction is that this group is not interested in the now commonplace hobbyist elements but rather the professional and business sector. More so, the interest here was in considering the advancement of this technology to support those latter interests. TAWG7 is interestingly also only comprised of SME business interests.

The following is a list of topics of interest to this TAWG.
Autonomy
Robustness and Safety
Certification
Sensors
Data Collection
Control and Optimization of Performance
Innovative Design

Technologies of Interest
A brief description of each of these areas and their importance to business oriented UAV development are now presented.

Autonomy:
The TAWG7 group is of the view that Autonomy is the key discipline of interest to UAV's. Our work proceeds with how this discipline can be applied and be of value to such an application for industry opportunities in Manitoba.

Autonomy has a connotation that is separate and distinct from previous work in this area (i.e. TAWG6 report, satellites). Autonomy for UAV's refers to the fact that this technology is increasingly capable of operating independently and is evermore able to interface with other UAV's without the support of an

operator. Key technology differentiators such as technology development cycles are also found in this area which are distinct from satellites.
Autonomy as a general precept is non-deterministic. That means that all the possible circumstances that the UAV will encounter, will not be anticipated in its design and development process, but nevertheless the craft will need to overcome those matters and remain on mission for the duration.

As a general specification, UAV's can be assigned for relatively short periods of time, in the order of minutes to days, depending on the design of the payload. The difference here is that if a "fix" is needed it can be accomplished during the downtime, if it cannot be accomplished while it is aloft. So, UAV's can readily be adapted and adjusted as the client prefers without serious consequences. Additionally, as new technology is developed, those elements of interest can be incorporated into an upcoming rebuild. A key differentiator for UAV's is that they have significantly more commercial potential compared to satellites. Satellites are highly government supported for a variety of broadly societal and governmental reasons. UAV's on the other hand can be singly purposed for a commercial entity, such as spectrum scanning in an area, for anomalies of one sort or another.

Autonomy is important to the UAV segment being considered. The human operator may be quite remote in certain applications and, given the likelihood that the UAV is in higher altitudes, it now falls into air traffic control requirements which call for software certification standards. In such cases the UAV may need to read and recognize environmental factors, and act appropriately.

TAWG7 notes that the regulatory industry in the USA has recently lifted. Until recently, Canada had an open sky environment for UAV development, and the USA had a very restrictive view of where these craft could operate. That restrictive approach in the USA is changing. We note that a considerable UAV proving ground was available near Grand Forks, ND. Likewise, another UAV proving ground is available near Stonewall, Manitoba.

UAV's are believed to have considerable opportunities in the future, while the Satellite industry is highly constrained by government funding limits.

for UAV's refers to the need for these airships to be self-managed in a swarm environment. In Manitoba, the remoteness of some applications would require theses systems to operate autonomously and likely without human line-of-sight observation. The key challenges for autonomy are processing power needed onboard and weight payload issues. We believe that opportunities for technology development here exist for autonomous processing of data for governmental and industry applications.

Robustness and Safety concerns for UAV's are parallel to those found in the general area of Robotics and IEC 61508 (International Electrotechnical Commission, Functional Safety). An interest was expressed in our working group to develop systems on how to manage the aircraft then there is a loss of power, etc. In these cases, autorotation is desirable for a reduced-risk landing

Certification

a. Certification is coming in to this sector. We note here that Manitobans are participating in Tech Committee: D0-178 (Software Considerations in Airborne Systems and Equipment Certification, FAA).
b. There is an need to be aware of the necessity to participate in these types of technical committees to learn and to promote our understanding of UAV's, etc.

Sensors

a. Unique sensors will need to be developed to support future UAV's as their mission expands.
b. Sensors need to be developed which can operate without GPS.
c. Further to sensors development is the need to continue light weighting of sensors.

Data Collection

a. Data collection and retention is possible when UAV's are transmitting back to the home station.
b. This data needs to be managed in post processing environment and reconciling multiple sources.

Control and Optimization of Performance

a. There is a need to create and innovate to improve light weighting.
b. There is a need to achieve weather proofing.
c. Complexity management is a concern.

Innovative Design

a. Designs need to be adaptive and innovative.

Technology Rankings were not attempted by this group. Our interests within TAWG7 were to select and start with one project of interest, given the small nature of our group and given business limitations.

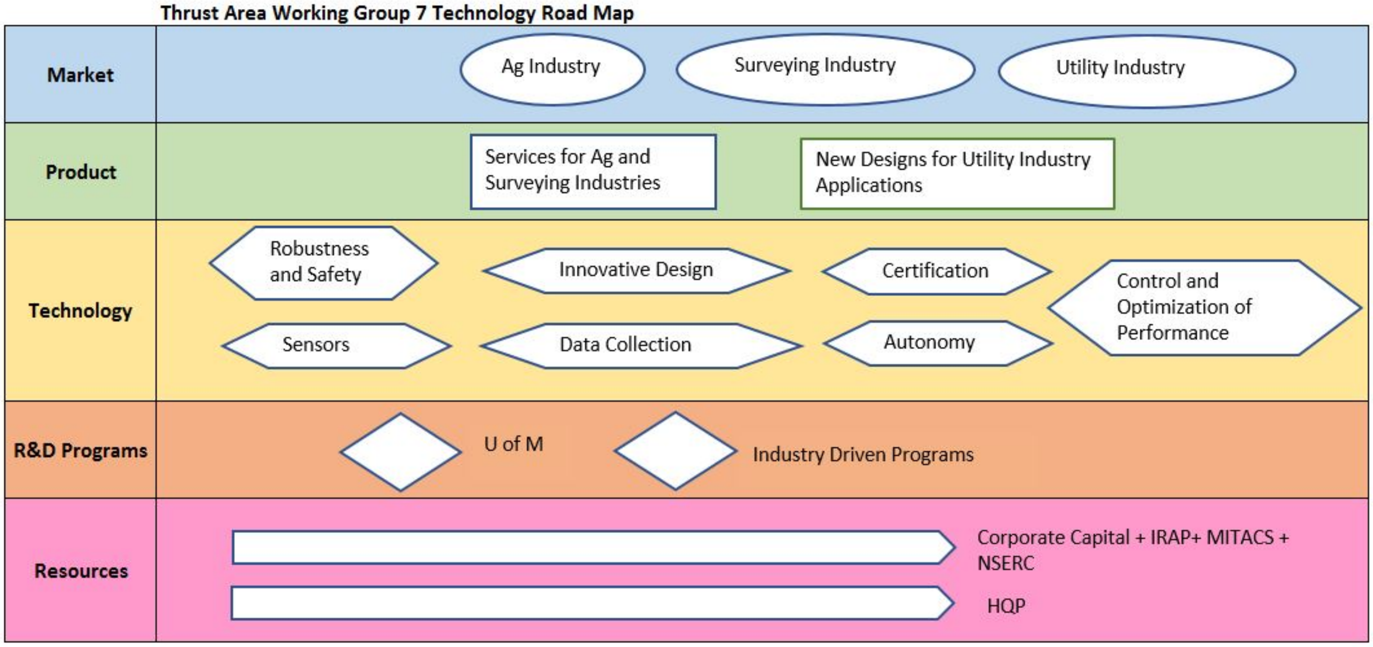
Projects of Interest to TAWG7 are listed in Table 11.

Table 11: TAWG7 Projects Identified

Technology	Cost	Timeline	Description
Autonomy	$1M	3 Years	Develop Swarm techniques and autonomous data processing
Robustness and Safety	$1M	3 Years	Autorotation on Loss of Power project
Certification	$1M	3 Years	Promote and develop certification to UAV industry with other appropriate partners such as TC and Unmanned Systems Canada
Sensor	$1M	2 Years	Work in conjunction with TAWG5; light weighting of sensors, sensor development for "no GPS" conditions
Data Collection	$1M	3 Years	Data Collection and management model development for UAV systems
Control and Optimization of Performance	$1M	3 Years	Improve light weighting, achieve weather proofing; develop new models for complexity management
Innovative Design	$1M	5 Years	Pursue new design concepts to advance UAVs for industrial purposes.

The following Technology Road Map is presented as a visual representation of the interests, means and opportunities to support TAWG7 identified technologies.

Thrust Area Working Group 7 Technology Road Map



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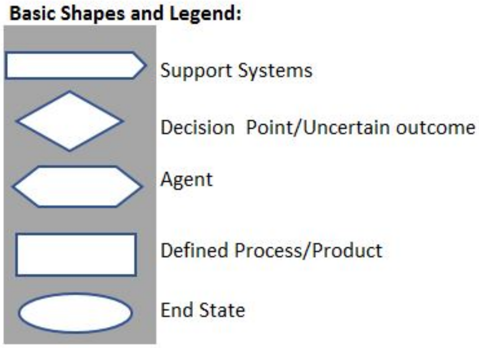

Projects Identified: A Synopsis of Critical Technologies

This section provides a summary of proposed projects arising from the TRM Update.

TAWG1 Advanced Manufacturing identified the following seven projects which covers the three major aerospace partners and many SME's as well.

Technology	Cost	Description
Additive Manufacturing	$5M	Additional AM technologies working with blended materials
Adaptive Machining	$5M	Joining in with an OEM to support Adaptive Machining
Joining and Post Processing	$20M	Retooling of the CATT Centre to support these new technologies
Heat Treating	$2M	Establishment of a capability to support this activity for local industry
Inspection	$5M	Development of Large Data and image capture capabilities to support inspection processes
Machining Strategies	$2M	New cooling, cutting and surface enhancement approaches
Nanotechnologies	$2M	Development of new Nano films for the aerospace industry

TAWG2 Robotics and Automation identified the following five projects which are principally focused on the Large Enterprises in our region.

Technology	Cost	Description
Robotic Applications	$1M	optimize productivity and quality in aerospace component manufacturing.
Robotic Integrated Sensing	$1M	feature identification, location and validation, including end effector use, effectivity, spatial positioning and awareness
Robot Communications	$1M	Industrial Internet of Things, Machine to Machine Protocols and Analytics.
Robot Software Systems	$1M	systems and tools to manage resources which are required to support robotic activity
Robot Safety Systems	$1M	the development and use of systems to protect collaborative humans from harm, as well as protecting the product and manufacturing environment from damage

TAWG3 Composites identified the following seven projects relevant to both large aerospace enterprises and selected SME's across the commercial, military and space sectors.

Technology	Cost	Description
Out of Autoclave	$1M	Design, product development and manufacturing with new prepreg systems using OOA approaches.
Mid Temp Resin Systems	$1M	Design, product development and manufacturing of Mid Temp Resin Systems
Resin Infusion	$1M	Design, product development and manufacturing of Resin Infusion systems, and in particular -oriented at very large structures.
Pre-forms	$1M	Pre-form technology use and capability development to support high volume production schemas.
Hybrid Processing	$1M	Design, product development and manufacturing using hybrid processing technologies.
Automated Fab – Right sized equipment	$1M	Automated Fab -RSE demonstrators
Automated Inspection	$1M	Support the introduction of NDI, Blue Light and others, into the inspection process.

TAWG4 Simulation, Modelling and Analysis considered the following three projects which covers the three major aerospace partners.

Technology	Cost	Description
Enhanced Technical Instructions and VR Training	$10M	development of aerospace specific training programs along with turnkey hardware for the VR system.
A Simulation Platform for Complex Interconnected Systems	$5M	Development of a high fidelity multi-discipline system simulation platform and developing a proficient local user base
Modelling of New and Emerging Composite Materials	$3M	Development requires verification through testing and the ability to access facilities with capable manufacturing systems to validate process models.

TAWG5 Testing and Certification identified the following three projects which covers the some of the major aerospace partners.

Technology	Cost	Timeline	Description
Ice Crystal Cloud Generator at UofM	$1M	2 Years	Support the development of new ice crystal cloud generator to investigate research areas of interest
Turboshaft Engine Test Facility	$10-20M	5 Years	Support the development of novel Turboshaft Engine Test Facility to test new designs in support of Climate Change challenges.
Advances Sensor Research Network	$10M	3 Years	Support the development of MASCoE.

TAWG6 Rockets and Space continues to work with Autonomy which covers one of the major aerospace concerns.

Technology	Cost	Description
Autonomy	$TBD	Development of algorithms and hardware which consider and manage failure detection, isolation of failed elements and possibly recovery of craft to either a "safe-hold" state or a fully operational state.

TAWG7 Unmanned Aerial Vehicles considered the following seven projects which principally originate from SME's and are applicable to other sectors.

Technology	Cost	Description
Autonomy	$1M	Develop Swarm techniques and autonomous data processing
Robustness and Safety	$1M	Autorotation on Loss of Power project
Certification	$1M	Promote and develop certification to UAV industry with other appropriate partners such as TC and Unmanned Systems Canada
Sensor	$1M	Work in conjunction with TAWG5; light weighting of sensors, sensor development for "no GPS" conditions
Data Collection	$1M	Data Collection and management model development for UAV systems
Control and Optimization of Performance	$1M	Improve light weighting, achieve weather proofing; develop new models for complexity management
Innovative Design	$1M	Pursue new design concepts to advance UAVs for industrial purposes.

Summary of Projects Identified in TRM 2017 Exercise

The following table summarizes the resources required to implement the TAWG recommendations for projects.

Table 12: Summative Table of TAWG Projects

TAWG's	Cost	Number of Projects Identified
TAWG1	$41M	7 Projects
TAWG2	$5M	5 Projects
TAWG3	$7M	7 Projects
TAWG4	$18M	3 Projects
TAWG5	$31M	3 Projects
TAWG6	$TBD	1 Project
TAWG7	$7M	7 Projects
Totals	**$109M**	**35 Projects**

The cumulative work of the TRM-2017 demonstrates that 35 projects have been identified at an investment point of about $109 Million.

This set of projects can now be identified to be the objective of the aerospace industry in Manitoba over the course of the next five years.

Discussion

The intent of the TRM 2017 update was to refresh the conclusions and recommendations of the TRM-2014 report as to which technologies are critical to the economic development and sustainability of Manitoba's aerospace industry.

The TRM-2017 process included 57 subject matter experts from across the Manitoba aerospace industry supported by technical leaders from the National Research Council. Thirty-five critical technology projects were identified in seven key areas (Appendix C).

These key areas are consistent with those identified by the national Technology and Innovation Working Group (circa 2012) working under direction of the Aerospace Industries Association of Canada but are reflective of Manitoba priorities.

The cross-sector working groups identified that the critical technologies are shared across their industry, and indicated clearly that further development in the proposed areas will benefit multiple companies and the sector as a whole in terms of competitiveness and future business development.

Many of the technologies were universally applicable in both manufacturing and MRO applications. Often the same technology that is required for the manufacture of an aerospace product is required for subsequent repair of the product at a later maintenance event. As a result, these key technologies provide a broad life-cycle portfolio of technologies. Moreover, several the technologies, for example composites, advanced manufacturing, simulation, will also support non-aerospace Manitoba companies in manufacturing, ground transportation.

The efforts required to develop many of the technologies will require collaborative approaches, both to form a critical mass of knowledge and facilities necessary to do the work as well as to share the risks and costs. The MAI acknowledges the value of collaborative R&D and has initiated a small pilot project which has the Industrial Technology Centre leading a joint Boeing/Magellan project. More such initiatives will be the foundation of moving forward with the development of Manitoba relevant technology projects.

Industry leadership and capacity to undertake collaborative research projects is fundamental to realizing the technical goals identified in the Technology Road Map. Financial assistance is available through existing aerospace focused programs such as CARIC, CRIAQ, and GARDN. The CIC, CRN and CCMRD offer partnership opportunities and models for collaboration. In addition, the new Technology Demonstration Program and the national applied research network being explored by Industry Canada may provide opportunities. However, industry leadership and contributions, in terms of expertise, management and finances is critical to success.

While these programs may provide opportunities, Manitoba's industrial sector will need to establish a strategy and a mechanism to pursue collaborative research and development. MARTC has an important role in fostering communication and in providing direction and coordination and thus maintaining continuity and momentum for the TRM initiative. Funding strategies will also be required.

To mobilize the technologies identified in this TRM an implementation strategy needs to be developed.

Implementation Strategy

Communications
Whilst MARTC members and Technology Action Working Group members are fully aware of the TRM 2017 update activities and recommendations, a communication strategy is required to engage a wider audience both within Manitoba and nationally/internationally. This communication strategy should be implemented to create a dialogue within industry, to brief external stakeholders and policy makers on Manitoba's technology development priorities and to engage key OEMs, academia, NPOs, government agencies and research organizations in these research thrust areas.

Prioritization
The TRM 2017 Update process identified 35 research projects over 7 technology areas requiring an investment of over $100M to implement. The industrial capacity to pursue all of these recommendations is not available so choices need to be made. The industrial partners will, based on their own strategic technology investment plans, decide which initiatives to pursue either unilaterally or collaboratively. Thus, there is no requirement to further prioritize the TRM 2017 recommendations but rather to use these recommendations as a pathway to forming collaborative partnerships based on stated interests. It is also important that the research and development community be fully aware of the technology interests stated by the industrial participants of the TRM 2017 Update and take actions to develop capabilities and seek opportunities to engage with the industrial participants.

Seeking Collaborative Opportunities
Through the Technology Road Map process, significant work has been done to identify technologies critical to economic success in Manitoba. What has not been done is establishing a way of facilitating the industrial community as it engages in unilateral or collaborative projects to develop Manitoba capabilities in these critical areas.

MARTC provides excellent coordination of general technology development discussions. What is required are facilitation efforts that moves these discussions from the general to specific project opportunities. These efforts can take several forms and must be reactive to potential industrial participant's requirements in terms of proprietary considerations, schedule, financing and IP access and sharing. These items are important to the industrial participants and have the potential of inhibiting the discussions on collaborative activities if not addressed early and often.

Still, there is a gap between the identification of general priorities and the more detailed formulation of a collaborative project that can only be bridged by discussion. MARTC, and perhaps IRAP, can play a role in bridging this gap through the organization of communication events that place potential partners in a technology area in a forum whereby they can comfortably discuss their technology requirements to the detail necessary to identify like interests and potential partners. These events could include workshops, both open and closed, dedicated meetings on specific technology topics with specialist speakers or perhaps a 'call for interest' in participating in a collaborative technology development area. B2B workshops with external OEMs and other large enterprises are a useful forum. Facilitating Manitoba participation in national initiatives that foster collaborations such as CARIC, CRIAQ, GARDN, CRN and CCMRD is also a real opportunity and must be supported.

It must be emphasized that to be effective, a proactive process must be developed, most effectively through MARTC, that seeks opportunities for collaboration rather than a passive process that reacts to opportunities already identified.

As a final comment, 'Facilitation' can take many forms. In essence, facilitation activities are meant to reduce the overhead on industrial participants, particularly SME's, in identifying, developing and implementing technology development initiatives. As noted above, in the formative stages of a collaboration, facilitation can include the organization of communication and networking events. As the idea for a collaboration develops, facilitation includes providing assistance to the participants in seeking financial support from appropriate sources and formulating the collaborative research agreement, including IP arrangements, project management and partner finances.

Conclusions

The Technology Road Map 2014 and 2017 activities were undertaken in response to the fact that Canada's aerospace sector is under increasing threat from a competitive global aerospace market. Technology is a key differentiator for the development of a solid future in this competitive environment. Within an atmosphere of substantial but limited resources, Manitoba's aerospace community undertook the TRM activities to identify the technology development processes, partnerships and fundamental technology areas of priority to ensure that these resources are invested in the most effective manner from an economic development and sustainability perspective.

Nationally, the Aerospace Industry Association of Canada is also pursuing technology identification processes and Manitoba are well represented in these initiatives. Nonetheless, Manitoba needed to identify its own strategic technology requirements to ensure that these priorities are reflected in any response to government by the AIAC and by any implementation plans by the government. In this competitive process, it is critical that Manitoba be prepared to ensure its needs and priorities are properly documented and marketed. The Manitoba Aerospace Technology Road Map and its current update was prepared to support this requirement. TRM 2017 has revitalized and in most cases, reinforced the technology requirements for economic development in Manitoba.

Industry leadership and capacity to undertake collaborative research projects is fundamental to realizing the technical goals identified in the Technology Road Map 2017 Update.

MARTC has a role in developing and implementing a Communications Strategy to ensure wide dissemination of Manitoba's technology requirements for economic development.

MARTC is ideally placed to provide pro-active facilitation and coordination of activities that lead to essential collaborative development initiatives.

Acknowledgments

The Manitoba Aerospace Research and Technology – Steering Committee wishes to thank the aerospace SME community which participated throughout this entire process as the TRM-2017 was developed. A whole range of new ideas has been generated by their participation and we hope that they will remain engaged as the implementation process moves on.

We acknowledge the participation of the National Research Council of Canada Industrial Research Assistance Program (NRC-IRAP) staff which fulfilled a dual role as observers in the MARTC and then as subject matter experts at the TAWG levels. NRC Staff elsewhere were also consulted in the development of the ideas that are presented in this report.

The Composites Innovation Centre is also recognized here as being ready and available to support our industry development needs. Staff and meeting resources were readily provided in this case and many times in the past.

There are many other participants from the Industry, Academic and Not-For-Profit sector who participated and contributed to this work throughout this past year. Their continued participation was a key component to the depth and presentation of this report. A complete listing of those who served in the MARTC Steering Committee or the Technical Area Working Groups is presented as an Appendix (A&B) to this report.

APPENDIX A: Manitoba Aerospace Research and Technology Development - Steering Committee

Chair
Mathew Shewfelt, Boeing Canada, Winnipeg Operations

Deputy Chair
Loren Hendrickson, CARIC, Regional Director

Secretariat
Alfonz Koncan, EnviroTREC, Director of Business Development and Government Relations

Members
John Bagan, Magellan Aerospace, Sr. Manager, Business Development
Walter Czyrnyj, Group Leader, Space Sytems
Oyedele Ola, Red River College, Manager, Technology Access Centre
Bob Hastings, WestCaRD, Executive Director
David Simpson, EnviroTREC, Executive Director
Shane Zakaluk, Cadorath Aerospace, Engineering Department Head (SME)
Jeff Thomas, Argus Aerospace, VP Operations, (SME)
Gene Manchur, Composite Innovation Centre, VP Aerospace, Materials and Processes
John McCutcheon, Cormer Aerospace, (SME)
Myron Semegen, Industrial Technology Centre, Manager, Advanced Technologies
Doug Thomson, University of Manitoba - Engineering, Professor and Associate Dean
Mark Tachie, University of Manitoba - Engineering, Professor
Cyrus Shafai, University of Manitoba - Engineering, Professor and Acting Associate Head (Electrical)
Chad Kaatz, StandardAero
Martin Petrak, Precision ADM, President and CEO, (SME)

MARTC Participants (non-industry):
James Prendergast, IRAP, Industrial Technology Advisor
Hong Yu, IRAP, Industrial Technology Advisor

APPENDIX B: Thrust Area Working Groups and Membership

TAWG1: Advanced Manufacturing
Chair
Martin Petrak, Precision ADM, President and CEO, (SME)
Deputy Chair
Alfonz Koncan, EnviroTREC, Director of Business Development and Government Relations

Members:
Bill Noakes, RRC, Chair: Mechanical, Manufacturing and Communication
Keith Jephcote, StandardAero, Manager, Process Engineering
Richard Scarle, StandardAero, Specialist, Process
Chris Godin, Boeing Canada, Operations Equipment Engineering
Dale Kellington, Precision ADM, GM/VP Business Development, (SME)
Leo Sousa, Cormer Industries, President, (SME)
Elliot Foster, Magellan Aerospace, Team Leader Quality Control
Subramaniam Balakrishnan, University of Manitoba – Engineering, Professor
Hong Yu, NRC-IRAP, Industrial Technology Advisor

TAWG 2: Robotics and Automation
Chair
Serge Boulet, Magellan Aerospace, Manufacturing Technology Engineering
Deputy Chair
Myron Semegen, ITC, Manager, Advanced Technologies

Members:
David, Boonstra, Boeing Canada, Boeing Research & Technology
Fred Doern, RRC, Research Chair
Brendan Guyot, Phantom Motion, President (SME)
Iraj Mantegh, NRC, Research Officer
Subramaniam Balakrishnan, University of Manitoba – Engineering, Professor
Shawn Schaerer, Schaerer Innovations Inc, President and CEO, (SME)

TAWG 3: Composites
Chair
Kevin Robbins, Boeing Canada, Boeing Research & Technology
Deputy Chair
Gene Manchur, Deputy Chair, CIC, VP Aerospace, Materials and Processes

Members:
John Bagan, Magellan Aerospace, Senior. Manager, Business Development
Chris Marek, Red River College, Instructor - Composites Manufacturing
Raghavan Jayaraman, University of Manitoba – Engineering, Associate Professor
Andrew Johnston, National Research Council, Group Leader

TAWG 4: Simulation Modelling and Analysis (from TRM 2014)
Chair
Doug Roberge, StandardAero, Senior Airworthiness
Deputy Chair
Ken Webb, MAA, Executive Director

Members:
Steve Crouch, CIC, Principal Engineer, Aerospace EIT
Ray Woodason, StandardAero, Director, Performance Engineering
Brent Jones, Magellan Aerospace, Mechanical Engineering, Space Systems
Hartley Waldman, Boeing Canada
Michael Thomlinson, ITC, Engineering Manager
Franco De Luca, B/E Aerospace, Design and Stress Manager
Nick Bellinger, NRC, Group Leader

TAWG 5: Testing and Certification
Chair
Bob Hastings, WestCaRD, Executive Director + Pointman, President and CEO
Deputy Chair
Alfonz Koncan, EnviroTREC, Director of Business Development and Government Relations

Members:
Doug Thomson University of Manitoba, Engineering, Professor and Associate Dean
Kathryn Atamanchuk, University of Manitoba – Engineering, Engineer-In-Residence
Fred Doern, Red River College, Research Chair
Jim MacLeod, National Research Council, Group Leader
Trevor Cornell, Industrial Technology Centre, Chief Operating Officer
Brent Osterman, StandardAero, Director of Engineering - GE TRDC
Kevin Luellman, IDERS Inc., Director, Products & Technologies, (SME)
Troy Ramnath, MDS AeroTest, General Manager, (SME)

TAWG 6: Space and Rocket Systems (from TRM 2014)
Chair
Diane Kotelko, Magellan Aerospace, Space Systems Engineer
Deputy Chair
Wendell Wiebe, MAHRC, Executive Director & GM
Members:
Igor Telichev, University of Manitoba, Assistant Professor
Howard Loewen, MicroPilot, President
David Bertin, Red River College, Research Technologist
Sylvie Beland, NRC, Director R&D Structures Materials and Manufacturing

TAWG 7: Ultra-Light Aerial Vehicles
Chair
Martin Petrak, Precision ADM, President and CEO, (SME)
Deputy Chair
Alfonz Koncan, EnviroTREC, Director of Business Development and Government Relations

Howard Loewen, MicroPilot, President, (SME)
Shawn Schaerer, Schaerer Innovations Inc. CEO, (SME)
Leon Hanlan, Altus Geomatics Limited Partnership, Special Projects Manager, (SME)
Nariman Sepehri, U of M, Engineering, Professor & Associate Dean -Mechanical Engineering
Hong Yu, NRC Industrial Research & Assistance Program, Industrial Technology Advisor

* All SME participants to this exercise are denoted by the (SME) encapsulated acronym at the end of the line, which identifies who they are and their organization.

APPENDIX C: Thrust Area Working Group - Critical Technology Reports

This is a stand alone report and is presented on the following websites:

Manitoba Aerospace Inc	EnviroTREC	WestCaRD
www.mbaerospace.ca	http://www.envirotrec.ca/projects/	www.westcard.ca

APPENDIX D: Listing of Acronyms used in this Report

$B	Billions of Dollars
$M	Millions of Dollars
3D	3-Dimensional
AI	Artificial Intelligence
AIAC	Aerospace Industries Association of Canada
AM	Additive Manufacturing
ASTM	American Society for Testing and Materials
B/E Aerospace	is not an acronym
BMI	Bismaleimide (a resin)
CAD	Computer Assisted Design
CARIC	Consortium for Aerospace Research and Innovation in Canada
CATT	Centre for Aerospace Technology & Training
CCMRD	Canadian Composites Manufacturing R&D Inc
CE	Cyanate Ester (a resin)
CEO	Chief Executive Officer
CIC	Composites Innovation Centre MB
CMT	Cold Metal Transfer
CNC	Computer Numeric Control
CRIAQ	Consortium for Research and Innovation in Aerospace for Quebec
CRN	UBC Composites Research Network
CSA	Canadian Space Agency
EIT	Engineer In Training
FAA	Federal Aviation Administration (United States)
FOD	Foreign Object Damage
GARDN	Green Aviation Research and Development Network
GE	General Electric
GLACIER	Global Aerospace Centre for Icing and Environmental Research
GM	General Manager
GPS	Global Positioning System
GTRO	Gas Turbine Repair & Overhaul
HQP	Highly Qualified People
ITC	Industrial Technology Centre
km	kilometers
MAI	Manitoba Aerospace Inc.
MARTC	Manitoba Aerospace Research and Technology Committee
MASCoE	Manitoba Aerospace Sensor Centre of Excellence
MRO	Maintenance, Repair and Overhaul
ND	North Dakota
NDE	Non-Destructive Evaluation
NDI	Non-Destructive Inspection

NDT	Non-Destructive Testing
NPO	Non-Profit Organization (Not For Profit)
NRC-IRAP	National Research Council-Industrial Research Assistance Program
NSERC	Natural Sciences and Engineering Council of Canada
NSFL	Nano-Systems Fabrication Laboratory
OEM	Original Equipment Manufacturer
OOA	Out Of Autoclave
OS	Operating System
PI	Polyimide (a resin)
Precision ADM	is not an acronym
R&D	Research and Development
RRC	Red River College
RSE	Right-Sized Equipment
RI	Resin Infusion (composite process also see Liquid Composite Molding LCM)
RTM	Resin Transfer Molding
SCISAT	Science Satellite
SME's	Small & Medium Enterprises
SQRTM	Same Qualified Resin Transfer Molding
TAWG	Thrust Area Working Group
TC	Transport Canada
TRDC	Test Research and Development Centre
TRM	Technology Road Map
U of M	University of Manitoba
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
USA	United States of America
VBO	Vacuum Bag Only
VP	Vice President
VR	Virtual Reality