Federal Aviation Administration

AVS Research, Engineering and Development

AVS RE&D Portfolio:

Aircraft Icing (A11Da)

Research Plan: 2022- 2027

January 26, 2022

Part 1: BLI Definition and Scope

Program Area: Aircraft Icing (A11Da)

FAA Domain: Environment/Weather Impact Mitigation

BLI Scope: Aircraft Icing (A11Da)

The FAA's Aircraft Icing research program focuses on ground icing and inflight icing effects on all types of aircraft. Ground icing focuses on aircraft deicing and anti-icing methods prior to takeoff. Inflight icing focuses on aerodynamic and operational effects of icing on all types of aircraft, rotorcraft and engines.

The ground icing program conducts research to maintain safe winter ground operations, evaluate the effects of changing ground operations, and develop testing and analysis methods to support these changes, and address the effects of innovative aircraft design, such as folding wing aircraft, and new formulations of fluids and innovative methods used in deicing and anti-icing procedures. The pre-takeoff Clean Aircraft Concept is to ensure that the critical surfaces of the aircraft are aerodynamically clean at takeoff, guiding FAA policy for ground icing.

The inflight aircraft icing program conducts research on the effects of icing and mitigation techniques and innovative methods to assure compliance with airworthiness standards. Inflight aircraft icing includes both super-cooled droplet icing conditions, which affect aircraft, rotorcraft, and engines, as well as ice crystal icing (ICI) that effects turbine engine operation and aircraft flight data probe functionality.

Part 2: Service/Office Research Requirements and Research Gap Analysis

1.0 Operational Capability: *Icing During Ground Operations (AI.02)*

Definition: Ground Deicing: Addresses safety for continued operations by addressing icing related accidents and incidents during take-off. Revise operator guidance which each operator must update and get FAA approval annually for their ground deicing program.

Primary S/O: Charles J. Enders, AFS-220
Secondary S/O: N/A

S/O Priority: 1

Outcome: Assure effectiveness of anti-icing procedures, utilizing a newly designed artificial snow machine that will be used to determine how long anti-icing fluid provides protection from frozen contamination (snow). Development of a validated artificial snow machine for evaluating de-icing and anti-icing fluids will result in a more effective test method and provide significant savings to the FAA, fluid manufacturers and commercial airlines. Currently it is necessary to wait for natural snow conditions (e.g. very cold conditions) to evaluate fluids. FAA guidance is very limited and requires more extensive snow condition simulation for fluid evaluation, which would be available using the artificial snow machine. Provide annual guidance to the airline industry for updating ground deicing programs. The FAA works collaboratively every year with Transport Canada to develop modifications and improvements to deicing/ant-icing "hold-over-time tables" and "allowance time tables" to revise the Notice 8900.xxx guidance ground operations in icing conditions.

Research Gap Analysis

Research Questions	Contribution	Research Output
1.1 Does current policy on HOT adequately address vertical surface contamination in order to adequately assure safe takeoff? What test data and analysis is required to address this issue.	30%	Improve deicing safety and process consistency by developing test data and analysis to support a decision for vertical surface policy to address safe operational deicing requirements.
1.2 Do current methods for determination of holdover and allowance times within identified mixed-icing conditions adequately assure safe takeoff in icing?	40%	Improve deicing safety and throughput by developing test data and analysis to support decision to modify FAA Deicing Program Notice 8900.xx. Add criteria to policy for mixed icing conditions.
1.3 Are aircraft aerodynamics, and other detrimental effects, negatively affected when thickened anti-icing fluids remain on aircraft surfaces, without precipitation occurring, or with some amount of frozen precipitation (i.e. frost, snow) when	20%	Develop methodology to determine fate of thickened aircraft anti-icing fluids remaining on the aircraft after being used for pre-treatment of anticipated icing conditions. Include research outcome in guidance to part

the fluids are not being subsequently completely washed off the aircraft, prior to departure?		121 operators using Notice 8900 approved deicing programs.
1.4 Does the newly improved artificial snow machine demonstrate good comparability to natural conditions and provide acceptable repeatability?	10%	Improved safe aircraft departures and improved departure schedule efficiencies. Revised FAA published hold-over-times (HOT) for snow conditions identified in Notice 8900.xxx. Repeatable snow generation validated against natural snow conditions for use in hold-over-time policy.

2.0 Operational Capability: *High Altitude Ice Crystal Icing Effects on Aircraft (AI.01)*

Definition: Unrestricted flight through high altitude ice crystal environments. Conduct an atmospheric flight campaign in 2022 or 2023 near an industrial center in the vicinity of Japan, where higher concentrations of aerosols exist, to measure its potential influence on the presence and/or prominence of ICI conditions. Modify the regulatory icing atmosphere. Develop guidance for turbine engine ice accretion assessment by test and evaluation using the ice crystal icing rotating rig known as ICE-MCR.

Primary S/O: Philip Haberlen, AIR-624
Secondary S/O: Alan Strom, AIR-617

S/O Priority: 2

Outcome: Improved safe operations in ice crystal icing atmospheres through corrected regulatory requirements and improved guidance. This research requirement addresses current shortfalls in the current rule, policy and guidance by flight test and validated rig-test for glaciated and mixed-phased icing conditions and their effect on turbine engine damage and powerloss. Industry and academia experts have limited understanding of the ice-crystal ice formations within turbine engines. This research directly addresses these shortfalls. A currently active ARAC committee has requested this research.

Research Gap Analysis

Research Questions	Contribution	Research Output
2.1 Can simulated high altitude ice crystal icing be used as an innovative approach to replicating ice accretions within the warm compressor sections of a turbine engine, which results in power loss, as seen in service?	10%	Innovative approach development to understand basic ice accretion within the warm compressor of a turbine engine, utilizing the previously developed 2-stage rotating rig while testing in simulated altitude ice crystal icing conditions.
2.2 Does engine size influence the ice accretions within turbine engines at high altitude? Does susceptibility scale?	25%	Address safety issue of power loss by defining scale effects for icing in turbine engines at high altitudes. Scale effects include aero swirl and ice centrifuging

		effects. This will advance available guidance on ice crystal icing effects on engines that result in power loss. Improved compliance methodologies.
2.3 Does high aerosol (i.e. pollution) directly influence the ice crystal icing (ICI) concentrations at high altitude, where turbine engines and aircraft air data probe accretions have caused accidents and incidents?	65%	Provide validated data (as-requested by ARAC), to show effects of pollution in highly industrialized areas, on high altitude ice crystal concentrations that result in engine power loss. ARAC will then use this validation data to revise the design certification envelope (appendix D of part 33) for ICI conditions. Also provides improved simulation of ICI conditions in test facilities as part of compliance demonstrations.

3.0 Operational Capability: *Urban Air Mobility (UAM) Icing (AI.06)*

Definition: Develop aircraft regulatory icing requirements and guidance for Urban Air Mobility (UAM)/Advanced Air Mobility (AAM) operations in icing environments.

Primary S/O: Paul Pellicano, AIR-625
Secondary S/O: Robert Hettman, AIR-623

S/O Priority: 3

Outcome: Sufficient understanding of icing effects on UAM/AAM to develop rules and guidance for operations in icing conditions as well as inadvertent encounters with icing conditions.

Research Gap Analysis

Research Questions	Contribution	Research Output
3.1 Can significant ice accretions form on UAM/AAM propulsive systems when in hover mode within a supercooled droplet icing cloud? What is the likelihood of accreted ice to shed and the associated operational safety risks?	50%	An experimental benchmark database will be developed for validation of computer codes that may be used as part of the future compliance process. Policy and guidance development based on knowledge gained of ice effects on UAM.
3.2 Can a freezing rain and freezing drizzle (aka SLD) ice detector provide adequate ice detection on a UAM/AAM in both hover and forward flight, when considering downwash effects? Can this be simulated in wind tunnel simulated icing conditions?	50%	This will allow FAA to type certify these aircraft in icing conditions and provide policy and guidance development for SLD detection systems that will be required on future potential autonomous UAM/AAM.

4.0 Operational Capability: *Modelling of Ice Accretions on Ice-Protected Surfaces (AI.07)*

Definition: Develop technical analysis capabilities to support certification process in the selection of most critical icing scenarios to be flight-tested to ensure safety for ice-protected aircraft operations.

Primary S/O: Paul Pellicano, AIR-625
Secondary S/O: Robert Hettman, AIR-623

S/O Priority: 4

Outcome: Identification of range of applicability of existing analysis tools that may be used in Certification/Qualification by Analysis (CQbA) for ice-protected aircraft operations.

Research Gap Analysis

Research Questions	Contribution	Research Output
4.1 Can existing numerical modeling tools be used, if so to what extent, in the determination of ice formations that is most critical for the safe operations of ice-protected (anti/de-iced) aircraft in multiple icing environments?	40%	Numerical approach for determination of critical ice shapes for use during aircraft icing certification. This will be reflected in guidance.
4.2 What type of test data can be obtained through flight campaigns in icing and aerodynamic wind tunnels for the icing scenarios encountered by ice-protected (anti/de-iced) aircraft?	40%	Experimental approach for determination of critical ice shapes for use during aircraft icing certification. This will be reflected in guidance.
4.3 Can computational tools used in 4.1, such as Computational Fluid Dynamics (CFD) and ice accretion solvers, be validated adequately using the test data obtained in 4.2 when determining the most critical ice formations on ice-protected (anti/de-iced) aircraft?	20%	Identification of range of applicability of analysis methods in the determination of the most critical ice formations for ice-protected aircraft to support certification. This outcome will be used in both guidance.

Part 3: RE&D Management Team Programming

BLI Planning 3 Year Funding Profile (FY22-24) as of 01/28/2022

YEAR	Appropriation or Formulation Contract Funding ($)	INITIAL BLI TEAM PLANNING CONTRACT FUNDING – AFN BLI Target minus the Hold Back ($)	AVS-1 APPROVED CONTRACT FUNDING ($)
FY22 formulation or appropriation (if known)	**$1,210,947**		
FY23 formulation	**$2,009,587**		
FY24 AFN funding allocation target		**$1,304,584**	**$2,524,584**

BLI Plan 5 Year Outlook (FY22-27)

Complete (C)	In Progress (IP)	Programmed (P)	Need (N)

Research Activities	FY22	FY23	FY24	FY25	FY26	FY27
Operational Capability 1.0: *Icing During Ground Operations (AI.02)*						
Research Question #1.1 Does current policy on HOT adequately address vertical surface contamination in order to adequately assure safe takeoff? Identify needed test data and analysis to address this issue.	P	P	N	*C*	*C*	*C*
Research Question #1.2 Do current methods for determination of holdover and allowance times within identified mixed-icing conditions adequately assure safe takeoff in icing?	P	P	N	N	N	N
Research Question #1.3 Are aerodynamics, and other potentially detrimental effects, negatively affected when thickened anti-icing fluids remain on aircraft surfaces, without precipitation occurring, or with some amount of frozen precipitation (i.e. frost, snow) when the fluids are not being subsequently completely washed off the aircraft, prior to departure?	IP	P	N	*C*	*C*	*C*
Research Question #1.4 Does the newly improved artificial snow machine demonstrate good comparability to natural conditions and provide acceptable repeatability? (Note: no FY24 funding requested)	P	P	N	C	C	C

Research Activities	FY22	FY23	FY24	FY25	FY26	FY27
Operational Capability 2.0: *High Altitude Ice Crystal Icing Effects on Aircraft (AI.01)*						
Research Question #2.1 Can simulated high altitude ice crystal icing be used as an innovative approach to replicating ice accretions within the warm compressor sections of a turbine engine, which results in power loss, as seen in service? (Note: no FY24 funding requested)	IP	IP	N	C	C	*C*
Research Question #2.2 Does engine size influence the ice accretions within turbine engines at high altitude?			N	N	N	N
Research Question #2.3 Does high aerosol (i.e. pollution) directly influence the ice crystal icing (ICI) concentrations at high altitude, where turbine engines and aircraft air data probes have caused accidents and incidents?	IP	IP	N	N	C	C
Research Activities	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**
Operational Capability 3.0: *Urban Air Mobility (UAM) Icing (AI.06)*						
Research Question #3.1 Can significant ice accretions form on UAM/AAM propulsive systems when in hover mode within a supercooled droplet icing cloud? What is the likelihood of accreted ice to shed and the associated operational safety risks? Conduct UAM icing testing in Penn State icing hover facility and icing wind tunnel.	IP	IP	N	N	C	C
Research Question #3.2 Can a freezing rain and freezing drizzle (SLD) ice detector provide adequate ice detection on a UAM/AAM in both hover and forward flight, when considering downwash effects? Can this be simulated in wind tunnel simulated icing conditions?		IP	N	C	C	*C*
Research Activities	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**
Operational Capability 4.0: *Modelling of Ice Accretions on Ice-Protected Surfaces (AI.07)*						
Research Question #4.1 Can existing numerical modeling tools be used, if so to what extent, in the determination of ice formations that is most critical for the safe operations of ice-protected (anti/de-iced) aircraft in multiple icing environments?	IP	N	N	N	N	N
Research Question #4.2 What type of test data can be obtained through campaigns in icing and aerodynamic wind tunnels for the icing scenarios encountered in ice-protected (anti/de-iced) aircraft?		N	N	N	N	C

Research Question #4.3 Can computational tools like CFD modelling be validated adequately using icing wind tunnel testing when determining critical ice shapes on ice-protected (anti/de-iced) surfaces?			N	N	N	N

Part 4: BLI Team Members

Participants Name	Role	Routing Symbol
Jorge Fernandez	BLI Chair	AIR - 670
Doug Rodzon	REDMT Voting Member	AFS - 430
John Fisher	STS –Aircraft Icing	AIR - 602
Chuck Enders, Alan Strom, Paul Pellicano, Bob Hettman	Sponsor SME's	AFS-220, AIR-624, AIR-625, AIR-623
Chris Dumont, Warren Underwood, Ezgi Oztekin, Tim Smith	Performer SME's	ANG – E282