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Transport Canada RPAS R&D yearly progress report (2022-2023)

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National Research Council Canada

Transport Canada RPAS R&D Yearly Progress Report (2022-2023)

LTR-SMM-2024-0018



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Introduction and Objectives

This document provides a high-level overview of the R&D activities that were performed by NRC during Fiscal Year (FY) 2022-2023 as part of NRC Integrated Aerial Mobility (IAM) Program and Transport Canada RPAS Task Force R&D collaboration. Hyperlinks to the detailed scientific reports are provided in this high-level report. A brief overview of the regulatory research activities history, presented at the Unmanned Canada 2022 conference, is also presented in appendix 2.

It should be noted that the research activities described in this document are performed under the IAM Program, as one of its objectives, is to **“Provide knowledge-based support to Transport Canada to enable sustained and advanced RPAS operations of RPAS in Canadian airspace”**. The IAM program also has for objective, to develop niche technologies, as well as stimulate a stronger Canadian RPAS industry. A brief overview of the IAM program is presented at appendix 3.

Research Areas and Project Overview

Fiscal year 2022-2023 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
- 9- Noise

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

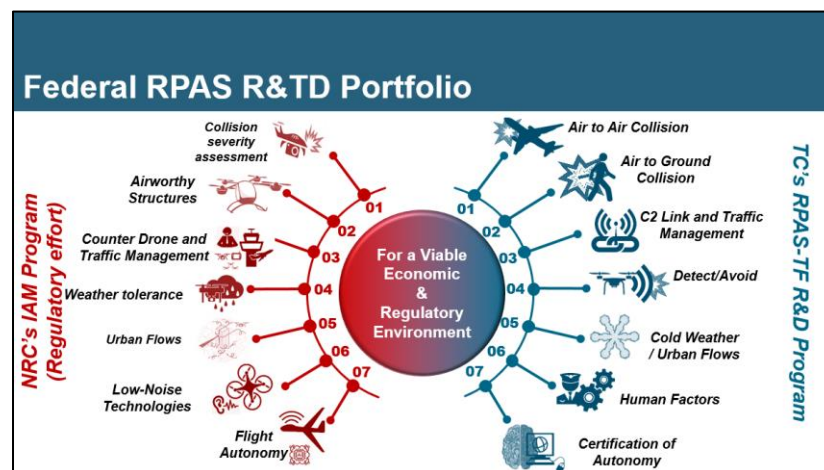


Figure 1 IAM and TC research focus

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	Work / Milestones achieved in FY2022-2023	Next Steps	Potential Impact on regulations
Air to Air collision probability and severity	1.1	Canadian Airspace Modeling	Mixed airspace models across Canada	TBC, Air Risk Class validation based on traffic densities	(Inform the regulatory risk thresholds) Align risk classes with Canadian airspace traffic
	1.2	Drone Impact Assessment (experimental impact testing)	AWM525 windshield on cockpit	TBC, potentially composite parts	Inform the regulatory risk thresholds
Air to ground collision probability and severity	2.1	Human injury Severity	Injury criteria that encompasses all population and injury Threshold and various sRPAS	TBD	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	Onboard DAA system evaluation (optical and Radar)	TBD	inform on the level of performance required in the regulations. Inform Standard 922.09
RTM	4.1	RTM Trials support	RTM simulator development	TBC, continuation of research simulator development	Provide a research tool and digital twin for the RTM flight trials to simulate various scenarios
Icing and extreme weather	5.1	Investigation of effect of icing on Small rotors	Development of a small outdoor test capability	TBDC, development of outdoor test capability for medium RPAS	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	Collect and analysis of RPAS performance at NRC M46 Wind tunnel exhaust	TBC, Validating the modeling of canadian urban airflow characteristics by measuring on-site flow field	
Certification of Autonomy	6.1	Certification of autonomous systems	Investigation of thrust in autonomy, Pilot intervention time study and Flight Test Techniques	TBC, continue supporting emerging requirements of applied autonomous systems	Certification of autonomy research will inform future regulations
Noise	7.1	Littérature Review	Littérature review on RPAS noise that is of relevance to the development of noise standards	TBC, quantify the source noise and propagation of commonly used RPAS	relevance to the development of noise standards for lightweight and small (MTOM < 150 kg) multi-rotor RPAS

Table 1 Research progress overview

Air to Air Collision Severity (1)

This multi-year project is a follow up investigation of windshield drone strike testing performed in Fiscal Year (FY) 2019-2020. This year's project is utilizing a real cockpit of an AWM 525 certified aircraft to conduct drone impact tests on windshields at representative speeds. Utilizing a real cockpit provides the real boundary conditions of the windshield attachment. The project has the following objectives;

- To perform drone impact tests on Part 25 aircrafts windshields
- To assess damage severity on windshields and cockpit structure
- To assess the lethality of windshield debris on aircraft pilots

To assess the lethality of the windshield debris resulting from the drone impact, two ballistic gel torsos simulating the pilot and co-pilot were located appropriately within the cockpit. Such dummies are made out of organic biodegradable materials and include the spine, rib cage, organs, neck and brain/blood in the skull.

In addition, the cockpit procured for the test was instrumented with the following:

- 1- Accelerometers to measure structural vibrations of the windshields structure and instrumentation panel during the impact.
- 2- High speed camera to capture the impact sequence, damage progression during impact and density and distribution of the glass debris as they spall off the windshield and travel towards the test dummies.
- 3- High speed camera to measure drone speed prior to impacting the windshield

A first impact test on the windshield on the AWM525 cockpit occurred in fall 2022. A second test is happening in winter 2023 with a different projectile. A hyperlink to the full report is provided below, in addition to hyperlinks to previous reports.

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 multi-year 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.

In FY 2022-2023, the close collaboration with Carleton University continued and phase 3 of the project focused on development of mixed airspace models across Canada.

Publications

- Report on model creation ([hyperlink](#))
- Software repository containing airspace models and reports ([hyperlink](#))

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

The effect of a ground collision between a small RPAS and a human is a potential concern. The effects of RPAS impact on humans, more specifically, 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.

In the previous Phase I of this project, a DJI Phantom 3 finite element model (FEM) was developed and both average male and small female skull and brain responses were simulated. Here, the main focus was set on validation of head injuries for the average male model, as the experimental data was available in the FAA ASSURE report for male head responses during different impact scenarios. During Phase I of the project, it was noticed that there is no suitable experimental data for the small female and children head responses during an impact with a flying object. For this reason, the Phase II work addresses several missing challenges that were not in the scope of the Phase I. In addition, in Phase I work, only one type of small RPAS (sRPAS) (Phantom 3) was modeled which limited the scalability to applying to various sRPAS types.

In the Phase II, Year 1 (FY 2020-2021) of this project, the project was stretched to accomplish three main objectives: 1) Validate the small female model based on data available in the literature, to better justify the large gender-related differences found in Phase 1; 2) Extend understanding of potential injuries into more vulnerable populations especially children; and 3) develop a new sRPAS model for Mavic Pro.

In this FY2022-2023 project (Phase II, Year 2), there are four main objectives that are built on learned knowledge out of previous projects. The first objective was to validate the developed Mavic pro model using experimental test data from ASSURE report #14. The second objective was to compare the Mavic pro impact simulation with the available data for DJI Phantom 3, to understand sRPAS-specific injury severity and tolerance. The third objective was to investigate vulnerable population (small female and children) using both DJI Phantom 3 and Mavic models. The fourth objective was to develop scalability on vulnerable population based on aforementioned collected data.

The Mavic pro model developed during Phase 2, in year 1, demonstrated good numerical stability under various impacts. The validation work will also demonstrate how different sRPAS could affect head responses during impact scenarios. Such knowledge is especially critical as various sRPAS models are expected in real-world usage and need to be studied.

Leveraging developed DJI Phantom 3 and Mavic Pro sRPAS models, and various impact simulations on the average male, small female, and 10, 6, and 3 YO children, an in-depth and comprehensive understanding of sRPAS impact to various populations' heads is being performed through simulation tools. In-house developed codes are used to analyze injury metrics including HIC (head injury criteria), BrIC (brain injury criteria), and CSDM (cumulative strain damage measure). By comparing all these data, the differences among male, small female and 3, 6 & 10 YO children are being identified, which provide a unique opportunity to understand how injury criteria should adjust according to each vulnerable population.

At the end, developing scalability is being conducted after grouping all collected data including two types of sRPAS to human head impacts, various kinetic energies, various impact directions, as well as various populations. It is expected that through such a comprehensive and systematic analysis, we can scale the safety regulations to various sRPAS under different impact scenarios.

Publications

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

Detect and Avoid (DAA) (4)

Transport Canada / NRC have identified several key areas of technology performance evaluation that are required to enable safe BVLOS operations. A specific one is RPAS detect and avoid (DAA) capability. Advancing technology performance assessment in this area will help guide operational risk assessments for future BVLOS SFOC applications as well as inform regulatory developments.

As a result, TC performed a targeted call for participation to industry, which targeted technologies/systems with detection technology onboard the RPA.

National Research Council Canada and Transport Canada obtained participation from 3 manufacturers of airborne DAA systems with different approaches to DAA (1 electro-optical and 2 radar-based) with the intent of conducting simultaneous performance evaluations via flight test. This performance validation will assist TC to better understand the current 'state of the art' regarding performance, applicability of current standards, as well as the associated means and methods of compliance related to DAA systems. All three candidate technologies were installed on Bell 205 helicopter ('ownship', Figure below)



Figure 2 DAA systems installation on NRC Bell 205

Phase 2 (FY2022-2023) of the project focuses on the collection and analysis of near mid-air collision intercepts using different geometries (speeds/angles). Two intruder aircrafts were selected, NRC Bell 206 Jet Ranger, a light single engine helicopter, the Jet-Ranger is representative of the smaller end of Radar Cross Section (RCS) for rotorcraft that are likely to be encountered in low altitude flight and the NRC Harvard Mk IV fixed wing aerobatic trainer aircraft, which is representative of fixed wing General Aviation traffic.

In FY2022-2023, the following main activities are being performed;

- **Identify Test Cases/Develop Test plan:** This defines all the intercepts required to fully test the performance of the systems. This test plan was developed in conjunctions with TC DAA SMEs.
- **Flight Test Campaign 1 (Jet-Ranger):** Conducting 5 hours of flight test intercepts of Jet-Ranger vs Bell 205.
- **Flight Test Campaign 2 (Fixed Wing):** Conduct 5 hours of flight test intercepts of the fixed wing GA aircraft (Harvard) vs Bell 205.

To date 67 intercepts have been conducted as part of the two flight test campaigns.

- **Data Analysis and Reporting:** This report details the system integration aspects, and performance of each DAA system during the flight testing providing an assessment of detection and tracking performance (range, accuracy) for each of the intercepts conducted.

Publications

- Ground based DAA performance evaluation report ([hyperlink](#))
- Airborne DAA trials ([Hyperlink](#))

RPAS Traffic Management (RTM) (5)

The FY2022-2023 work consists of the second phase of a collaboration project aimed at developing an RTM Simulator. Initiated by National Research Council Canada (NRC) during FY 2021-2022, the project's objective is to provide a research tool for the RTM flight trials to simulate various scenarios.

During the first phase of this collaboration, NRC embarked on investigating different design patterns for the simulator architecture as a distributed software that can easily scale up to interface with service implementations and user interfaces across various platforms. The architecture design was implemented with data definition for the 24 services that make up RTM service. It also defined interface end-points to communicate with open-source UAV simulators such as ROS/Gazebo and AIRSIM to exchange data for visualization and rendering. The software design is scalable and allows for remote connections through a layer of Remote Procedure Calls (RPC) that invokes the services.

During FY2022-2023, the following main activities are performed;

- Revise and implement NRC Sim's high-level design according to the updated RTM service definitions and a notional architecture
- Implement priority services (Remote ID, flight planning, geo-fencing and surveillance), and provide interface to integrate with the NRC traffic and density modeling
- Run simulations and use cases with synthetic data for BVLOS in low-risk environment

The major project output will be a software package that has a modular, service-oriented architecture (SOA) design and is implemented in a high-level programming language to interface with external and remote RTM services with specified communication protocols. Based on existing literature or standards (where applicable) a logic for Remote ID, Flight Planning, Geo fencing, and Surveillance services is being coded to accommodate simulation testing. NRC is testing the implementation with multiple use cases for BVLOS low risk environment with and without data communication noises factored in to gauge the robustness of the design and software.

This project directly supports the RTM AT objectives and the Systems Engineering Sub-Working group for developing SE technical tools and capabilities that facilitate data-driven decision and policy making

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 Remotely Piloted Aircraft Systems (RPAS's) that operate at lower altitudes and lower speeds where the frequency of icing events is increased and the resulting ice accretion enhanced when compared to larger aircraft. In addition, RPAS's often lack the ability to detect the occurrence of an icing event from which the risk can be assessed and appropriate corrective action performed.

The previous icing research has concentrated on the degradation in performance that rotors and propellers may experience when exposed to an icing environment and has demonstrated that levels of thrust loss and power consumption increase can occur that would be detrimental to maintaining safe flight of the system.

While the information that has been gained from the experimental studies on RPAS rotors and propellers in icing has been vital to understanding the influence of adverse weather on vehicle performance, there was a need to translate this information to the operation of the RPAS as a complete unit. Consequently, an experimental capability is being developed at the NRC which extends the previous testing, performed as part of phases 3 and 4 of this study on medium size rotors (around 21 inches in diameter), and allows

for full RPAS system icing tests to be performed. Considering the increase in size of the test volume that is required to provide a simulated icing environment for the whole vehicle as well as the need to access GPS signals in order to maintain steady and controlled flight, this updated icing rig is being positioned outdoors where the ambient temperature in the winter months (December to March) will provide the necessary conditions for the icing simulation.

By testing the full RPAS in icing and examining the vehicle performance through data provided by the onboard control system, e.g., rotor power and stability, it will be possible to evaluate the overall susceptibility to icing and relate this to the rotor performance degradation obtained in the previous project phases.

The work to be conducted as part of this test phase is separated into three sections. Firstly, a spray rig capable of providing a controlled cloud of water drops with known drop size distribution and liquid water concentration was designed, built and calibrated in an outdoor location in Ottawa, Canada, on the Montreal Road campus of the NRC. Secondly, a series of tests is being performed in which small RPAS are flown in the spray cloud under atmospheric conditions that will ensure drop supercooling and, therefore, icing of the system will occur. And, lastly, information from the RPAS operation and control system will be analyzed to ascertain performance degradation with output compared to rotor only data obtained during the previous phases of this study. Considering this approach involves the development of a unique test capability for outdoor operation of RPAS in icing, the experimental rig used in this project phase will be considered as a pilot system with flexibility to address potential design and operational challenges that may occur during this study and help de-risk development of a larger test facility that may form part of future project phases.

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](#))
- Investigation of tolerance for icing of UAV rotors/propellers: phase 4 ([Hyperlink](#))

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

This is the third year of the project, Phase III, of a multi-year collaboration between TC and NRC on Urban Flows. The first phase of this collaboration included categorization of flow types within the urban environment that are expected to challenge RPAS operation. The five urban airflow types identified during Phase I as potentially hazardous to RPAS are: speed, direction, shear, turbulence and vorticity (S^1DS^2TV).

For the second year, flow-fields of four urban models representing Canadian cities were evaluated using model scale wind tunnel testing to determine the magnitudes and locations of the extreme airflow features, S¹DS²TV. The turbulence intensity results from the urban airflow test were used to determine the full-scale flow conditions for a second wind tunnel test where five small RPAS were evaluated for flight stability for a range in turbulence. The wind speed limit for stable flying for each RPAS was found for a range in turbulence intensity determined by the ability of the auto-pilot to maintain hover position.

To complete the evaluation of the RPAS response to urban airflow types, for Phase III, the results of the urban airflow test for the remaining three airflow types including direction, shear and vorticity (DS²V) were analysed. The airflow types were simulated at full scale for a second small RPAS wind tunnel test to determine what effect each of the flow types has on RPAS stability and to understand which of the S¹DS²TV urban airflow types will govern guidance for safe urban operations.

The project objective is to support the TC RPAS Task Force development of regulations for safe operation within urban environments, by wind tunnel testing to evaluate the flight response of commonly used RPAS within simulations of the extreme airflow types expected within Canadian cities. Impacts on potential regulations and benefits to the RPAS industry include:

- Safety of RPAS operations in cities improved by:
 - Providing aerodynamic knowledge of RPAS operational limits within typical Canadian urban airflows for the purpose of developing regulations for higher-risk RPAS operations; and
 - Preparing technologies to inform future amendments to Regulations (CARs) for RPAS; and
 - Developing methods for assessing RPAS response to representative urban flow features.
- Support the Canadian RPAS industry by:
 - Improving knowledge of urban flows with RPAS manufacturers to ensure safe design and product specifications; and
 - Enabling Canadian RPAS operators to partner with NRC to mutually benefit from RPAS wind tunnel testing.

The main activity for FY 2022-2023 is to facilitate and collect data from flight tests of RPAS at the outdoor test platform located at the exit flow of the NRC 3 m x 6 m Wind Tunnel. The response of each RPAS to a range of values in wind speed for the urban flow types is video recorded and time synchronized with wind tunnel flow characteristic data for evaluation of operational limits and flow type effects.

Publications

- Urban airflow: what drone pilots need to know ([Hyperlink](#)).
- Link to the video ([Hyperlink](#))
- Urban airflow FY2021-2022 report ([hyperlink](#))
- RPAS operator guidance and safety assurance tools for the urban environment phase 3 ([hyperlink](#))

Certification of Autonomous Systems (8)

Over the last number of years Remotely Piloted Aircraft Systems (RPAS) operators, manufacturers, 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 applying increased automation (a.k.a. autonomy) to aircraft operations. Although technical and regulatory challenges remain, research, experimentation and development are already rapidly evolving to focus on autonomous operations of UAS through to larger platforms, including crewed aircraft and Optionally Piloted Vehicles (OPV). In the area of certification, autonomous aircraft operations present a complex challenge in a number of domains. Certification approaches traditionally applied to aircraft may not be well suited for autonomous systems without revision. For example, with increasing levels of automation, tasks traditionally performed by the pilot (such as specific types of decision making) could be assigned to an autonomous agent. Thus, regulations that are currently specified for operations or pilot certification may require a complementary certification stipulation. The potential for non-determinism in the decision-making process of autonomous algorithms presents an equally challenging topic for certification.

The NRC has commenced a large multi-year research project focusing on the development of a vertical lift autonomy demonstrator through collaborations with other government departments (specifically DND), a major OEM along with a number of Canadian academic institutions and Small to Medium Enterprises (SMEs). This project is entitled the Canadian Vertical Lift Autonomy Demonstration (CVLAD). The objective of the project is to demonstrate autonomous vertical lift flight technologies, evaluate technology maturity levels, provide insight into concept development and operations of autonomous vehicles, and to create an Autonomous X-Aircraft capability to support on-going development of autonomy in Canada. The autonomy demonstration project affords a unique opportunity to gain insight into the certification considerations applicable to autonomous aircraft, beyond a simple literature survey but rather as part of the research and development of full-scale autonomous flight systems. As a result, a Canadian Certification of Autonomous Flight Systems (CCAFS) Working Group (WG) has been formed between the TCCA's RPAS Task Force, the DND's Directorate of Technical Airworthiness and Engineering Support (DTAES) and NRC to focus the benefits of this autonomous research into the regulatory domain. The overall objective of this work is to provide information and data to support and guide TC and DTAES in the creation of new, or amending existing, regulations which would support the certification of autonomous flight systems. In particular, this activity should support TC and DTAES in developing a set of performance-based airworthiness requirements for autonomous flight, along with the associated means of compliance. This effort will take multiple years to complete and will be based upon experience and expert knowledge gained through the development of autonomous flight systems as part of the on-going research at NRC related to autonomous flight systems.

In FY 2022-2023 the autonomous flight system research focused on system design, algorithm development, as well as development of test techniques to assess autonomous flight systems.

The main activities conducted in FY 2022-2023 are;

- Co-Lead the CCAFS WG, along with co-chairs from TC and DTAES.
- Investigate the human role in limiting behaviour of adaptive/non-deterministic systems
- Continue the pilot intervention time study
- Development and evaluation of flight test techniques for assessment of autonomy
- Perform the pilot task analysis of CVLAD build III architecture
- Report on autonomy envelopes
- Develop a report on trust of autonomy

Publications

- Canadian Certification of Autonomous Flight Systems Working Group (CCAFS WG) – Summary Report FY19 through FY22 ([hyperlink](#))

Noise (9)

The utilization of Remotely Piloted Aircraft Systems (RPAS) has significantly increased over the years. New applications such as package delivery, medical supply, or urban videography are leading to an increase in the use of such aircraft systems particularly in dense urban city centres. For RPAS use to be sustainable, sound levels may have to be kept near or below the region's usual background noise levels. This can vary considerably from large city centres to suburbs to rural areas. Further, studies have shown that noise pollution from RPAS can potentially be a significant barrier to public acceptability, suggesting that future noise regulations may have to take social acceptance into account, i.e., not just safe noise levels, but also noise annoyance and human perception.

Currently, it is not clear what level of noise regulation will be required for RPAS as these systems can have a wide range of noise source characteristics due to different fuselage designs, propulsion configurations, weight, and flight modes. Characterizing their noise in a standardized way is challenging, but will be key to ensure sustainable operation. The work performed in this FY2022-2023 project consists of a literature review on RPAS noise that is of relevance to the development of noise standards for lightweight and small (MTOM < 150 kg) multi-rotor RPAS. In addition, the review will also identify shortcomings of current noise standards (e.g. ICAO standards for helicopters) and propose some guidance for future standards that are relevant to RPAS with a particular consideration given to human noise perception, sound annoyance, and societal acceptance.

Publications

- FY23 report ([Hyperlink](#))

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 Std council Canada
- NATO: FT 3 Flt Test Tech Team
- NATO: Rotorcraft Modelling
- RTCA: SC-147 TA&CAS
- RTCA: SC-228 MOPS UAS
- RTMAC
- RTMAC System Engineering WG
- SAE: G10 – Aero Behavioral Eng.
- SFTE/SETP eVTOL Flight Test Committee

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 fourth call for RPAS projects in the 2022-2023 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 correspond to “enabling technologies” for BVLOS operations.

In total, 12 Organizations submitted project ideas. The call for proposals that went out is presented in Appendix 1 of this report.

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.

Conclusion

The strategic partnership between TC and NRC continued in FY2022-2023, with the delivery of scientific data supporting regulation development in the priority areas.

This progress report is a living document which has a main objective 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 reports generated by each research project.

Appendix 1, 2022 CRIAQ-NRC-TC RPAS Call for proposals

Program Details & Objectives

CRIAQ is organizing a fourth call for project ideas on Remotely Piloted Aircraft Systems (RPAS) technologies in collaboration with the National Research Council of Canada (NRC) and Transport Canada (TC).

This program aims to identify innovative technology ideas and collect scientific data that will support the development of regulations, test methods and certification methods of compliance that will enable the safe operations of RPAS (also known as UAV or UAS) 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:

Promoting collaborative research activities to support the development of the Canadian regulatory framework.

Supporting other key initiatives as required.

This year's theme is looking at technologies development and/or demonstrations that will enable Beyond Visual Line of Sight (BVLOS) operations of RPAS. Interested industrial partners are invited to submit a project idea in collaboration with research partners for the "Beyond Visual Line of Sight (BVLOS) Enabling Technologies" theme.

Details on project funding

This program does not guarantee access to funding for your project; funding will need to be secured through a specific funding program.

Applicants who receive a positive evaluation of their project idea will be provided with contact information to local funding agencies by CRIAQ.

Submission Process:

For this Call edition, all applicants are invited to pitch their project idea in front of the evaluation during the RDV Forum 2023 to be held on February 14th and 15th in Montreal.

Please note that the participation at the event is not mandatory for the project selection. It is, however, recommended to find project partners, meet the committee and network with your peers.

For each proposal, please follow the link below to complete the submission form(s) by December 9th, 2022: Please click here. For more information, please contact projets@criaq.aero with the Subject « RPAS Call for Project Ideas »

Application submission and approval process

All project ideas will be evaluated by a joint committee composed of representatives from CRIAQ, the NRC and TC. CRIAQ will act as the contact point for receiving project ideas and coordinating the initiative. 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. Depending on the content of the final project plan, Transport Canada may act as an advisor or observer of the project.

Eligibility Criteria:

- Projects must address the theme BVLOS Enabling Technologies.
- 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 sale and/or annual investments 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.

Appendix 2, NRC Aero - TC RPAS TF collaborative research update

Transport Canada / Transports Canada

RPAS R&D Projects Reports Summary

Based on R&D conducted in FY 21-22

Presented by Charles Vidal (NRC)
Prepared by Carlos Ruella (TC) - October 2022

Canada

UNCL RPAS TASK FORCE

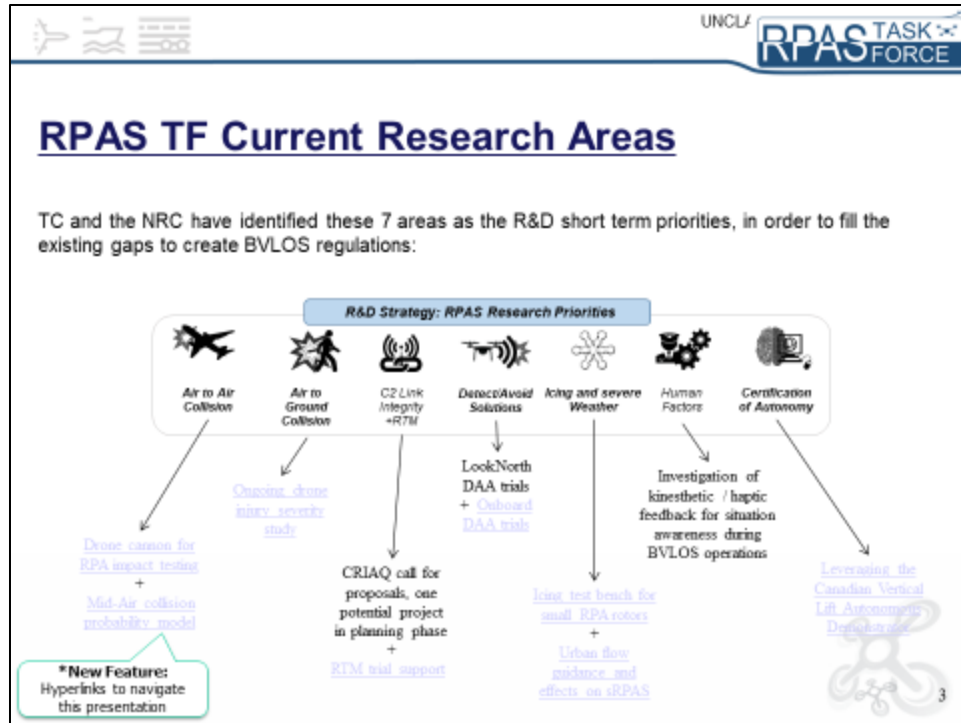
RPAS TF R&D Mandate and Partners

- Provide R&D data that supports regulatory and policy framework development.
- TC is collaborating with the FAA and FAA Assure to share R&D data and reduce duplication of research.
- TC is working with the 'National Research Council Canada' (NRC) to perform R&D to support the regulatory development for RPAS operations.
- The [Innovation Center](#) within Transport Canada supports the growth of applied and technology R&D.

```

    graph TD
      FAA((FAA)) -.- RPAS_TF[RPAS Task Force]
      FAA -.- FAA_ASSURE[FAA ASSURE]
      FAA_ASSURE -.- U_S_Academia((U.S. Academia))
      RPAS_TF -.- TC_Innovation_Hub[TC Innovation Hub]
      RPAS_TF -.- NRC((NRC))
      NRC -.- Peer_Review_Team[Peer Review Team]
      NRC -.- Funding_Mechanism[Funding Mechanism]
      Funding_Mechanism -.- Canadian_Industry((Canadian Industry))
      Funding_Mechanism -.- Canadian_Academia((Canadian Academia))
  
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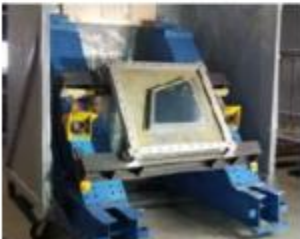
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UNCL **RPAS TASK FORCE**

Drone Impact Assessment (Part 25 windshield testing)

- **General Description:**
 - Back in 2019 we assessed the impact severity of a drone against a windshield of a Part 25 aircraft.
 - Interest in repeating this experiment using a full size Part 25 cockpit, also instrumenting the inside of the cockpit to better understand the impact to the flight crew.
- **Organizations Involved**
 - DRDC – Funding and Technical Support
 - TC RPAS Task Force / TC NAC – SMEs
 - NRC – Project Execution




2019 test setup


4

UNCL **RPAS TASK FORCE**

Drone Impact Assessment (Part 25 windshield testing)

- **Work executed:**
 - Cockpit of a Dash 8 was obtained to perform the testing during the current FY 22-23.
- **Expected relevant results :**
 - Better understanding of impacts with a more realistic test setup
 - Internal instrumentation will be placed to assess the amount of glass shed and its impact on the pilots






UNCL **RPAS TASK FORCE**

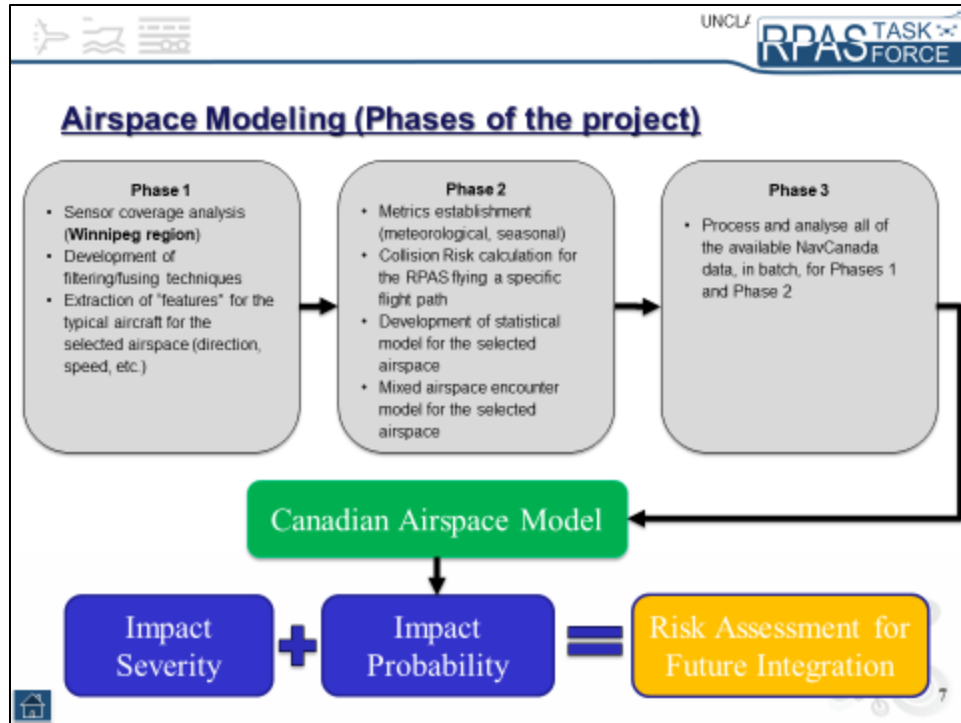
Airspace Modeling

- **General Description:**

Development of statistical models of Canadian airspace using aircraft track data provided by NAV Canada. The project is comprised of 3 phases to be completed by March 2023.
- **Organizations Involved:**

TC RPAS Task Force – Research coordinator
NRC – Research coordinator
NAV Canada – SME and Data support
Carleton University – Project Execution






UNCLF **RPAS TASK FORCE**


Human Injury Severity


- **General Description:**
To support the development and amendment of injury criteria for small RPAS to human impacts. Also to investigate how **vulnerable populations** respond differently during RPAS head impacts.

This phase focussed on further validating the small female human head-model, looking at the head response of children and developing a new sRPAS model to study

Organizations Involved:
 TC RPAS Task Force – Research coordinator
 NRC – Research coordinator
 Western University – Project Execution









Human Injury Severity

- **Testing executed:**
 - Extensive literature review conducted
 - Identified cadaveric data appropriate for small female model validation
 - Mid-report is primarily focused on describing cadaveric literature that is suitable for model validation.


- **Relevant results :**
 - Preliminary validation in terms of brain displacement showed that the small female model was valid in demonstrating brain motions and could be reasonably justified as being appropriate to study brain strains




(b) Lateral Impact with 0 degrees




(c) Frontal Impact with 90 degrees




(d) Lateral Impact with 30 degrees




(e) Top Impact with 90 degrees



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RTM Trial Support

- **General Description:**


As part of our R&D program we collaborate with the NRC to support the execution of the ongoing RPAS Traffic Management (RTM) trials.

 1. Analyze the data coming out of the trial participants to validate it and provide the Task Force with a summary report
 2. Develop a simulation tool to assess the interaction of the different services present in the RTM environment

Organizations Involved:
 TC RPAS Task Force – Research coordinator
 NRC – Project execution




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UNCLF
RPAS TASK FORCE

RTM Trial Support

- **Work executed:**
 - NRC reviewed the data coming from the RTM trial participants.
 - The "RTM simulator" has a modular structure that will allow users to easily simulate the different modeled RTM services (work in progress), or interface their own particular service implementations, and change/monitor their behaviours as required.
 - With the architecture of the simulation complete, the specific services can be designed and incorporated.




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UNCLF
RPAS TASK FORCE


Onboard DAA NRC / TC trials


- **General Description:**
 The purpose of these trials is to evaluate the performance level of **Non-Cooperative, airborne**, DAA systems. This trial is targeted directly at DAA systems manufacturers.

Trial participants:

- Iris Automation (Onboard **camera** based DAA system, 360deg FOV)
- Echodyne (Onboard **radar** based DAA system)
- Fortem Technologies (Onboard **radar** based DAA system)

- **Organizations Involved:**
 TC RPAS Task Force – Research coordinator
 NRC – Project execution
 DAA Manufacturers – Provide a loaner system for testing



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UNCL **RPAS TASK FORCE**


Onboard DAA NRC / TC trials

- **Testing Strategy:**
 - NRC and TC establishing a test plan
 - The DAA systems are installed on the Bell 205 surrogate RPAS host
 - 2 NRC aircraft will pose as the surrogate traditional aviation intruder:
 - o Jet Ranger
 - o Harvard
 - All aircraft are fully instrumented to provide high quality truth data
- **Work Executed :**
 - Last FY all 3 DAA systems were integrated onto the Bell 205, and the airworthiness clearance was given to conduct flight testing.
 - The DAA performance testing is happening during summer/fall 2022, fix wing intercepts were completed.




Bell 205


Intruders:




Harvard



Jet Ranger



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UNCL **RPAS TASK FORCE**


Drone Propeller Icing Tolerance


- **General Description:**

Further assessment of RPAS rotor in icing conditions was performed. The focus was on development of guidance materials and future regulations/standards related to flight in icing conditions.
- **Organizations Involved:**


TC RPAS Task Force – Research coordinator
 TC NAC – SMEs
 FAA – SMEs reviewed test planning
 NRC – Project Execution







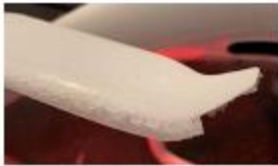


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RPAS TASK FORCE

Drone Propeller Icing Tolerance

- **Relevant results :**
 - In general, it was observed that there is an improvement in thrust performance at -5° C compared to -12° C
 - For **freezing drizzle**, thrust values were maintained beyond the 122 second limit
 - For **freezing rain**, dependent on precipitation strength and temperature, in some cases the thrust is significantly reduced before reaching the theoretical limit of 122 seconds
 - Applying different size grit roughness to the leading edges demonstrated the ability to emulate only some of the results from icing testing
 - More results and graph will be available in the final publicly available report


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UNCLF
RPAS TASK FORCE

Urban Airflow

- **General Description:**
 The purpose of this multi-phase project is to support Transport Canada (TC) with the development of knowledge and tools to promote RPAS operator awareness and safety assurance for flight within the urban environment.
- **Organizations Involved:**
 TC RPAS Task Force – Research coordinator
 NRC – Project Execution





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UNCL **RPAS TASK FORCE**


Urban Airflow

- Testing executed:**


Wind tunnel testing to evaluate the flow-fields of four urban models to determine the magnitude and locations of extreme airflow features identified as potentially hazardous to RPAS operations

Wind tunnel testing of five off-the-shelf small RPAS which were evaluated for flight stability for a range of turbulence


Preliminary 2.5 safety margin, i.e. an RPA that can fly safely at 25km/h clean flow winds, should not be flown in a city when winds are reported over 10kmh.




(a) Vancouver




(b) Toronto




(c) London




(d) Artificial city




(a) Mavic Mini.




(b) Mavic Zoom.



(c) EVO II Dual Pro.



(d) Phantom 4 Pro.



(e) Matrice 300.


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UNCL **RPAS TASK FORCE**

Certification of Autonomy

- General Description:**
 - Study on how to accredit and/or certify flying systems with higher levels of autonomy
 - Long term project 2018-2024
 - NRC researchers drafted documents and proposals that were then discussed within a multi-disciplinary working group.
- Organizations Involved**

TC RPAS Task Force – Research coordinator / SMEs
 TC NAC – SMEs
 DND DTAES – SMEs
 NRC – Project Execution
 FAA – SME participating in working groups
 NASA– SME participating in working groups




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UNCL **RPAS TASK FORCE**

Certification of Autonomy

- **Overall Objectives:**
 - Autonomous obstacle (air, ground, static and dynamic) detection and mapping
 - Autonomous Path Planning (Deterministic & Non-Deterministic)
 - Autonomy in Human-Machine Teaming
 - **Development of Flight Test Techniques to assess autonomous flight systems capabilities/performance**
- **Relevant results FY 2022 :**
 - **Summary report**, this will get published and will summarize the work done in the past 4 years
 - Human Role in Limiting Adaptive ND - Literature Survey
 - Pilot intervention study
 - CVLAD test plan open and close loop, including a preliminary flight test report
 - System safety assessment updated
 - Trust in autonomy updated document
 - These reports and presentations are the basis for the next year's work.




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UNCL **RPAS TASK FORCE**

TC/NRC Published reports

- One of the main goals of our R&D program is to publish our results and share them with the international community to avoid duplication of effort.
- Reports/papers already published online:
 - [Part 25 drone impact assessment report](#)
 - [Part 23 drone impact assessment report](#)
 - [RPAS icing literature review](#)
 - [Small RPAS propeller icing tolerance report](#)
 - [RPAS specific icing test rig development and calibration report](#)
 - [Medium RPAS propeller icing tolerance report](#)
 - [Investigating small RPAS ground impact injury severity criteria](#)
 - [Urban Air Flow Report \(Operator guidance video\)](#)
 - [Urban Air Flow - RPAS testing report](#)
 - [Modeling sRPAS system to head impact for investigating craniocerebral response](#)
 - [Public Opinion Research Study on Drone Users' Familiarity with the New Rules & the General Public's Social Acceptance of Drones](#)
 - [Strategies to Improve the Social Acceptability of Drones | Max Bell School of Public Policy - McGill University](#)
 - [Transport Canada RPAS R&D yearly progress report \(2020-2021\) - NRC Publications Archive - Canada.ca](#)
- The following reports are under review and should be published online soon:
 - [LockNorth/TC/NRC DAA trials report coming soon](#)
 - RPAS Icing report
 - Certification of Autonomy Summary Report (describing 4 years of work)



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UNCL 

For any additional questions regarding the Transport Canada RPAS Task Force R&D program, please contact Carlos Ruella: carlos.ruella@tc.gc.ca

Canada

 Transport Canada 

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Appendix 3, NRC Aero IAM Program presentation





INTEGRATED AERIAL MOBILITY PROGRAM

Charles Vidal, Program Leader
 Ali Benmeddour, Operating Environment Technology Lead
 Behnam Ashrafi, Integrated Design Technology Lead
 Derek Gowanlock, Flight Autonomy Technology Lead



National Research Council Canada / Conseil national de recherches Canada



The National Research Council of Canada

The NRC is Canada's largest federal R&D organization.

Mandate

- Support business innovation
- Advance scientific and technical knowledge
- Deliver policy solutions for government

3,700 scientists, engineers and technicians	1,000 companies with R&D collaborations	\$1B annual budget	7,500 SME clients
100s of national and international partners			



NATIONAL RESEARCH COUNCIL CANADA

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Aerospace Research Center Laboratories / Programs



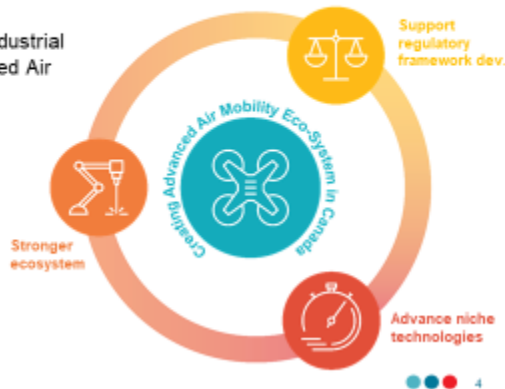
IAM Program Objectives

Goal and Objectives

Support the ecosystem and grow Canada's industrial capabilities in the strategic and global Advanced Air Mobility market.

NRC Mandate:

- Support business innovation
- Advance scientific and technical knowledge
- Deliver policy solutions for government



NATIONAL RESEARCH COUNCIL CANADA

Advanced Aerial Mobility application spectrum

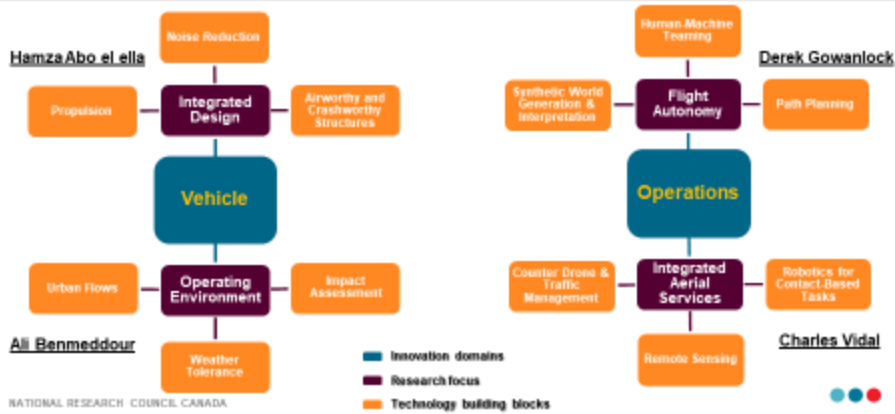
Mobility of:



Commercial and security/defence

Integrated Aerial Mobility (IAM)

IAM Program Scope



Integrated Aerial Mobility Operating Environment

- Multi-year goals**
- Develop experimental and computational Modelling and simulation capabilities and tools for AAM
 - Characterize RPAS icing and develop effective ice detection and ice protection technologies
 - Evaluate extreme airflows within Canadian cities and investigate stability limits and suitability of novel control systems
 - Determine small RPAS air-to-air and air-to-ground collision impact for safe operations in civilian airspace and populated areas



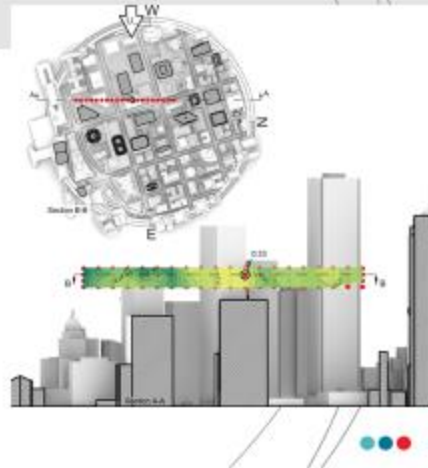
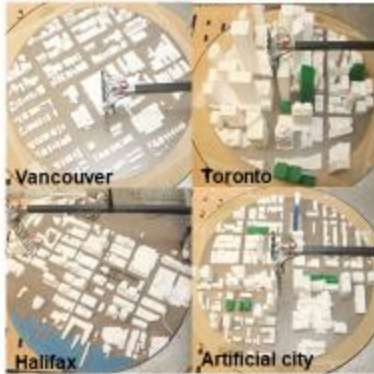
A Three year project:

Project summary – RPAS in Urban Airflow

YEAR 1	YEAR 2a – Urban Airflow	YEAR 2b - RPAS	YEAR 3 - RPAS
A VIDEO	A WIND TUNNEL TEST	A WIND TUNNEL TEST	AN OUTDOOR WIND TUNNEL TEST
acronym S ₁ -D-S ₂ -T-V is defined	measure S ₁ -D-S ₂ -T-V	fly RPAS in S ₁ & T	fly RPAS in D, S ₂ & V (direction, shear & velocity)

RPAS in Urban Airflow

Urban airflows – Canadian city evaluation:



Drone cannon facility

Operating environment



- Unique "super cannon" has been developed at NRC in close collaboration with Transport Canada & Defence Research and Development Canada



National Research Council Canada

10

Drone cannon facility

Operating environment



- Impact testing has been conducted on selected aircraft components (part 25 and part 23)

Cessna 172 components



National Research Council Canada

11

Drone cannon facility

For full scientific reports: nrc-publications.canada.ca

Operating environment



- Experimental results being used by Transport Canada to develop regulatory framework and guidelines for the operation of UAVs in the Canadian airspace
- Experimental database used to validate and fine-tune numerical simulations at NRC and international partners
- Current work is focused on lethality assessment for drone impact on part 25 windshields



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12

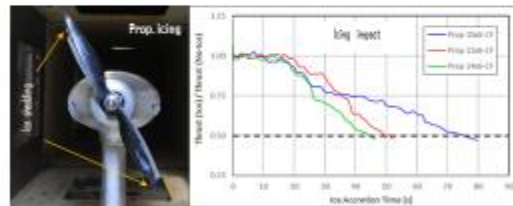
Icing of small RPAS propellers & ice risk mitigation for RPAS

Operating environment



Icing of small RPAS propellers

- Development of a testing capability for small props
- Investigation of tolerance for icing of small props, at high RPM



National Research Council Canada

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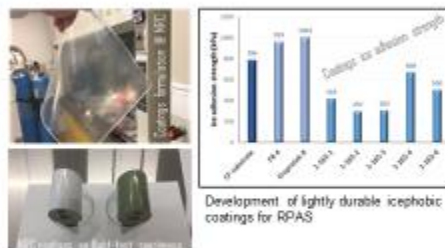
Icing of small RPAS propellers & ice risk mitigation for RPAS

Operating environment



Ice risk mitigation for RPAS

- Formulation of novel, erosion resistant slippery polyurethane (SPU) icephobic coatings
- Characterization of hydrophobic, icephobic and sand erosion resistance properties of SPU coatings
- Formulation of low thermal conductivity (low-TC) SPU coatings (ongoing)
- In-flight demonstration of icephobic coating technology (NATO AVT activity, ongoing)



Development of lightly durable icephobic coatings for RPAS

National Research Council Canada

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Drone rotor icing facility

Operating environment



Unique drone facility for testing medium to large rotors in icing (12-36" diameter)

- Calibrated environment in cold room to simulate drone in-flight icing encounters
- Test stand measures rotor performance as ice builds on blade surfaces



National Research Council Canada

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Drone rotor icing facility

Operating environment



Results overview

- Small and large drop (freezing rain) icing conditions achieved
- Drop size and water concentrations influence rate of rotor thrust loss
- Facility description and test results available at: nrc-publications.canada.ca



National Research Council Canada

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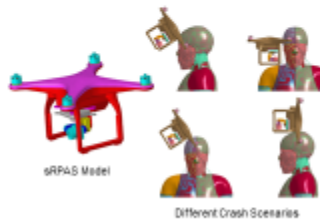
Ground collision human safety

Operating environment



Investigated drone to head impact responses

- Developed and validated a representative quadcopter finite element model
- Comprehensively investigated head responses and various injury metrics and supported using head injury criteria (HIC) under frontal, lateral, and vertical impacts
- Identified differences between average male and small female, highlighting the need to protect vulnerable population
- Identified large structural effects related to drone design



National Research Council Canada

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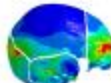
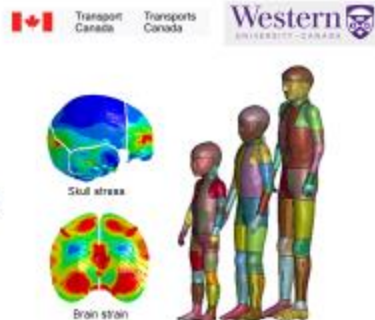
Ground collision human safety

Operating environment

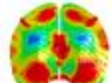


Ongoing activities

- Investigating how vulnerable populations such as children respond during collisions
- Investigating structural effects of a new drone model
- High-speed testing of drone impact responses



Skull stress



Brain stress

Natural Research Council Canada

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Integrated Aerial Mobility Flight Autonomy



Multi-year goals

- Develop and publically demonstrate safe & efficient autonomous flight algorithms
- Develop Validation & Test/Benchmarking Techniques for different levels of automated systems
- Provide expert understanding of autonomy to enable regulation development



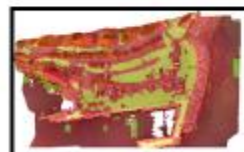
Trajectory Command Integration into Flight Controls



Mission Management & Trajectory Planning



Autonomy Displays



ML Based Landing Zone Identification

Canadian Vertical Lift Autonomy Demonstration - Project Objectives

Demonstrate kit based, advanced autonomous flight technology on the Bell 412 and CH147 Chinook

- Reduce crew workload
- Provide Improvements to operational capability
- Vehicle life extension through envelope protection
- Research & Technology Development to TRL 7



Link the demonstration to a viable production path

Create a Strategic Autonomy capability within Canada

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Canadian vertical lift autonomy demonstration



CVLAD hardware & infrastructure development



National Research Council Canada

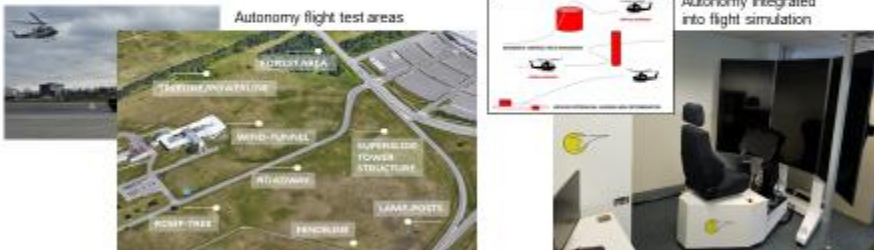


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Canadian vertical lift autonomy demonstration



CVLAD hardware & infrastructure development



National Research Council Canada

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Canadian vertical lift autonomy demonstration



CVLAD algorithm and software development



National Research Council Canada

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Detect and Avoid

Airborne DAA Sensor Performance Eval (TC):

1. Echodyne EchoFlight Radar
2. Fortem R20i Radar
3. Iris Casia X Optical

Flight Test:

- 2 Campaigns (Bell 206 & Harvard)
- 35 Intercepts Flown To Date



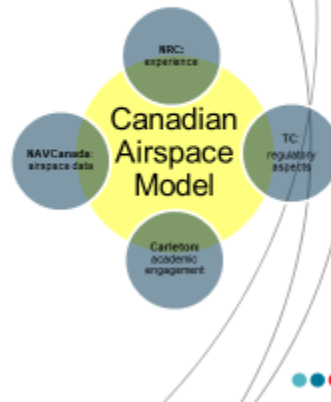
Figure 2. Detect and Avoid sensors on Bell 206



Figure 3. Engineering Technician performing tests

Canadian Airspace Modeling

- Objectives:
 - Aid the introduction of RPAS in Non-segregated airspace by developing a Canadian specific tool to assess collision risk between RPAS and intruder aircraft
 - Develop models and methods to allow risk assessment for RPAS with specific performance envelopes in various airspaces in Canada



Integrated Aerial Mobility Integrated Aerial Services

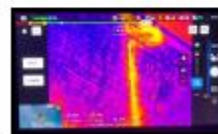
Integrated Aerial Services

Integrated Aerial Services

Integrated Aerial Services

Multi-year goals

- **Aerial Robotics:** Develop aerial robotics technologies for inspection and maintenance of elevated structures and security applications.
- **Counter Drone and RPAS Traffic Management (RTM)** Develop and validate advanced AI-enabled Counter drone technologies, and develop- implement new capabilities to enable RTM in Canada and support regulation developments
- **Advanced Remote Sensing** Utilize an integrated system of sensors (e.g. hyperspectral, LiDAR, aeromagnetics and thermal-IR) to develop BVLOS applications. Implement advance analytics (e.g. data fusion) for different applications for natural and man-made.

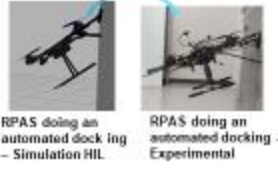


Contact Inspection and Maintenance deployment from UAS



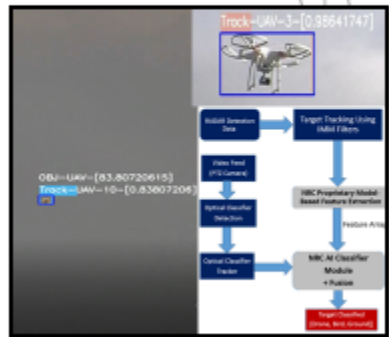
- Technological Challenges**
- Stability
 - Dexterity / Precision positioning
 - Changing CG, Flight dynamics
 - Coupled dynamics

- Ongoing Development (NRC)**
- Docking mechanism
 - Sensing and Automation
 - New onboard manipulators



Counter Drone and Target Detection

- Improvement of classification at far distance for small targets using meta data from multiple sensors e.g., radar and PTZ camera
- Multiple NATO conferences presentations
- 6 Peer-reviewed IEEE papers (Conf and Journal)
- 2nd Place in an International Competition <https://wosdetc2019.wordpress.com/committee/>

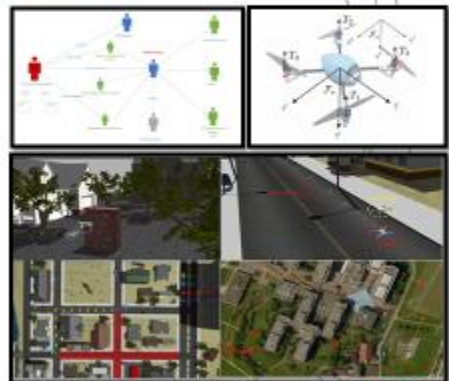


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RPAS Traffic Management (RTM)

- R&TD to support roll out of RTM architecture and network in Canada
- RTM Technology Measures of Performance – Guideline for Trials
- RTM software development for multiple drone
- Algorithm developments- Optical-based object detection systems and collision avoidance



NATIONAL RESEARCH COUNCIL CANADA

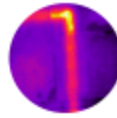
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IAM – Remote sensing and advanced analytics

Integrated aerial services



- UAV-thermal based heat loss determination (CFB Galetown and Kingston)
- Emerging technologies for monitoring and Managing water levels around railway tracks (NRC's automotive and surface transportation/ Transport Canada)
- UAV hyperspectral for climate change research (Canadian Airborne Biodiversity Observatory –CABO)
- Development of data fusion algorithms



UAV: Thermal



UAV: Hyperspectral



UAV: Photogrammetry/RGB/LIDAR

National Research Council Canada

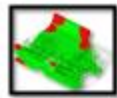
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Integrated Aerial Mobility Integrated Design



Multi-year goals

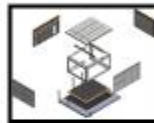
- **Integrated UAM Cabin Project** Multi-objective optimization and prototype manufacturing of a subfloor and side floor cabin structure.
- **Noise reduction and Urban Air Mobility Propulsor Aeroacoustics** Develop and demonstrate low-noise UAM propulsion.
- **Low-order simulations of flying taxi solutions** Prediction of aerodynamic performance of UAM configurations and rotors.
- **Specialized Propulsion Facilities**



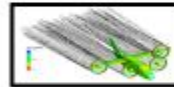
Example M1/70 results



Acoustic meta-materials



Drone acoustic test facility



Nexus configuration in cruise



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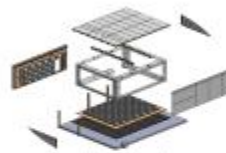
Integrated design

Integrated design



Noise reduction

- UAM specific acoustic testing facilities
- Low noise propulsion technologies – computational optimization and experimental validation



Anechoic chamber



Airfoil optimization

Propulsion

- Specialized propulsion facilities
- UAM propulsion systems sea-level & altitude testing



Altitude testing

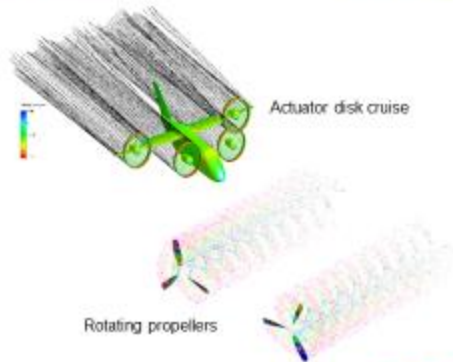
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Low-order simulations of flying taxi solutions for the IAM program



- Development of quick aerodynamic analysis prediction tools for air mobility configurations, including propeller/rotor slipstreams
- Automation for variable positioning; tilted wings or propeller nacelles



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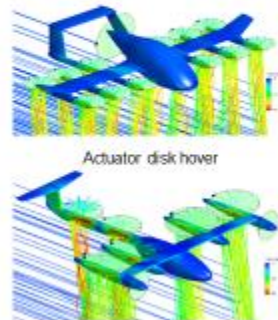
33

Low-order simulations of flying taxi solutions for the IAM program



Ongoing activities

- Investigation configurations with coaxial and ducted fans
- Investigation propeller performance in ground effect



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Detailed conceptual design of a UAM (phase 1)



- Created and utilized an iterative component sizing and mass calculation code
- Selected components (batteries, motors, etc.) that fulfill the power and mass requirements



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Detailed conceptual design of a UAM (phase 1)



Airframe configuration

- Performed stability analysis on 10+ unique concepts
- Produced detailed CAD interpretation of proposed design



CAD rendering



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THANK YOU

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<https://nrc.canada.ca/en/research-development/research-collaboration/programs/integrated-aerial-mobility-program>

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