Stratospheric Payload Delivery
Undergraduate Individual Design Competition
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Background
Solar Radiation Management (SRM) may offer a way to cool the planet while other technologies are developed and deployed to reduce global warming climate change. If the planet warms to the point where governments need a temporary option to reduce the average temperature, multiple options have been proposed. One radical approach is to inject aerosol particles in the stratosphere where they reflect some of the incoming solar radiation and alter the planetary energy balance and reduce the temperature. These particles circulate for some time before falling to the ground and a continuous dispensing of particles would be required to maintain the artificial cooling. One method of dispensing these particles is with a fleet of high-altitude aircraft.

This Request for Proposal (RFP) is for the design of an airplane capable of conducting a payload dispensing mission at 65,000 ft with an entry into service (EIS) date 2031.

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

- **General Requirements**
  - (M) Capable of taking off and landing from concrete runways
  - (M) Cruise Mach $\geq$ 0.5
  - (M) Capable of VFR and IFR flight
  - (M) Capable of flight in known icing conditions
  - (M) Meets applicable certification rules in FAA 14 CFR Part 23
    - All missions below assume reserves and equipment required to meet applicable FARs
  - (M) Engine/propulsion system assumptions documented and the use of an engine that can be in service by 2030.
    - Document assumptions on, at a minimum, specific energy consumption/efficiency, thrust/power and weight should be specified
- **Design Missions**
  - (M) Crew: 4 flight crew
  - (M) Passenger capacity: 0
  - (M) 400 nmi Payload Dispensing Mission
    - Payload assumptions
      - Minimum payload weight of 30,000 lb (13,608 kg)
      - The payload should be assumed to be a liquid sulfuric acid and should be contained in an appropriate tank. The tank weight and a dispersing pump and nozzles should be included in the aircraft system weights.
      - Payload is dispensed during the mission, starting at the beginning of the cruise leg, and can be considered 0 lb at the end of the cruise leg.
      - Payload liquid density is 15 lb/gal (1797 kg/m3)
      - Note that more benign payloads may to developed by 2030, but use these assumptions for this RFP.
    - Cruise range of 200 nm (370.4 km) out and 200 nm (370.4 km) back
    - Time to climb $\leq$ 1 hour. No range credit for climb and descent legs
    - Constant cruise altitude of 65,000 ft (19.812 km)
    - Maximum takeoff and landing field lengths of 8,000’ over a 50’ obstacle to a runway with dry pavement (sea level ISA + 61^{o} F day).
    - Takeoff and landing performance should also be shown at on a standard day (sea level ISA +0^{o} day) and also at 2,500’ above mean sea level (ISA + 57^{o} F).
  - (M) 3000 nmi Ferry Mission
    - No payload
    - Minimum range of 3,000 nm (5,556 km)
    - Takeoff and landing requirements are the same as for Payload Dispensing Mission

Other features and considerations

- Flying qualities should meet CFR Part 23
- Identify all systems functionality and components that are required for the aircraft to operate in both controlled and uncontrolled airspace.
- List the equipment required to conduct the payload dispensing and ferry missions
- Base your estimated fleet size on your assumed daily utilization of the aircraft fleet and a requirement to dispense 3 million metric tons of payload a year

Design Objectives

- Minimize the total cost to dispense the payload. The primary metric should be cost to build and operate the aircraft divided by metric ton a payload dispensed.

Notes and assumptions:

- Assume an EIS of 2030 when making technology decisions

Proposal and Design Data Requirements

The technical proposal 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 requirement or 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 Federal Aviation Regulations (FAR) 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.
        i. Cross-section showing payload configuration
        ii. 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 payload and energy weight allocation. Establish a forward and aft center of gravity (CG) limits for safe flight in the normal categories.
    a. Weight assessment summary shall be shown at least at the following level of detail:
        i. Propulsion
        ii. Airframe Structure
            1. Wing
            2. Empennage
            3. Landing Gear
            4. Fuselage
        iii. Control systems
        iv. Payload
        v. Systems
            1. Instruments and Avionics
            2. Fuel/oil (battery if electric)
            3. Hydraulic/pneumatic/electrical systems (if chosen)
            4. System to contain and dispense the liquid payload
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
10. Summary of basic stability and control characteristics; this should include, but is not limited to, static margin.
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 of direct operating cost per metric ton of payload dispensed
12. Lifecycle emissions analysis, which includes:
   a. Emissions associated with aircraft production
   b. In-service emissions
      i. Analysis should include key greenhouse gases such as Carbon Dioxide and Nitrous Oxide

The proposal response 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.

A) The student is 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 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 submittal 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 RFP

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

1. Mission performance and sizing for the definition of 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.

Procured Data

No data is procured as part of this RFP.

Reference Material

- 14 CFR Part 23
  - https://www.ecfr.gov/cgi-bin/text-idx?SID=77b75e4594e5c1b7992d66b816d9f3c6&mc=true&tpl=/ecfrbrowse/Title14/14cfr23_main_02.tpl
- Bingaman, at el., "A Stratospheric Aerosol Injection Lofter Aircraft Concept: SAIL-01", AIAA-2022-0618.
  - https://doi.org/10.2514/6.2020-0618
  - Contains a list of additional references on climate change and Stratospheric Aerosol Injection (SAI)

Representative High Altitude Aircraft Designs

- Martin RB-57F
- Lockheed U-2S
- Ryan AQM-91
- Boeing B-47