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Transport Canada RPAS R&D yearly progress report (2020-2021)

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Transport Canada RPAS R&D Yearly Progress Report (2020-2021)

LTR-SMM-2021-0033

Presented to:

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Date: February 17th 2021

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Introduction and Objectives

This document provides a high level overview of the R&D activities that were performed at NRC during Fiscal Year 2020-2021 as part of NRC and Transport Canada RPAS Task Force R&D collaboration. Hyperlinks are provided to the detailed scientific reports.

The long term strategic collaboration between NRC and TC is highly valued for the future of the RPAS sector in Canada, since:

1) NRC has unique and highly valuable RPAS technical expertise developed in the course of the Civil UAS program (2013-2019), and is continuing to grow as part of the Integrated Aerial Mobility program (2019-2026), which is very important in order to scientifically support RPAS Beyond Visual Line of Sight (BVLOS) and RPAS Traffic Management (RTM) Regulatory development. NRC's support is critical to the RPAS TF for developing evidence based regulations to enable a safe and strong RPAS industry in Canada.
2) NRC's network is very useful in order to enhance engagement with academia, the industry and international partners;
3) NRC researchers have unique, long standing and advanced technical expertise in Canada and provide highly valued contributions to the TC RPAS TF to help TC shape current and future Canadian RPAS regulations.

For the regulator, the advantages of the R&D dimension consists of the following:

1. Allows maintaining and improving the regulator scientific and technical skills, contributes to its independence and helps to build public confidence in the regulatory system.
2. Allows managing safety and uncertainties (unknowns) of new technology. Thus, R&D is necessary for the identification and characterization of uncertainties as well as for the understanding of their safety relevance.
3. The regulator has a continuing role to review the safety case, which has to be regularly updated to remain an adequate basis for making decisions throughout the implementation of new technologies and use cases. The review aims to determine whether the safety case has been developed to an acceptable level in terms of quality and confidence in safety to move to the next phase.
4. These activities are therefore more a "complement to" and a "verification of" rather than a "duplication of" the R&D activities performed by the industry.

The objective of the research can be described as follows;

1) Inform development of regulations based on a foundation of scientifically credible data;
    a. Developing R&D and Test and Evaluation criteria
    b. Sponsor testing and evaluation of potential technologies and designs that allow for automated or built in compliance with regulations

c. Identify potential technological solutions to address risks and hazards associated with safe integration of UAS into the national airspace
d. Identify technology gaps and R&D strategy for Canada leveraging domestic capabilities and international collaborations to avoid duplication of R&D efforts

2) Remove uncertainty for the industry by helping supporting the development of a clear regulatory framework
3) Foster collaboration between industry, academia and government
4) Position Canada as a leader in the RPAS sector at global stage

Research Areas and Project Overview

Fiscal year 2020-2021 research focus

1- Air to Air collision severity
2- Air to Air collision probability
3- Air to Ground (People) collision probability and severity
4- Detect and Avoid
5- RPAS Traffic Management (RTM)
6- Icing
7- Urban Flows
8- Certification of Autonomous Systems

The following image shows the correlation between IAM regulation related research areas and TC's R&D plan.

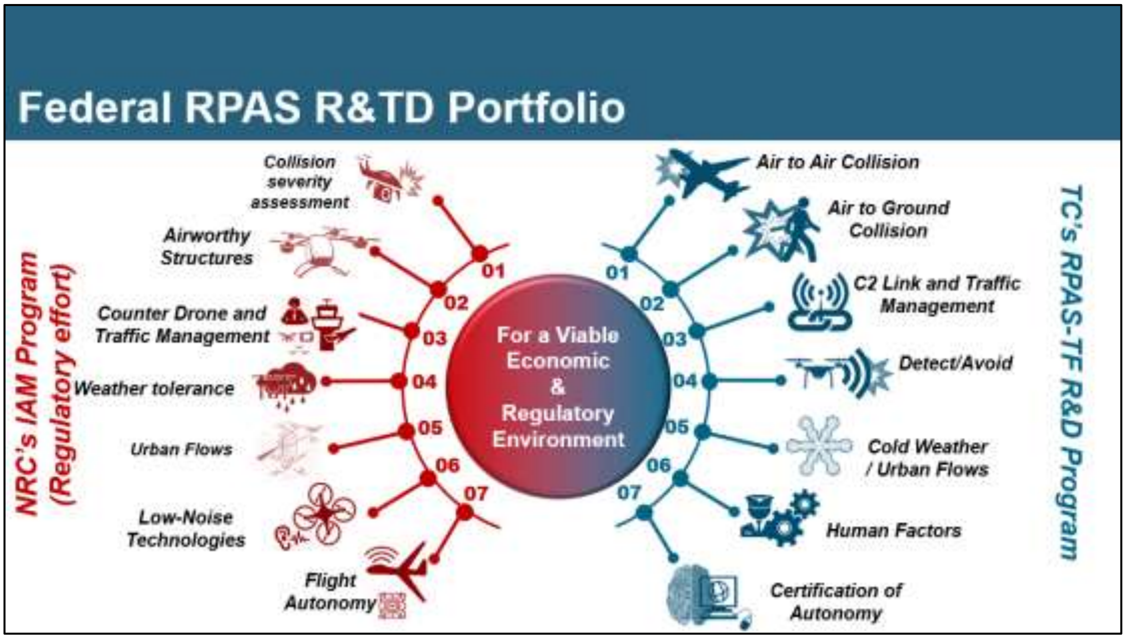


Figure 1 IAM and TC research focus

The following table presents work/milestones achieved, future research and the research projects' regulatory impact. More detailed information on the projects is provided in the subsequent sections of this report.

Research supporting Regulation Project list						
Research area	**#**	**Projects**	**Project start**	**Work / Milestones achieved**	**Next Steps**	**Potential Impact on regulations**
Air to Air collision probability and severity	**1.1**	Canadian Airspace Modeling	FY20-21	Data gathered	Airspace modeling	(Inform the regulatory risk thresholds) Align risk classes with Canadian airspace traffic
	1.2	Drone Impact Assessment (experimental impact testing)	FY18-19	Part 25 (tested) part23 (ongoing)	Rotorcraft (TBC)	Inform the regulatory risk thresholds
Air to ground collision probability and severity	**2.1**	Human injury Severity	FY19-20	Injury criteria that encompasses all population (50 percentile male, 5 percentile female)	Develop injury threshold and test / simulation procedures	Understanding of injury severity and mitigation requirements Inform the regulatory risk thresholds as well as Standard 922 appendix C.
Detect and Avoid	**3.1**	DAA system testing	FY19-20	DAA system tesging (ongoing)	Analyse the results (ongoing)	inform on the level of performance required in the regulations. Inform Standard 922.09
RTM	**4.1**	RTM Trials support	FY20-21	Technology matrix developed	Support upcoming trials	RTM trials will inform regulatory risk threshold for future Canadian RTM system
Icing and extreme weather	**5.1**	Investigation of effect of icing on Small rotors	FY18-19	Tested small rotors at high RPM. Testing larger rotors.	Develop means of compliance	Inform environmental effects, and required monitoring, restriction or measures to be put in place to operate in challenging environmental conditions. Will also inform on standard methods to test system performance in those conditions. Informs standard 922.11
	5.2	Investigation of effect of wind in different environments	FY20-21	Guidance material for the general public	Investigate flows in canadian cities and RPAS performance evaluation	
Certification of Autonomy	**6.1**	Certification of autonomous systems	FY18-19	Establishment of working group, Gap analysis, Pilot task analysis	TBD	Certification of autonomy research will inform future regulations
Planning and coordination	**7.1**	R&D planning and coordination	FY18-19	Coordination of multiple project and initiatives, and with other organizations	Continue coordination of current activities and expand to new initiatives	Coordination of research projects Creation of working groups of experts Collaboration with other organizations

Table 1 Research Progress overview

Air to Air Collision Severity (1)

This year's project aims at performing a series of experiments simulating impacts between a medium-size remotely piloted aircraft system (RPAS) and various Part 23 aircraft components at representative speeds. DRDC is also a collaborator in this project.

NRC's Super Cannon was used to perform the tests. The cannon is mainly composed of a stand-alone pressure vessel, high-speed valve, transition adapter (expander), stainless steel barrel and a supporting frame.

The objectives of FY2021 experimental testing was:

- Determine damage severity level of drone impact on Part 23 aircraft structures. Impact tests are being performed on the struts, wings, propellers, flaps and horizontal and vertical stabilizers.

Publications

- Drone impact assessment on aircraft structure: flat plate testing and analysis (Hyperlink)
- Drone impact assessment on aircraft structure: windshield and leading edge testing and analysis (Hyperlink)
- Drone impact on Part 23 aircraft structures (Hyperlink).

Air to Air Collision Probability Project (2)

Near mid-air collision (NMAC) risk is an impediment to the integration of Remotely Piloted Aircraft Systems (RPAS) into non-segregated airspace. Since NMAC rates vary with the airspace density, various regions of Canada are expected to have different safety requirements. The main objective of this work is to develop statistical models of various Canadian Airspaces, which will allow for the assessment of risk when incorporating RPAS with specific performance envelopes into various airspaces in Canada. The developed models will make use of real flight data obtained from NavCanada and StatsCanada, and will then allow to simulate encounters of an RPAS with the typical airspace intruders. The results of current series of projects will subsequently facilitate the determination of the operational standards and requirements for Detect & Avoid systems and will feed into Transport Canada's "Modified SORA approach".

NRC is executing this work in collaboration with Carleton University. Phase 1 includes sensor coverage analysis and sensor coverage models verification. Phase 2 focuses on the development of methods to analyze and fuse data from various sensors, and then establishes characteristics of the typical intruder aircraft (speed, direction, etc.). Phase 3 concludes with the development of statistical models across Canada.

There are many potential positive impacts from such a project, including the development of the statistical dataset upon sensor coverage, and the track database itself. This project overlaps with other important projects in collaboration with Transport Canada, e.g. Drone Site Selection, BVLOS DAA trials, etc.

Air to Ground Collision Severity (Injury severity) (3)

The effect of a ground collision between a small RPAS and a human is a concern to the public and government officials. The effects of RPAS impact on humans, more specifically, on head injuries are not well documented. Furthermore, little is known about the effects of RPAS rigidity and mass on the human body during an impact.

This research work, performed in collaboration with Western University, consists of evaluating the impact severity of small RPAS (under 25 kg) collisions on humans (different genders, mass, age, etc.) under different impact conditions. RPAS head impact can induce large head rotations, which can lead to brain injury such as diffuse axonal injury. To prevent brain injury, U.S. NHTSA has proposed Brain Injury Criteria (BrIC), which uses peak X, Y, and Z head rotational velocities to calculate BrIC. This value should be correlated with critical geometries and rotational forces on the head. Using BrIC and Head Injury Criteria (HIC) is generally accepted in the surface transportation for regulatory purposes. Hence, more research on developing BrIC and HIC related to RPAS impact is needed.

The objective of the current project is to combine HIC and BrIC to evaluate safety benefit by directly evaluating risk of the skull fracture and traumatic brain injury for different genders and ages. More specifically, this research focuses on finding injury thresholds during different impact scenarios for average male and female models using a combination of numerical simulation and validation tools. The intention is to provide simple tools and testing procedures that could be used to evaluate the HIC and BrIC for RPAS impact, which can help drone manufacturers during the development phase to design and manufacture safer products.

Publications:

- Phase 1 ground severity report is available online (Hyperlink).

Detect and Avoid (DAA) (4)

Detect and avoid is a mean to reduce air to air collision risk by reactively detecting and avoiding potential collision with other aircrafts (cooperative and non-cooperative).

A call for proposals to investigate DAA technologies performance via flight test that was performed by LOOKNorth, and supported by NRC and TC. NRC is currently providing support to the planned tranche of DAA exploratory trials being conducted by three Canadian companies who have received the financial support of LOOKNorth. NRC's role in these trials is to provide guidance, analysis, and ultimately recommendations regarding these field trials.

NRC's Flight Research Laboratory has been working with TC to assess the applications and refine the flight test plans to ensure that the testing performed and data collected is of sufficient consistency and quality to make meaningful assessments of the viability of the candidate technologies. NRC is supplying Inertial Navigation Systems (INS) to serve as consistent high precision data sources for installation in intruder aircraft.

NRC is establishing the minimum set of recorded data that will enable a comparative evaluation of the performance of the DAA technology under investigation. The data records are expected to come from a combination of system recorded log (e.g. from the GCS), as well as from 3rd party aircraft (e.g. installed low cost INS). NRC constructed low cost INS devices suitable for logging truth data for the flight trials. This system can be powered from a 12-28V adapter, and easily stowed for take-off/landing phases, providing an easily installable data system capable of yielding 100Hz position/velocity/attitude information. The system records data in a proprietary format, thereby preventing the proponents from inspecting the data prior to also sending their DAA system data. NRC have developed a set of comprehensive instructions describing the installation and monitoring of the INS, enabling the proponents to install and verify the correct operation of the INS themselves, thereby eliminating the need for travel to participate in the trials.

NRC staff is conducting analysis of the data collected during the flight test campaign to assess the accuracy, coverage, and limitations of the DAA technologies under investigation. The lessons learned from the trial planning and conduct are being fed back to ASTM committee F-38 and are influencing the content of a “DAA ‘Detect’ function test method” which is currently under development.

It should be mentioned that the recent COVID-19 situation has cast some uncertainty onto the scheduling of flight testing activities. At the time of writing only one of the three proponents have completed their planned flight testing. It is expected that two of the three companies will have completed testing prior to the end of this fiscal year.

RPAS Traffic Management (RTM) (5)

The growing interest and trend for deploying Remotely Piloted Aircraft System (RPAS) in civil applications requires robust traffic management approaches that can safely integrate the unmanned platforms into the airspace. Although there have been significant advances in autonomous navigation, especially in the ground vehicles domain, there are still challenges to address with the integration of RPAS in the airspace.

Over the past decade, developments in the aviation industries have led to a growing number of aerial platforms and traffic across the globe. This increase has been augmented by the recent advances in the field of unmanned aircraft systems (UAS) and GNSS (Global Navigation Satellite Systems) positioning that has led to the phenomenal growth in the number of UAS platforms. A growing number of application areas such as infrastructure inspection, precision agriculture, search and rescue and cargo delivery have attracted many new and legacy operators of these areas to utilize UAS. To accommodate for the increasing traffic, especially at the lower altitude in urban areas, robust traffic planning and management is required. The requirement for the safe integration of the UAS into the airspace has become ever more pronounced and critical in the recent years and one that presents a major technological and regulatory challenge for the ecosystem as a whole. Regulators and aerospace organizations around the world are working diligently for the solutions to ensure safe integration of UAS into national airspace. In the US, NASA introduced the UAS Traffic Management (UTM) concept in July 2015 at its Ames Research Centre. Several topics such as safety and security and strategies for low-altitude traffic management were discussed and have been part of the UTM development.

In Europe, the SESAR (Single European Sky ATM Research), which develops the next generation of Aircraft Traffic Management (ATM) in parallel to NextGen in US, introduced the concept of U-space in 2017. The U-space "is a set of new services and procedures designed to support, efficient, and secure access to airspace by a large number of drones". It is capable of supporting operations in all operating environments and all airspace (unlike UTM which considered low altitude). The U-space concept architecture is organized in 4 levels (U-1 to U-4). Flight path planning and validation are among the key enablers that will be rolled out in the early stages (U-2. A number of projects have been launched under the U-space initiative in 2017 and 2018 and a roll out of U-1 is expected in 2019-2020. The European Commission has also launched the Smart Cities and Communities (SCC) initiative which supports drone operations for wider transportation context. Starting May 2018 a number of European cities (e.g., Geneva, Hamburg) have joined the Urban Air Mobility (UAM) initiative of SCC.

In Canada, Transport Canada has launched an RTM (RPAS Traffic Management) initiative and organized an action team (RTMAT) comprised of the regulator, NAV Canada, National Research Council, Department of National Defense, and various industry representatives. The RTMAT architecture and roadmap announced by TC in 2019 identifies key services and performance levels for the full RTM roll out and plans a set of technology trials for airport security, rural and urban applications. The trials that will be selected through a proposal and committee review process are aimed to investigate the potentials and gaps in the existing technologies to accommodate the services and also support the development of operational procedures.

NRC has actively participated and contributed to the RTMAT meetings and discussions, effectively taking lead for assessments and gap analysis of the candidate RTM technologies and also technical advice for upcoming trials. It has been engaged by TC and contracted to provide technical and scientific support for the design of RTM System and roll out of technology trials. During the phase 1 of the project in FY2021, NRC assisted TESC in selection of RTM Phase 1 applicants for rural trials, which is currently underway and to be completed in Spring/Summer 2021. Also, at RTMAT 11 meeting in February 2020, we provided NRC Technology Matrix: a high level classification of the candidate technologies based on their potentials for the RTM Foundational and Primary services. While this preliminary assessment has been helpful to gain common understanding about the technologies by the RTMAT members, there is a need for a more detailed and careful assessment that can establish an objective guidance for the trial selection and subsequent data acquisition and analyses. The objective is on one hand to assist RTMAT's Trial Executive Selection Committee (TESC), of which NRC is a member, in assessing the technologies demonstrated during Phase 1 of RTM trials, and on the other hand to provide guidelines for identifying technology gaps and selection of candidate companies for the subsequent phases of RTM trials.. This work continues into FY2022 and will focus on developing performance requirements and measures of performance for the RTM technologies and software and simulation tools to help make better assessment of the trials.

Publications:

- State of the art in RTM technology for phase 2 trials (Hyperlink)

Icing (6)

Aircraft encounters with icing conditions during flight are recognized as a major safety hazard, with the resulting accretion of ice on critical surfaces leading to degradation of aerodynamic performance such as increased drag and stall at higher speeds and lower angles of attack. The threat posed by in-flight icing encounters is particularly concerning for RPAS that operate at lower altitudes and lower speeds where the frequency of icing events are increased and the resulting ice accretion enhanced when compared to larger aircraft. In addition, RPAS often lack the ability to detect the occurrence of an icing event from which the risk can be assessed and appropriate corrective action performed.

When a RPAS encounters icing conditions, a particular concern is the degradation in performance of the rotors and propellers. These would tend to collect ice more rapidly, leading to loss of thrust, abrupt increase of power consumption and, with sufficient exposure to the icing environment, may lead to a catastrophic failure of the vehicle.

Phase one of this work (FY 18/19) provided an extensive literature review and the acquisition and development of equipment for the simulation of propeller / icing interaction within a wind tunnel environment. Phase two of this project provided data using small rotors within an icing wind tunnel, namely the NRC's Altitude Icing Wind Tunnel (AIWT). This work provided important insight into degradation of aerodynamic performance of these rotors when subjected to in-flight icing conditions. The test conditions used in the phase 2 study were chosen to represent standard icing environments for civil aviation platforms for flight through clouds containing supercooled water droplets. While, this may not be a true representation of the icing conditions that an RPAS may encounter during operation, i.e., altitude < 400ft and below the cloud base, the wind tunnel was chosen as it has a calibrated environment in terms of cloud parameters (e.g., drop size, Liquid Water Content, etc.) and freestream conditions (e.g., velocity, static temperature, etc.).

The objective of this next phase was to extend this work by examining the aerodynamic performance under icing for larger rotor diameters. However, due to size constraints of the AIWT test section, an alternative (larger) test facility capable of providing a simulated icing environment was required. While, a preliminary review has highlighted a number of potential test facilities that could accommodate this work, these do not offer the necessary precision and accuracy in terms of simulating the icing conditions expected to be found in nature.

With this in mind, this work was divided into two main objectives, i.e.

- Development of a RPAS icing facility in the NRC's M17 cold room
- Using the RPAS icing facility to assess performance under icing of larger (>20" diameter) rotors

Developing a unique and dedicated RPAS icing facility allows the cloud conditions to be carefully controlled and calibrated to provide close representation of natural atmospheric conditions. The facility provides a fully calibrated, low cost and accessible test capability necessary for the testing larger diameter RPAS rotors. As well as accommodating the test requirements of this test phase, it is envisaged that the test facility will provide a longer term solution for assessment of RPAS concepts under icing conditions.

Publications:

- Investigation of tolerance for icing of small UAV rotors/propellers: phase 1 (Hyperlink)
- Investigation of tolerance for icing of small UAV rotors/propellers: phase 2 (Hyperlink)
- Investigation of tolerance for icing of UAV rotors/propellers: phase 3 test rig development and calibration (Hyperlink)
- Investigation of tolerance for icing of UAV rotors/propellers: phase 3 test results(Hyperlink)

Urban Flows: Effect of wind in different environments project (7)

This ongoing project was designed to support TC with communications tools to promote operator awareness, and to develop tools for safety assurance through interfacing with RPAS users/manufacturers/designers. Specifically, it provides an educational video focusing on dangerous atmospheric conditions within the urban environment due to atmospheric winds, including turbulence around structures, and potential icing conditions that increase flight risk, for the purpose of educating RPAS operators and reducing accident incidents for the small RPAS category. Additionally, methods for wind tunnel testing of small RPAS are investigated, to prepare for follow-on testing to develop static equivalency tools for manufacturer/owner safety assurance.

Publications:

- Urban airflow: what drone pilots need to know (Hyperlink).

Certification of Autonomous Systems (8)

Over the last number of years RPAS operators, manufactures, regulators and researchers alike have been focusing attention on the development of Beyond Visual Line of Sight (BVLOS) operational capabilities. As the potential for true BVLOS operations comes more plausible and possible in Canada (and around the world) it is apparent that operators will look to gain efficiencies and enhanced capabilities achievable through autonomous aircraft operations. Although technical and regulatory challenges remain, research, experimentation and development is already rapidly evolving to focus on autonomous operations of RPAS and Optionally Piloted Vehicles (OPV) in the coming BVLOS environment. In the area of certification, autonomous aircraft operations present a complex challenge in a number of domains. Certification approaches traditionally applied to aircraft avionics may not be well suited for autonomous systems. For example, the use of systems safety analyses and software certification standards do not fit well with machine-learning, artificial intelligence based autonomous systems. The potential for non-determinism in the decision making process of autonomous algorithms presents an equally challenging topic for certification. Recent experience with the certification of fly-by wire systems, amongst many other examples of advanced technology, have highlighted the need for regulators to better understand and anticipate the technical complexities of these rapidly evolving technologies.

The overall objective of this work is to provide guidance and recommendations to TC regarding the creation of new, or amending existing, regulations which would support the certification of autonomous flight systems. In particular, this activity supports TC in developing a set of performance based airworthiness requirements for autonomous flight, along with the associated means of compliance. DTAES is also collaborating in this project.

Ongoing activities include, but are not limited to:

- Levels of Attentiveness – Following on from the initial Pilot Task Analysis completed in FY 19-20, NRC initiated research into the concept of levels of attentiveness for a pilot supervising autonomy. This research uses the tasks identified in the Pilot Task Analysis as a basis, and will draw upon a survey of existing research. The goal of this concept development will be to define a construct or model of the spectrum of attentiveness that a pilot supervising autonomy may require as well as the consideration of a framework to describe the transitions required to change from one level of attentiveness to another.
- Flight Test Techniques for Assessment of Autonomy – NRC staff continues the development and evaluation of a preliminary set of test techniques designed to enable the assessment of autonomous flight systems.
- Trust of Autonomy – In FY 19-20 NRC developed a tool for the measurement of operator trust of autonomy. Additionally, a brief autonomy integration flight test permitted an abbreviated assessment of the tool. In FY 20-21 this tool is assessed during two planned flight research campaigns involving a prototype autonomous flight system.

International Committees Engagement

NRC Aero researchers active on the abovementioned projects are currently involved in the following related committees:

- AHS: Handling Qualities
- ASTM: AC377
- ASTM: F38/WK62668 DAA
- ISO TC20/SC16
- NATO: FT 3 Flt Test Tech Team
- NATO: Rotorcraft Modelling

- RTCA: SC-147 TA&CAS
- RTCA: SC-228 MOPS UAS
- RTMAT
- RTMAT System Engineering WG
- RTMAT Supplier Services WG
- SAE: G10 – Aero Behavioral Eng.
- TTCP-AER-TP 12

Research Funding Mechanisms

R&D funding mechanisms are explored as a way to help encourage research to be done by industry and academia,

CRIAQ

TC and NRC worked with CRIAQ to perform a second call for RPAS projects in the 2020-2021 fiscal year. The objective was to use CRIAQ'S network, and CRIAQ would sponsor projects to be performed by University and in industry. The research areas proposed by TC-NRC were those in which there was opportunity to complement the research already being performed, namely:

- BVLOS-1: Airborne Collision Avoidance System Qualification: To provide risk mitigation data on specific DAA (detection and avoidance) systems in order to inform the regulator and assist in the issuance of BVLOS Special Flight Operations Certificates (SFOCs).
- BVLOS-2: Robust Communication Links: Provide the regulatory requirements for Command and Control (C2) link characteristics for BVLOS operations at low altitudes (<500 feet) using a small to medium sized RPAS.
- BVLOS-3: Probability of injury: Inform the regulatory requirement on the probability of impact of RPAS on persons, in the event of an accident for low altitude BVLOS operations, by small to medium size RPAS.
- BVLOS-4: Pandemic Response: Develop RPAS technologies to enable effective RPAS solutions to mitigate the impact of pandemics such as Covid-19 on Canadians.

In total, ~30 Organizations submitted project ideas. An initial technical review of those received projects ideas was performed by a team composed of TC, NRC, NRC IRAP and CRIAQ. Depending on the potential for contribution to regulation development, as well as other eligibility criteria, each project was reviewed and redirected towards the optimal agency.

NRC IRAP

Collaboration with the National Research Council-Industrial Research Assistance Program (NRC-IRAP) was significant in the current fiscal year. IRAP Aerospace Sector Team Lead at IRAP were very involved in the CRIAQ Call for Proposals.

LookNorth

LookNorth can sponsors R&D efforts, with calls for proposals, to SME. NRC and TC collaborated with LookNorth to perform a call for proposal to specifically test DAA systems in 2019-2020. The testing of the DAA systems, are still ongoing at the time of writing this report.

Innovative Solutions Canada (ISC)

This mechanism is being explored for R&D projects. There is an opportunity for TC-NRC to elaborate a technical challenge that would support regulation development.

Créneau des drones du Québec

The Québec drone cluster also supports RPAS R&D projects. This mechanism is still being explored at the time of writing this report.

Integrated Aerial Mobility (IAM) Program at NRC

NRC has a program, which leverages its experience in RPAS activities, and extends its research activities beyond small civilian RPAS, to also include large size / cargo drones as well as passenger drones (also known as Air taxis or eVTOL). Those two additional areas fit within the Next Generation type of RPAS operations, for which it is believed that the regulatory framework will be addressed after the BVLOS or RTM regulations are completed.

The three high level objectives of the IAM program are:

- Develop and support the development of critical niche technologies and then qualify them through demonstrations in both virtual and physical domains
- Stimulate the establishment of a sustainable RPAS industry in Canada through a stronger supply chain
- **Provide knowledge-based support to Transport Canada to enable sustained and advanced RPAS operations of UAS in Canadian airspace**

Major R&D coordination activities performed during the fiscal year

At the date of writing this report, the following Research planning and coordination major activities had been performed;

- Recurrent discussions with stakeholders and working groups for each research area

- Multiple meetings with FAA and FAA ASSURE. TC and NRC have been coordinating with FAA in order to ensure there would be no duplication of effort and also that planned research was relevant to both organisations.
- Preparation and launch of CRIAQ Call for Projects, fall 2020.
- Presentation of the R&D activities, Unmanned Canada 2020 conference
- Discussions with R&D funding organizations (CRIAQ, NSERC, NRC IRAP, etc.) to support academia and industry.
- Monthly R&D progress update

Conclusion

The strategic partnership between TC and NRC gained momentum in FY2020-2021, as there is now a significant research effort being deployed generating scientific data. At the FAA Research International Roundtable, where many countries are present, it is clear that Canada is one of the leaders in this sector.

With this strategic governmental alliance, TC can move ahead in the coming years with confidence, knowing that they can count on NRC to provide the scientific data necessary to develop evidence-based regulations, capable of providing to Canadians and Canadian industry a flexible regulatory framework that enables investments creating an efficient, environmental friendly, and safe transportation system for all Canadians.

This progress report is a living document which main objective is to provide a yearly high level update on the TC-NRC collaborative RPAS research effort. For more details, the reader is invited to consult the report generated by each research project.

Appendix 1, 2020 CRIAQ-NRC-TC RPAS Call for proposals

Program Details

The National Research Council of Canada (NRC) is collaborating with Transport Canada (TC) to generate scientific data to support the development of regulations for aviation systems used in visual-line-of-sight (VLOS) / beyond-visual-line-of-sight (BVLOS), remotely piloted aircraft systems (RPAS) and to identify technological advances, testing and certification that will enable the safe operation of RPAS (also known as UAV, UAS or UAV) in Canada.

CRIAQ will support Transport Canada and NRC in the deployment of a research and development program on RPAS, using their networks with the objective of:

- Stimulate, create and support opportunities for industry, universities and governments to conduct **collaborative research activities** to support the development of the Canadian regulatory framework.
- **Support other key initiatives** as required.

Call for Project Ideas

In this context, a second call for project ideas is launched by CRIAQ, NRC and Transport Canada in the following themes:

- **BVLOS-1: Airborne Collision Avoidance System Qualification:** To provide risk mitigation data on specific DAA (detection and avoidance) systems in order to inform the regulator and assist in the issuance of BVLOS Special Flight Operations Certificates (SFOCs).
- **BVLOS-2: Robust Communication Links:** Provide the regulatory requirements for Command and Control (C2) link characteristics for BVLOS operations at low altitudes (<500 feet) using a small to medium sized RPAS.
- **BVLOS-3: Probability of injury:** Inform the regulatory requirement on the probability of impact of RPAS on persons, in the event of an accident for low altitude BVLOS operations, by small to medium size RPAS.
- **BVLOS-4: Pandemic Response:** Develop RPAS technologies to enable effective RPAS solutions to mitigate the impact of pandemics such as Covid-19 on Canadians.

Program Objectives

The objectives of this program include the development of technological breakthroughs and new enabling technologies, generating significant economic benefits for Canada (jobs, income, etc.).

Interested industrial partners are invited to submit a project idea in collaboration with research partners for this specific RPAS call.

Eligibility Criteria:

- Projects must address one of the topics listed above.
- Project ideas must be submitted by an industrial partner.
- Industrial partners must have an R&D presence and/or manufacturing facility in Canada, and operations in Canada must be able to commercialize the R&D results of the project.
- The industrial partner(s) must have an annual sales and/or investment of $500,000.
- Intellectual property arising from the project will be managed by the project participants, as CRIAQ-NRC-TC does not claim or manage intellectual property rights.

Submission Process:

For each proposal, please follow the link by topic to complete the submission form(s) by October 21, 2020:

- **BVLOS-1: Qualification of Collision Avoidance Systems**
- **BVLOS-2: Communication links**
- **BVLOS-3: Probability of Injury**
- **BVLOS-4: Response to pandemic**

Details on Project Funding

Access to funding is subject to program eligibility criteria – a representative of the relevant program will contact you after you submit your idea.

Application Submission and Approval Process

CRIAQ will act, on behalf of the RPAS committee, as the contact point for receiving project ideas and coordinating the initiative. All project ideas will therefore be evaluated by a joint committee composed of representatives from CRIAQ, NRC-IRAP and TC.

Applicants who receive a positive evaluation of their project idea will be invited to prepare a full project proposal to a funding agency.

All Quebec-led projects dealing with Technological Readiness Level (TRL) 2 to 6 and meeting CRIAQ criteria will also be invited to follow the CRIAQ process.

Project teams may also make direct contact with other Canadian funding agencies if they meet their eligibility criteria.

Transport Canada will accompany the project team as an advisor during the course and completion of the project.

Appendix 2, NRC Aero - TC RPAS TF collaborative research

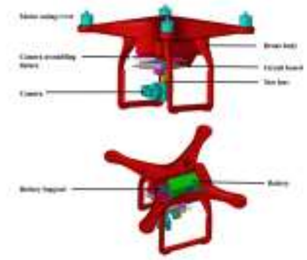
Ground Impact Injury Severity

- **General Description:**

To expand the currently used injury severity metrics to include the effects on more vulnerable populations. Also to determine what level of injury is considered "acceptable" from a brain response perspective.

- **Organizations Involved**

TC RPAS TF, NRC, Western University



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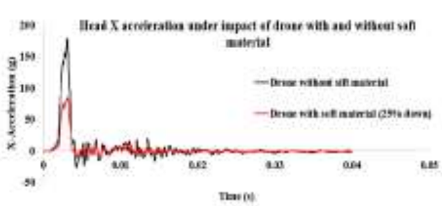
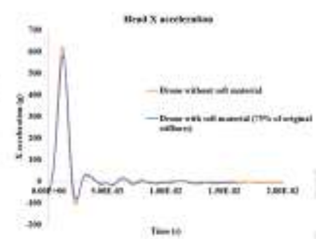
Ground Impact Injury Severity

- **Testing executed:**
  - Simulated representative model head impacts from drones at various angles for 50% male and 5% female
  - FAA ASSURE previously conducted 50% male cadaver and ATD tests

Drone-Body-First   Arm-First





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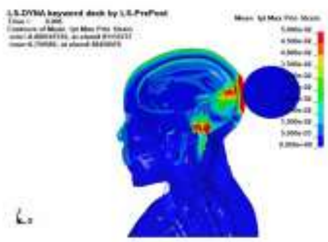
Ground Impact Injury Severity

- **Relevant results :**
  - Female head experienced 42% more linear acceleration
  - Female head experienced a 138% higher HIC
  - Drone arm to head is more dangerous than body to head impact
  - For light drones, at lower speeds, softer body materials may reduce injury

Male



Female

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Drone Propeller Icing Tolerance

- **General Description:**

Investigation on how 10″, 12″ & 14″ propellers perform in icing conditions

- **Organizations Involved**

TC RPAS Task Force, TC NAC, NRC

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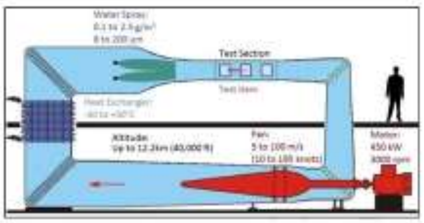
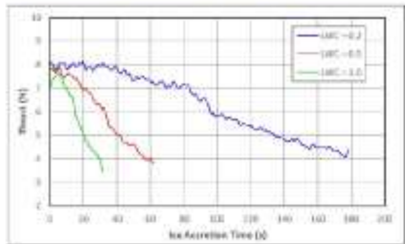
RPAS TASK FORCE

Drone Propeller Icing Tolerance

- **Testing executed:**
  - Wind tunnel testing with spray bars in NRC Altitude Icing Wind Tunnel
  - Propellers mounted on fixed motor with instrumented test bench
  - Fail scenario reached when propellers' thrust reduced to 50% due to ice build-up
  - Temperature, droplet size and liquid water content all varied





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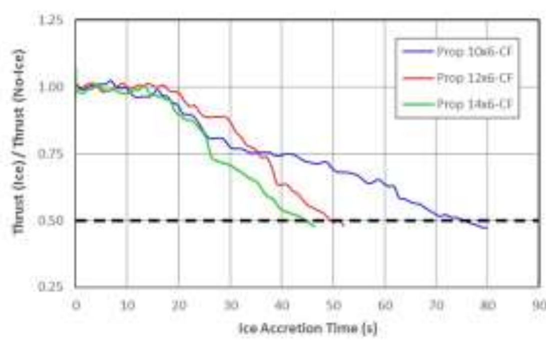
RPAS TASK FORCE

Drone Propeller Icing Tolerance

- **Relevant results :**
  - **The larger propellers degrade thrust much faster than smaller propellers**
  - The higher the liquid water content in the air, the more ice built up
  - Variation of droplet size does not effect propellers
  - Smaller propellers shed ice more



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Drone Impact Assessment

- **General Description:**

Impact severity assessment of a quadcopter shot from drone cannon against windshield & wing leading-edge of Part 25 representative aircraft.

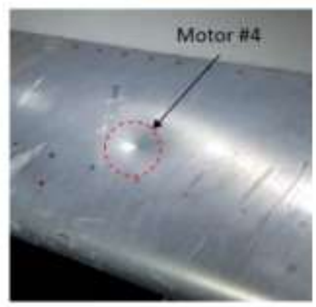
- **Organizations Involved**

TC, DRDC, NRC, FAA ASSURE

Full scientific reports available online: nrc-publications.canada.ca; search keyword « drone impact»
https://nrc-publications.canada.ca/eng/view/object/?id=9d4ecd38-e032-4f73-80f1-51b77e0aa679
https://nrc-publications.canada.ca/eng/view/object/?id=28f1d264-a3c2-449b-bbc1-39747f58e632

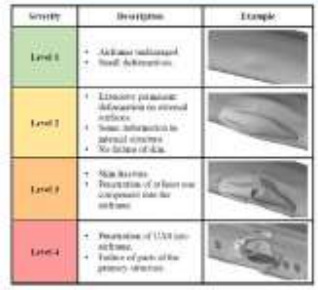
Drone Impact Assessment

- **Testing executed:**
  - 1.2Kg popular drones shot at windshield and leading edge of slat
  - Impacts speeds of 140kts and 250kts
  - Cameras used to measure speed and orientation
  - Conditions meant to simulate typical approach and cruise speeds under 10,000ft



Drone Impact Assessment

- **Relevant results :**
  - Battery cells regardless of charge level do not pose fire risk
  - Windshield tests received a fail with loss of vision and glass in cockpit
  - Impacts do not cause immediate harm to aircraft
    - Technical damage such as lack of flap deployment or retraction may occur
    - Emergency may need to be declared



* FAA ASSURE impact severity metrics

	AWM 525 (Part 25) Aircraft							
	Leading edge slat						Windshield	
	Deployed (140 kn)				Retracted (250 kn)		140 kn	250 kn
Case	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 1	Test 2
Severity	Level 1	Level 2	Level 2	Level 2	Level 2	Level 3	Fail	Fail
Fire risk	No	No	No	No	No	No	No	No

Certification of Autonomy

- **General Description:**
  - Guide research to support understanding how Canada accredits and/or certify aircraft with increasing complexity in autonomous flight systems
  - Long term project 2018-2023
  - Focused NRC research areas; guided and discussed within a multi-disciplinary working group.

- **Organizations Involved:**
  - TC RPAS Task Force, TC NAC, DND DTAES, NRC, FAA

Certification of Autonomy

- **Areas of Focus:**
  - Behaviour of adaptive/nondeterministic systems
  - Operation without continuous human oversight
  - Modelling and simulation
  - Roles of Personnel & Systems
  - Safety & Efficiency
  - Stakeholder trust
  - Verification, Validation & Certification (development of Flight Test Techniques to assess autonomous flight systems capabilities/performance)

- **Relevant results FY 2020 :**
  - Gap analysis updated
  - Pilot task analysis
  - Preliminary flight test techniques for autonomous systems
  - SORA analysis of NRC's Bell 412 as a supervised autonomy demonstrator
  - System safety analysis
  - Trust in autonomy concept development
  - These reports and presentations are the basis for the next year's work.

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CRIAQ / NRC / TC calls for projets

- **1st call for projects was launched on June 19th 2019**
  - +30 project ideas received.
  - Down selected to 12 full project proposals.
  - 2 projects completed the funding process and are currently ongoing.

- **2nd call for projects was launched the 21st of September 2020**
  - This call will focus of the following areas:
    - DAA system qualification;
    - C2 link robustness;
    - Human injury probability;
    - Pandemic response.
  - Selection process to complete in November 2020, selected projects to start early 2021.

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RPAS R&D Past, Present and Future

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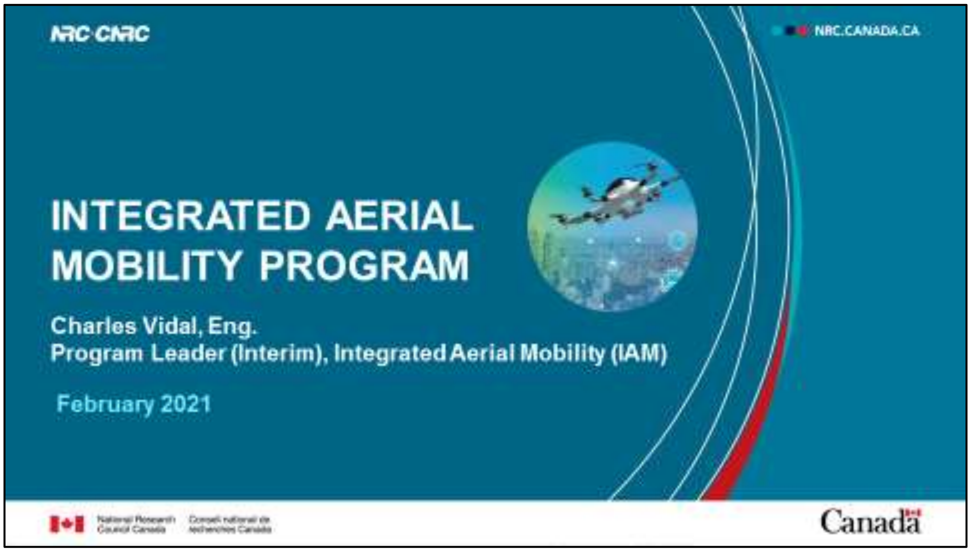
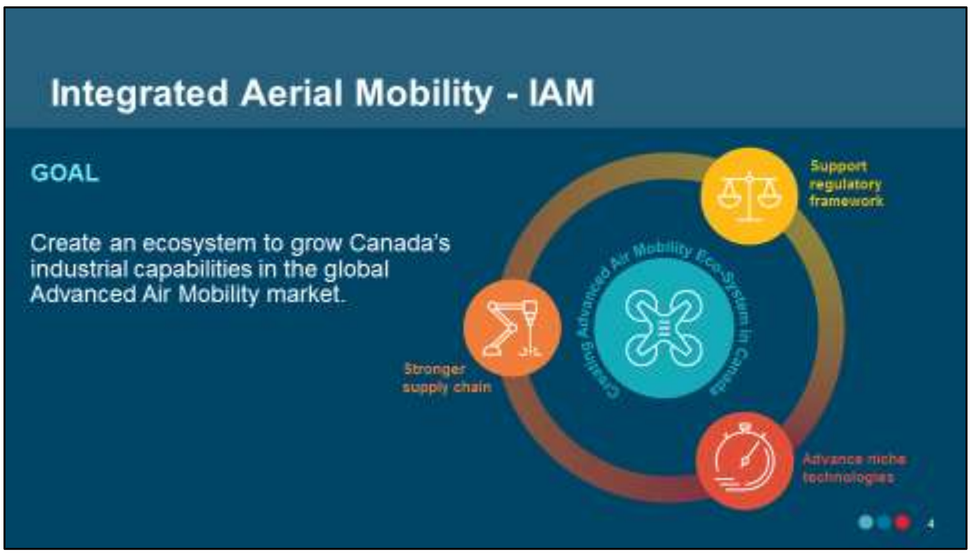
National Research Council Canada
RPAS TASK FORCE

Canada

Appendix 3, NRC IAM Program presentation




Aerospace Research Center
Laboratories - Programs
Aerodynamics Lab
Aerospace Manufacturing Technology Center
Flight Research Laboratory
Structures and materials Performance Laboratory
Gas Turbine Laboratory
Integrated Aerial Mobility
Air Travel Research
Aerospace Product Development & Certification
Defence Technologies
3


Integrated Aerial Mobility - IAM
GOAL
Create an ecosystem to grow Canada's industrial capabilities in the global Advanced Air Mobility market.
Support regulatory framework
Stronger supply chain
Advance niche technologies
Creating Advanced Air Mobility Eco-System in Canada
4


Aerial Mobility Application Spectrum
Services
Cargo
People
Security/Defence
IAM - INTEGRATED AERIAL MOBILITY
5

Integrated Aerial Mobility - IAM

INNOVATION DOMAINS	MASTER PROJECTS	TECHNOLOGY BUILDING BLOCKS
Vehicle	Integrated design	Low-noise technologies; Airworthy and crashworthy structures
	Operating environment	Weather tolerance; Impact assessment; Urban flows

6

Integrated Design

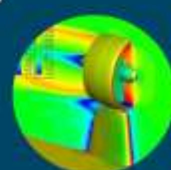
INTEGRATED DESIGN

Low Noise Technologies

- UAM Propulsor Noise
- UAM Cabin Noise

Airworthy / Crashworthy Structures

- Design of UAM structure with safety and crashworthiness considerations
- Simulations to optimize UAM vehicle performance
- Investigations on low cost structures for UAM



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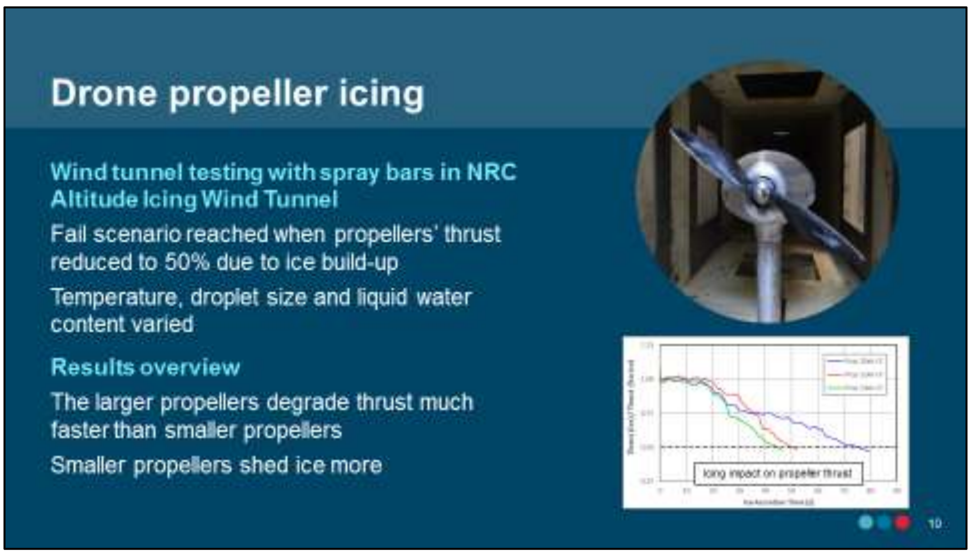
Operating Environment

OPERATING ENVIRONMENT

- Develop testing and computational M&S capabilities for RPAS (icing, rain, urban airflow, air-to-air & air-to-ground collision)
- Develop operator guidance and certification tools for safe operation of RPAS in urban environments
- Determine small RPAS air-to-air and air-to-ground collision impact severity

8


Drone cannon facility
Unique "Super Cannon" has been developed at NRC in close collaboration with Transport Canada & Defence Research and Development Canada.
Impact testing has been conducted on selected aircraft components
FULL SCIENTIFIC REPORTS AVAILABLE:
nrc-publications.canada.ca
9


Drone propeller icing
Wind tunnel testing with spray bars in NRC Altitude Icing Wind Tunnel
Fail scenario reached when propellers' thrust reduced to 50% due to ice build-up
Temperature, droplet size and liquid water content varied
Results overview
The larger propellers degrade thrust much faster than smaller propellers
Smaller propellers shed ice more
Icing impact on propeller thrust
10


Integrated Aerial Mobility - IAM
INNOVATION DOMAINS
MASTER PROJECTS
TECHNOLOGY BUILDING BLOCKS
Operations
Flight autonomy
Synthetic world generation & interpretation
Human-machine teaming
Path planning
Integrated aerial services
Counter drone & traffic management
Remote sensing
Robotics for contact-based tasks
11

Flight Autonomy

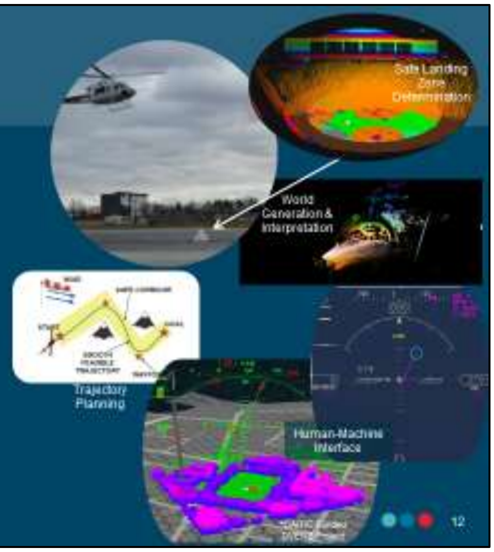
Develop and publicly demonstrate safe & efficient autonomous flight algorithms

Detect and Avoid Flight Test Technique Development

Develop Validation & Test/Benchmarking Techniques for different levels of automation

Provide expert understanding of autonomy to enable regulation development

Develop measures of Trust in Automation in Aviation (Crew and Public)



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Integrated Aerial Services

Aerial Robotics

- Develop aerial robotics technologies(patented) for inspection and maintenance of elevated structures and security applications.

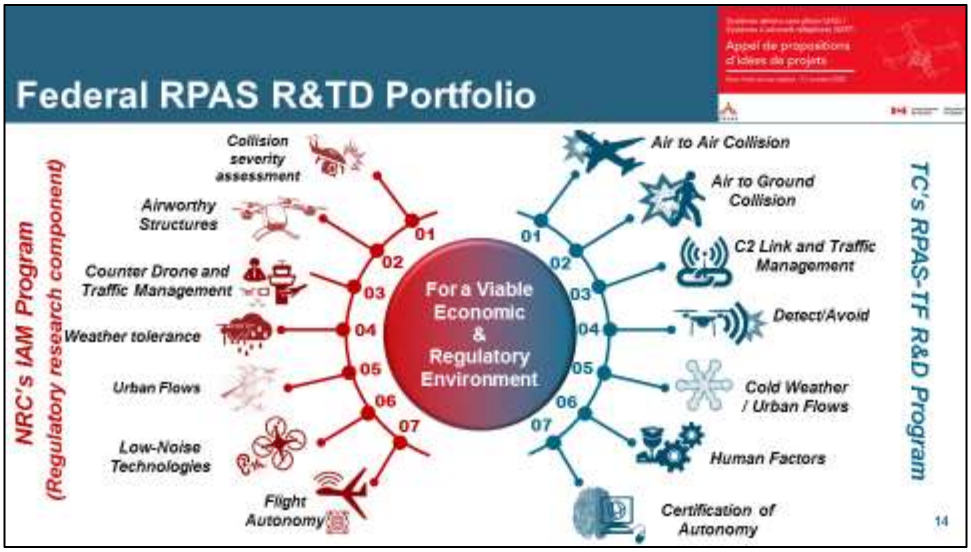
Counter Drone and Traffic Management

- Develop advanced Counter drone classification algorithms Develop-implement RTM technologies.

Remote Sensing

- Advanced sensor systems and analytics

13


Federal RPAS R&TD Portfolio
Appel de propositions d'idées de projets
NRC's IAM Program
(Regulatory research component)
Collision severity assessment
Airworthy Structures
Counter Drone and Traffic Management
Weather tolerance
Urban Flows
Low-Noise Technologies
Flight Autonomy
01
02
03
04
05
06
07
For a Viable Economic & Regulatory Environment
Air to Air Collision
Air to Ground Collision
C2 Link and Traffic Management
Detect/Avoid
Cold Weather / Urban Flows
Human Factors
Certification of Autonomy
TC's RPAS-TF R&D Program
14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https://nrc.canada.ca/en/research-development/research-collaboration/programs/integrated-aerial-mobility-program
National Research Council Canada
Conseil national de recherches Canada
Canada