

Arctic STOL Aircraft

Request for Proposal

2025-2026 Graduate Team Aircraft Design Competition

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1. OPPORTUNITY DESCRIPTION

Harsh climate and living conditions make it very difficult for people to live north of the Arctic Circle. Nevertheless, approximately 4 million people currently live there. These people typically live in small remote communities and have a need for aircraft for transportation, goods, and emergency medical services. Aircraft that operate in this difficult environment encounter gravel fields and unprepared landing surfaces, quick weather changes, extremely cold temperatures, and cold, wet conditions.

2. PROJECT OBJECTIVE

The objective of this project is to design a new, affordable, aircraft that will operate north of the Arctic Circle with Short Take-Off and Landing (STOL) field capability to serve small communities by providing transportation of people and goods and emergency medical services. Special consideration should be given to the aircraft features, such as boarding, egress, and cargo loading that improves the passenger and operator experience. The aircraft must reliably operate in the extreme environmental conditions that exist north of the Arctic Circle including icing conditions, cold weather, and with minimal supporting infrastructure. The primary objective should be to develop a robust platform with low direct operating costs to maximize profits for operators.

3. DESIGN REQUIREMENTS AND CONSTRAINTS

3.1 General Design Requirements and Constraints

- Certification:
 - Planned certification to 14 CFR Part 23
 - Certification and entry into service (EIS) shall be no later than 2033.
 - All subsystem technologies should have achieved Technology Readiness Level (TRL) 6+, i.e., demonstration of an actual system prototype in an operational environment.
 - If technologies have not yet achieved TRL 6+, risk statements with mitigations should be included.
 - Must be certified for flight into known icing (FIKI) conditions

- Configurations and Payload Capacity
 - The aircraft shall be reconfigurable and capable of carrying the following payloads:
 - Configuration 1 - Passenger transport
 - 9 passengers / 2,250 lb (200 lb + 50 lb baggage per passenger)
 - Minimum 31" seat pitch
 - Configuration 2 - Cargo transport:
 - Cargo weight equivalent to the 9-passenger configuration (2,250 lb + weight of the removable seats)
 - Must be capable of transporting a 8,000 watt generator and 55 gallons of diesel fuel (in no more than 3 containers, preferably one)
 - Configuration 3 - Aerial Ambulance
 - 1 litter (50 lb stretcher), 4 passengers (2 medical technicians, 1 patient, 1 patient escort, all 200 lb each), 300 lb of additional medical supplies & equipment: 1,150 lb total

- Crew
 - 2 pilots / 400 lb (180 lb each + 20 lb baggage per pilot)

- Propulsion
 - The aircraft may be of single or multi-engine design
 - The engine(s) for the proposed aircraft shall be an existing production design or able to be certified by 2030

- Operations and Performance
 - Must be capable of cold weather operations down to -30° F
 - Pressurization is not required, but is allowed if justified
 - Must be capable of operating on gravel runways
 - Capability to take off and land on other types of unprepared surfaces is desirable
 - Service Ceiling \geq 18,000 ft
 - Rate of Climb \geq 800 ft/min at MTOW, ISA+5
 - Maximum velocity (VNE) \geq 180 KTAS

Any deviations from the requirements listed in this document must be justified by considerations relating to cost (development and/or operating) or operations.

3.2 Mission Requirements

Missions are flown at ISA+5, zero wind conditions, with sea level field elevation for takeoffs and landings.

Reference mission

The reference mission is the expected typical mission flown an average of ten times per week and should be used to optimize and assess operating costs. The reference mission is flown at 90% payload weight in Configuration 1. Aircraft will operate on both asphalt and gravel (unpaved) runways at all times of the year. Account for summer and winter runway conditions in the TOFL predictions.

Mission profile:

1. Warm up and taxi for 10 min.
 2. Take off over 50' obstacle in ≤ 500 ft
 3. Climb to cruise altitude
 4. Cruise
 5. Descend to sea level
 6. Land over 50' obstacle in ≤ 500 ft, with fuel/energy on board remaining sufficient for:
 - a. Climb to best loiter altitude
 - b. Loiter at best endurance speed for 45 minutes
 - c. Descend to sea level
 7. 10 min. taxi and shutdown
- Total range of flight segments 3-5 ≥ 450 nmi
 - Average ground speed segments 3-5 ≥ 130 ktas
 - No altitude requirements for cruise

Medevac mission

The Medevac mission is flown in Configuration 3. The total mission time for the round-trip flights must be minimized to improve likelihood of positive health outcomes for the patient. Refueling at the patient pick-up location is not available, therefore the aircraft must carry enough fuel to complete outbound and inbound flights, including the ability to loiter on both. Assume the use of gravel runways in both locations.

Outbound Flight

1. Warm up and taxi for 10 min.
 2. Take off over 50' obstacle in ≤ 500 ft
 3. Climb to cruise altitude
 4. Cruise
 5. Descend to sea level
 6. Land over 50' obstacle in ≤ 500 ft, with fuel/energy on board remaining sufficient for:
 - a. Climb to best loiter altitude
 - b. Loiter at best endurance speed for 45 minutes
 - c. Descend to sea level
 - d. Inbound flight including loiter segments (13a-13c)
 7. 10 min. taxi and shutdown
- Total range of flight segments 3-5 ≥ 350 nmi
 - No speed or altitude requirements for cruise
 - Outbound flight is flown with a full suite of medical equipment and stretcher on board, as well as two medical technicians
 - Assume a 45-minute turnaround time for assessing and loading the patient and patient escort on board when calculating the total mission time

Inbound Flight

8. Warm up and taxi for 10 min.
9. Take off over 50' obstacle in ≤ 500 ft
10. Climb to cruise altitude
11. Cruise

12. Descend to sea level
 13. Land over 50' obstacle in ≤ 500 ft, with fuel/energy on board remaining sufficient for:
 - a. Climb to best loiter altitude
 - b. Loiter at best endurance speed for 45 minutes
 - c. Descend to sea level
 - d. Loiter segments (6a-6c) on outbound flight
 14. 10 min. taxi and shutdown
- Total range of inbound flight segments 10-12 must equal the range of outbound flight segments 3-5, and be ≥ 350 nmi
 - No speed or altitude requirements for cruise
 - Inbound flight is flown with a full suite of medical equipment and stretcher on board, as well as two medical technicians, a patient, and a patient escort
 - Total mission time should be calculated as the time required for the outbound flight (without loiter segments 6a-6c), the 45-minute turnaround time, plus the inbound flight (without loiter segments 13a-13c)

4. Report Requirements

The technical proposal must clearly and concisely present the design of the aircraft covering all relevant aspects, features, and disciplines. Pertinent analyses and studies supporting design choices must be presented with sufficient detail. A full description of the aircraft is expected along with performance capabilities and operational limits. These include, at a minimum:

1. Aircraft weight statement; aircraft center-of-gravity envelope reflecting relevant payload and fuel allocations and limits for safe flight.
2. Materials selection for main structural groups and general structural design, including layout of primary airframe structure.
3. Complete geometric description, including clearances, control surfaces, and internal arrangement of passengers, cargo, and crew. 3-views, internal arrangements, and 3-D model imagery of appropriate quality are expected.
4. Important characteristics and performance descriptions for key mission segments during the design mission (including but not limited to: segment altitude, L/D, velocity, rate-of-climb, duration, fuel consumption, etc.), including takeoff and landing performance as well as flight into icing.
5. Performance flight envelope, payload-range, and V-n diagrams.
6. Propulsion system description and characterization of propulsion performance (including impacts of system operation).
7. Summary of basic stability and control characteristics including, but not limited to static margin, pitch, roll and yaw derivatives.
8. A discussion of the cruise speed and altitude trades and justification of the values chosen for development of the concept.
9. Discussion of equipment, technologies and/or concepts to improve passenger experience and technology acceptance (this may include, but is not limited to approaches to: reduce cabin noise, improve aircraft ride quality, safety, survivability, decrease manufacturing and operating costs)
10. Discussion of equipment, technologies and/or concepts included in the design to enable reliable operation in icing and cold weather conditions.
11. Cost estimates and business case analysis, including variable cost for reference mission, direct operating costs for the reference mission, and production cost per unit at 200, 500, and 1000 units.

The proposal response must include trade documentation on the two major aspects of the design development: the concept selection trades and the concept development trade studies.

- A) The team shall develop and present the alternative concepts considered leading to the down-select of their preferred concept. The methods and rationale used for the down-select must be included. At a minimum, a qualitative assessment of strengths and weaknesses of the alternatives shall be given, discussing merits, leading to a justification as to why the preferred concept is the best proposal response. Quantitative justification of why the selected proposal is the best at meeting the proposal measures of merit(s) will strengthen the proposal.
- B) In addition, the report shall include the major trade studies conducted justifying the optimization, sizing, architectural arrangement, and integration of the specifically selected proposal concept. Quantitative data shall be presented showing why their concept 'works' and is the preferred design compromise that best achieves the requirements of the RFP.

Specific analysis and trade studies of interest sought in proposals include:

1. Mission performance and sizing for the mission profiles.
2. Overall aircraft concept selection (airframe and propulsion system) vs. design requirements objectives

All concept and technology assumptions must be reasonable and justified for the EIS year.

5. Reference Material

- ASTM F3120: https://store.astm.org/f3120_f3120m-20.html

Appendix A: Flight into Known Icing Supplementary Information

Introduction

In-flight icing is a fundamental design requirement for all modern aircraft. Some aircraft are designed and certified to fly into known icing conditions. In these cases, icing is critical for performance and handling qualities leading to fundamental design requirements and sizing. For aircraft designed and certified to detect and exit icing conditions, or even avoid all together, ice detection methods or instrumentation and inadvertent icing encounters still must be addressed. Icing can have an influence on stall and operating speeds, flight controls, avionics, and overall aircraft integration.

Flight into Known Icing (FIKI) Mission Requirements

The icing environments for which fixed wing aircraft are certified are defined in Appendix C and O of Part 25 for transport category airplanes. The icing environment for small airplanes in ASTM F3120 (Standard Specification for Ice Protection for General Aviation Aircraft) is the same.

The Appendix C envelopes are based on analyses of airborne measurements in supercooled clouds at altitudes to about 20,000 ft. over the United States during the winters of 1945 through 1948. Since that time, these envelopes have served as the accepted meteorological data for use in the design and certification of ice protection equipment on civil airplanes.

The reference mission section for the RFP indicates that the aircraft is to be designed and certified to fly into the known icing conditions contained in Appendix C. It also notes that the certification options for Appendix O need to be specified and addressed.

The 14 CFR Part 23 regulations can be found at the following [link](#)¹. Section 23.2165 (Performance and flight characteristics requirements for flight in icing conditions), which can be found in Subpart B (Flight), provides the requirements for flight in icing. It refers to part 1 of the Appendix C icing envelope and notes that it is found in 14 CFR part 25. Part 1 of Appendix C can be found at the following [link](#)². It also states in § 23.2165 paragraph (a) that an applicant may wish to certify in “any additional atmospheric icing conditions.” This is intended to be covered by the icing envelope captured by 14 CFR 25 Appendix O:

¹ <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-23?toc=1>

² <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-25/appendix-Appendix%20C%20to%20Part%2025>

Supercooled Large Drop (SLD) Icing Conditions. A link to Appendix O can be found at the following [link](#)³. Additionally, for satisfying the detection requirements of §23.2165 paragraph (d), ASTM F3120 should be considered.

The RFP also states that the Supercooled Large Drop Icing (Appendix O) certification path should be identified. This is referring to the three SLD certification options specified in 25.1420, which are also options for complying with 23.2176(a) and (b) for icing conditions outside of Appendix C. These are referring to showing

- 1) that the aircraft can detect and safely exit icing conditions after an SLD encounter
 - 2) the aircraft can safely operate in a portion of Appendix O
- or
- 3) the aircraft can safely operate in all of Appendix O

Ice Protection System Considerations

Upon selection of ice protection systems (IPS), the effects of the IPS must be addressed/discussed. All IPS have an impact on airplane integration and performance. There are several common IPS types:

De-icing Boots

De-icing boots can be included to protect the leading edges of lifting surfaces. They operate by periodically inflating and causing ice to fracture and shed. They are typically pneumatically actuated. Considerations include intercycle ice (impacts of ice built up between de-icing cycles or over several deicing cycles at low speed and cold ambient temperature) which influence performance and handling qualities.

Electro-mechanical De-icing Systems

These systems operate by using electro-mechanical systems to impart an impact/vibration impulse that breaks the ice bond on the leading edge of a lifting surface. In some cases, these systems are informally referred to as “thumpers.” Similar to de-icing boots, intercycle ice needs to be addressed.

³ <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-25/appendix-Appendix%20O%20to%20Part%2025>

Pneumatic Anti-/De-icing Systems

Pneumatic IPS generally work by pumping hot air into the leading edge of lifting surfaces. This heat can be supplied continuously when the system is activated to provide fully evaporative or running wet anti-icing protection. They can also be cycled as a de-icing system. In addition to the consideration of de-icing similar to boots or electro-mechanical systems, these can also generate runback ice which will need to be addressed if present. Additional considerations are energy offtake from the engine, heat delivery to the leading edge, and special/volume integration.

Electro-thermal Anti-/De-icing Systems

Similar to pneumatic IPS, these systems work by turning electrical energy into thermal energy delivered to the leading edge of lifting surfaces to provide evaporative or running wet anti-icing protection, or de-icing. Additional considerations are energy offtake from the engine, heat delivery to the leading edge, and special/volume integration.

Fluidic/Weeping Ice Protection

Weeping ice protection systems work as anti-icing systems by delivering a freezing point suppressant, like a glycol-based fluid, through porous lifting surface leading edges in a thin layer continuously during IPS operation. Considerations include integration of pumps, deicing fluid weight/volume, and the volume of fluid required for safe mission planning.

The Aircraft Icing Handbook Vol. II (apps.dtic.mil) has example trade studies for airplanes of different sizes that consider different ice protection technologies.

Performance and Handling Qualities Impacts of Ice Shapes

Ice accretions can have large impacts on the performance and handling qualities of aircraft. Small shapes can have unexpectedly large impacts on lift loss and handling qualities impacts due to the three-dimensionality of the flow-fields (particularly when the wing flow is breaking down). This is why preactivation ice, residual ice, intercycle ice, and runback ice need to be addressed.

There are numerical modeling codes, in conjunction with computational fluid dynamics (CFD), which can be used to calculate ice shapes. It is common practice to generate ice shapes with these tools and then determine the impacts of the ice shapes using dry-air wind-tunnel testing or flight testing with simulated ice shapes. CFD still has challenges in calculating smooth surface separation leading to accurate C_{LMAX} and handling qualities predictions. That also holds true for ice shapes.

For the purposes of this RFP, the students can use the following information as guidance for determining the impacts of icing. If higher fidelity analysis is performed, that can be used instead.

It may be assumed that as an order of magnitude estimate, ice on leading edges such as wings and engine inlets can grow to 3-inch thickness in 45 minutes. This equates to 0.067 inch/minute, which may be used to estimate values such as pre-activation ice and inter-cycle ice thickness.

If using an ice detector, the minimum activation ice thickness is typically 0.02 inch, but thicker values have been used for applications that do not require high sensitivity. There may be additional ice accumulated in the time that is required for the protection system to become effective.

The following information is for sectional properties:

Preactivation Ice (see Appendix O, Part II, paragraph e for definition)

Ice thickness: 0.02 inches + growth during time for protection to be effective

$\Delta C_{l_{max}}$ = See Brumby chart below

ΔC_d = based on ice thickness

Intercycle Ice

Ice thickness: based on an accretion rate of 0.067 inch/minute

$\Delta C_{l_{max}}$ = See Brumby chart below

ΔC_d = based on ice thickness

Hold Ice

Ice thickness: 3 inch glaze ice horn

$\Delta C_{l_{max}}$ = See Brumby chart below, can limit reduction to -25%

ΔC_d = based on frontal area

It should be noted that the maximum lift loss covered in Brumby is sectional lift. For an airplane with the ice accretions associated with a hold in icing conditions with an operating Ice Protection System (IPS), the C_{LMAX} loss can be assumed to be -25% unless a more detailed analysis is shared. When determining stall angle of attack with ice, a linear lift curve slope up to stall can be assumed.

Ice on leading edges can have different shapes based on icing and flight conditions.

FIGURE 3-1. CLEAR ICE



FIGURE 3-2. CLEAR ICE BUILDUP WITH HORNS



FIGURE 3-3. RIME ICE



from "Pilot Guide: Flight in Icing Conditions", AC 91-74B faa.gov

Selected Aircraft Icing Terms

Anti-icing: The prevention of ice formation on airframe surfaces. The use of heat is the most common means of anti-icing.

Appendix C: Appendix C of the United States Chapter 14 Code of Federal Regulations Part 25 that defines icing conditions used for certification of large transport category aircraft.

Appendix O: Appendix O of the United States Chapter 14 Code of Federal Regulations Part 25 that defines large drop icing conditions used for certification of large transport category aircraft. It defines conditions for freezing drizzle and freezing rain.

Collection efficiency: The ratio of actual water collection rate to the water catch rate when water drop paths are straight lines. Also termed catch efficiency.

Continuous Maximum Icing: Icing category defined in Appendix C for "Stratiform Clouds", commonly used for design of wing, empennage, and windshield ice protection on transport aircraft.

De-icing: The removal of ice that has formed on airframe surfaces.

Fully evaporative anti-icing: Anti-icing with sufficient power to prevention of ice formation on airframe surfaces.

Freezing Drizzle: Drizzle size water drops at temperature slightly below freezing and characterized by relatively large water drops that may freeze in contact with airframe surfaces.

Freezing fraction: That part of the water catch that freezes.

Freezing rain: Rain at temperature slightly below freezing and characterized by relatively large water drops that may freeze in contact with airframe surfaces.

Glaze ice: Clear ice with rapid growth rate and characteristic "double horn" or "mushroom" formation. (This term is also used by pilots to describe a smooth film of ice covering leading edges at temperatures just below the melting point of ice.)

Ice accretion: A growth or buildup of ice; an ice formation.

Impingement limits: The end of the water impingement region on both upper and lower surfaces of an airfoil.

Intermittent maximum icing: Icing category defined in Appendix C, based on cumuliform clouds having high liquid water content for short times.

Langmuir drop size distribution: A seven-bin drop size distribution defining at representative drop size for each bin, and a fraction of the total water content of a cloud, something like a normal or "bell" curve. Named after Iring Langmuir, who proposed several distributions circa 1945. See FAA Advisory Circular 20-73A (Aircraft Ice Protection)

Liquid water content: Water contained as free moisture in a volume of air (does not include water in vapor form). Typically measured in g/m^3 (grams per cubic meter).

Mean effective drop diameter (MED): Half the volume of water in a given sample of air is contained in larger drops, half in smaller drops. Functionally interchangeable with MVD.

Mixed Ice: Simultaneous appearance of rime and clear ice or an ice formation that has the characteristics of both rime and glaze (or clear) ice. See [figure](#).

Median volumetric diameter (MVD): drop diameter defined by the condition that half the volume of water in a given sample of air is contained in large drops, half in small drops. Functionally interchangeable with MED.

Micrometer (μm): One millionth of a meter. Sometimes called "micron" in older literature.

Rime ice: Milky white, low-density ice formed at low temperatures with a relatively streamlined shape; also referred to as spearhead and knife-edge ice. See [figure](#).

Runback ice: Ice accumulated aft of the protected region, resulting from the water running back area freezing (may be found with partially evaporative anti-icing systems and with de-icing systems at temperatures near freezing). See [figure](#).

Running wet: A condition at which an airframe surface is maintained above 32°F (by a heating anti-icing system) so that impinging water drops will not freeze.

Supercooled water drops: Small water drops suspended in the air at temperatures below the melting point of ice (0°C or 32°F).