Hybrid-electric Regional Turboprop RFP

Background

The regional turboprop market currently has products that are based upon older designs that have their origins in the 1980's with the ATR72 and De Havilland Canada Dash 8 Q400 being the current incumbent products.

The industry analyses forecast a ~2,000-unit regional aircraft market over the next 20 years. This presents an opportunity to develop new regional aircraft to satisfy the 50-seat portion of the market that meets the US domestic "Scope Clause" that has significantly better fuel burn and economics than existing options. The overall goal is to be at least 20% better than existing 50 seat regional turboprops in 500 nmi block fuel per seat with a cost to build that is comparable to the existing aircraft, including the hybrid propulsion system.

In order to minimize the direct emissions from the aircraft, the propulsion system is to be hybrid-electric. The amount of hybridization and architecture (serial or parallel hybrid) is a design choice that that the teams are free to make.

Requirements (M) = Mandatory Requirement (T) = Tradable requirement

- **General Requirements**
  - Figure of merit
    - 20%+ Reduction in block fuel on a 500 nmi mission vs. current turboprops
    - Reduction in emissions (CO_2, NOX, soot, etc) vs. current turboprops
  - Entry Into Service (EIS)
    - (M) 2035 for airplane
    - (M) Use existing engine(s) or one that reflect a technology level which could be certified by 2034, at least a year prior to the airplane EIS.
      - Assumptions on at least specific fuel consumption/efficiency, thrust/power and weight must be documented.
      - Engine/propulsion system assumptions documented
        - Use of engine (s) that reflect a technology level which could in service by 2035.
        - Assumptions on at least specific fuel consumption/efficiency, thrust/power and weight should be specified.
        - Ensure that the power used by alternators, generators or other devices are accounted for.
        - Use of electric motor(s), controller(s) and batteries which could be in service by 2034 and document battery energy and power density assumptions based on reasonable technology trends.
          - Document system efficiency including at least the efficiency of the batteries, wires, controllers, thermal management system, connectors, motors and propellers to calculate a total propulsive efficiency. (Example)
          - Exact components will depend upon the type of hybrid system chosen
- Passenger Capacity
    - (M) 50 +0/-4 passengers in a single class seating arrangement at a 30" seat pitch
  - Design Range with full passengers
    - (M) 1,000 nmi
  - Cruise Speed
    - (M) Minimum Cruise Speed of 275 KTAS
    - (T) Target Cruise Speed of 350 KTAS

- Seat Width
  - (M) Minimum seat width of 17.2”
  - (T) Target seat width of 18”
  - (M) At least a 2” arm rest width
- Cross-Section
  - (M) Stand up height in the aisle similar to competitive aircraft
  - (M) Baggage compartment is tall enough to be serviced ergonomically
  - (M) 18” minimum aisle width
- Wing Span
  - (T) Maximum of ICAO Code B (< 24 m)
  - (M) Maximum of ICAO Code C (< 36 m)
- Performance
  - (M) Approach speed category C (<141 knots)
  - (M) Design Range mission performance
    - Maximum takeoff field length of 4,500’ over a 50’ obstacle to a runway with dry pavement (sea level ISA + 18°F day).
    - Maximum landing field length of 4,500’ over a 50’ obstacle to a runway with dry pavement (sea level ISA + 18°F day) at maximum landing weight
    - Takeoff, and landing performance should also be shown at 5,000’ above mean sea level (ISA + 18°F)
    - Distance to climb up to initial cruising altitude less than 200 nmi
    - Initial cruising altitude of at least FL280
  - Economic Missions
    - (M) Show fuel burn performance per trip and per seat and compare with the appropriate competitive aircraft at 500 nmi
- (M) Meet 14 CFR 25.121 Climb Gradient Requirements
- Certifications
  - (M) Capable of VFR and IFR flight with an autopilot
  - (M) Capable of flight in known icing conditions
  - (M) Meets applicable certification rules in FAA 14 CFR Part 25
    - All missions below assume reserves and equipment required to meet applicable FARs
  - (T) Provide systems and avionics architecture that will enable autonomous operations
    - Provide a market justification for choosing to either provide or omit this capability
    - Determine how the design would change

- **Payload Requirements**
  - (M) Crew: 2 pilots and 1 cabin crew member for every 50 passengers
  - Pilot and baggage weights
    - Pilot/Crew weight of 190 lb
    - Baggage weight per pilot of 30 lb and volume of at least 4 cubic feet per person
  - Passenger and baggage weights
    - 200 lbs per passenger
    - 40 lb (5 cubic feet) of baggage per passenger

Design Objectives

- Minimize production cost by choosing materials and manufacturing methods appropriate for the annual production rate that is supported by the team’s assessment of the potential market size.
- Make the aircraft visually appealing so it will be marketable and identify what features are important to the operators for different missions.

- Make the aircraft reliability equal or better than that of comparable aircraft.
- Make the aircraft maintenance equal or better than that of comparable aircraft.

Other features and considerations

- Flying qualities should meet CFR Part 25.
- Identify all systems functionality and components that are required for the aircraft to operate in both controlled and uncontrolled airspace.
- List the equipment required.
- Consider what features will be basic and which will be optional to a customer.

Report and Design Data Requirements

The technical report shall present the design of this aircraft clearly and concisely; it shall cover all relevant aspects, features, and disciplines. Pertinent analyses and studies supporting design choices shall be documented.

Full descriptions of the aircraft are expected along with performance capabilities and operational limits. These include, at a minimum:

1. A description of the design missions defined for the proposed concepts for use in calculations of mission performance as per design objectives. This includes the selection of cruise altitude(s) and cruise speeds supported by pertinent trade analyses and discussion.
2. Aircraft performance summaries shall be documented and the aircraft flight envelope shall be shown graphically.
3. Payload range chart(s)
4. A V-n diagram for the aircraft with identification of necessary aircraft velocities and design load factors.
    a. Required gust loads are specified in 14 Code of Federal Regulations (CFR) Part 25.
5. Materials selection for main structural groups and general structural design, including layout of primary airframe structure as well as the strength capability of the structure and how that compares to what is required at the ultimate load limits of the aircraft. The maximum dive speed of the aircraft shall be specified.
6. Complete geometric description, including dimensioned drawings, control surfaces sizes and hinge locations, and internal arrangement of the aircraft illustrating sufficient volume for all necessary components and systems.
    a. Scaled three-views (dimensioned) and 3-D model imagery of appropriate quality are expected. The three-view must include at least:
        i. Fully dimensioned front, left, and top views
        ii. Location of aircraft aerodynamic center (from nose)
        iii. Location of average CG location (relative to nose)
        iv. Tail moment arms
    b. Diagrams and/or estimates showing that internal volume requirements are met, including as a minimum the internal arrangements of the cargo, cargo and maritime surveillance variants.
        i. Cross-section showing cargo seats
        ii. Layout of cargo compartment
        iii. Layout of cockpit
        iv. Layout of passenger cabin, cargo compartment, and size and location of passenger and cargo doors
        v. Fuselage centerline diagram
    c. Diagrams showing the location and functions for all aircraft systems.
7. Important aerodynamic characteristics and aerodynamic performance for key mission segments and requirements

8. Aircraft weight statement, aircraft center-of-gravity envelope reflecting payloads and fuel allocation. Establish a forward and aft center of gravity (CG) limits for safe flight.
    a. Weight assessment summary shall be shown at least at the following level of detail:
        i. Propulsion (engine/motor, batteries, controller, wiring, heat sink, cowl, strut, propeller, spinner etc. as applicable)
        ii. Airframe Structure
            1. Wing
            2. Empennage
            3. Landing Gear (including wheels tires and brakes)
            4. Fuselage
        iii. Control system (flight controls linkages, hydraulics, wires, actuators bellcranks, engine controls etc.)
        iv. Payloads (Cargo Layouts with all container and pallet types, cargo barrier, etc.)
        v. Systems
            1. Instruments and Avionics
            2. Fuel/oil
            3. Hydraulic/pneumatic/electrical systems (if chosen)
9. Propulsion system description and characterization including performance, dimensions, and weights. The selection of the propulsion system(s), sizing, and airframe integration must be supported by analysis, trade studies, and discussion
    a. Breakdown of the battery system to include metrics at the cell level and system level, and also include a technical overview of pack integration strategies.
10. Summary of basic stability and control characteristics; this should include, but is not limited to static margin, pitch, roll and yaw derivatives.
11. Summary of cost estimate and a business case analysis. This assessment should identify the cost groups and drivers, assumptions, and design choices aimed at the minimization of production costs.
    a. Estimate the non-recurring development costs of the airplane including engineering, FAA/EASA certification, production tooling, facilities and labor
    b. Estimate the fly away cost
    c. Estimate the price that would have to be sold for to generate at least a 15% profit
        i. Show how the airplane could be produced profitably at production rates ranging from 3-6 airplanes per month or a rate that is supported by a brief market analysis
    d. Estimate of direct operating cost per airplane flight hour
        i. Fuel, oil, tires, brakes, battery, and other consumable quantities
        ii. Estimate of maintenance cost per flight hour
        iii. Flight crew costs per hour
12. Follow AIAA"s "Guidelines for Analysis of Hybrid Electric Aircraft System Studies" for the hybrid-electric portion of the analysis and documentation.

The design report will include trade documentation on the two major aspects of the design development, a) the concept selection trades, and b), the concept development trade studies.
The student(s) is (are) to 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 shall be presented. 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 was the best design. Quantitative justification of why the selected concept is the best at meeting the measures of merit(s) will strengthen the report.
In addition, the submittal shall include the major trade studies conducted justifying the optimization, sizing, architectural arrangement and integration of the specifically selected concept. Quantitative data shall be presented showing why their concept 'works' and is the preferred design compromise that best achieves the design requirements.

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Specific analysis and trade studies of interest include:
Mission performance and sizing for the definition of a mission profiles.
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.

Reference Material

https://www.embraermarketoutlook2021.com/
https://www.airbus.com/aircraft/market/global-market-forecast.html
https://www.boeing.com/commercial/market/commercial-market-outlook
Guidelines for Analysis of Hybrid Electric Aircraft System Studies

Existing Regional Aircraft and Reference Information
https://en.wikipedia.org/wiki/Scope_clause
https://www.skybrary.aero/index.php/ICAO_Aerodrome_Reference_Code
https://en.wikipedia.org/wiki/Embraer_next-generation_turboprop
https://en.wikipedia.org/wiki/ATR_72
https://en.wikipedia.org/wiki/De_Havilland_Canada_Dash_8

FAA 14 CFR Part 25
https://www.ecfr.gov/cgi-bin/text-idx?SID=ffa15036a5063e0af45f080a365945dc&mc=true&tpl=/ecfrbrowse/Title14/14cfr25_main_02.tpl