

Request for Proposal

Electric Vertical Takeoff and Landing (E-VTOL) Aircraft

Opportunity Description

The recent and continuing development in technological state-of-the-art for electric motors, power electronics, and most importantly batteries has led to substantial interest in the design of flight vehicles with all-electric propulsion. In such vehicles, propulsive power requirements are met using electric batteries relative to fossil fuels limits the feasibility of all-electric propulsion for larger vehicles flying longer distances.

There is, however, an exciting opportunity for applying all-electric propulsion to smaller vehicles doing short-hop flights as part of an On-Demand Mobility [ODM] or Urban Air Mobility [UAM] concept of operations. The former requires vehicles with very short turn-around times, while the latter essentially-mandates vertical takeoff and landing [VTOL] capability. Electric propulsion offers a broad spectrum of vehicle configuration possibilities through which designers may use aero-propulsive synergies to their advantage.

In light of the above, this Request for Proposal [RFP] is for the design of an Electric Vertical Take-off and Landing [E-VTOL] flight vehicle to meet the ODM/UAM mission and performance requirements that follow, with the applicant given significant freedom with regard to the configuration of the vehicle itself.

Project Objective

The over-arching goal is the design of an Electric Vertical Takeoff and Landing [E-VTOL] flight vehicle to meet ODM/UAM requirements. The vehicle must be capable of transporting four occupants. More detailed requirements follow. The applicant is given significant leeway with regard to the configuration of the vehicle. However, safety of flight following major failure modes (e.g., power-plant, propulsors, etc.) must be assessed. Assumptions regarding technologies and their states-of-the-art must be referenced and shown to be consistent with an intended 2028 Entry Into Service (EIS). Adequate consideration should be given to passenger experience, including but not limited to ease of boarding and egress, interior cabin noise, and overall ride quality. The applicant must adequately document vehicle dimensions, mass properties, propulsion and energy system sizing and specifications, as well as overall vehicle performance.

Requirements and Constraints

- **Crew and payload:** Vehicle must be designed for 4 occupants, either 1 pilot/operator and 3 passengers, or an autonomous design with 4 passengers.

-Pilot/operator (if present): 180 lb; Passengers (each): 180 lb + 20 lb baggage

- **Sizing mission description:** The vehicle must be sized for the following mission, which may be assumed to be flown in standard atmosphere (ISA + 0), with no wind. For simplicity, sea-level elevation may be assumed for takeoff and landing surfaces. The mission is flown with a full crew and payload (weights defined above).
 1. Takeoff and post-takeoff hover: Vertical takeoff terminating in hover 50 ft above takeoff surface. Total time duration (takeoff + hover) – 90 seconds.
 2. Transition (if applicable) and climb: Minimum level-off altitude of 1,500 ft MSL. Credit may be taken for distance traversed during transition (if applicable) and climb. Average rate of climb: 500 feet/minute minimum.
 3. Cruise to destination: Distance between origin and destination site: 60 statute miles (note the unit). Minimum cruising altitude 1,500 ft MSL.
 4. En-route descent: No distance credit. Descent terminates 50 ft above landing surface. Instantaneous descent rate not to exceed 1,000 feet/minute.
 5. Pre-landing hover and landing: Hover at 50 ft above landing surface followed by vertical landing. Total time duration (hover + landing) – 90 seconds.
 6. Reserve mission definition: Landing attempt aborted at 50 ft above landing surface. Climb to 1,000 ft MSL. Divert 2 statute miles to alternate landing destination. Pre-landing hover and vertical landing, with 90 seconds duration (hover + landing).
 - Note: Average speed measured over Segments 2-4 must be minimum 150 mph.

- **Typical/economic mission description:** The following typical mission may be considered for economic analyses and optimization for operating efficiency. The mission may be assumed to be flown in standard atmosphere (ISA + 0), with no wind. For simplicity, sea-level elevation may be assumed for takeoff and landing surfaces. The mission is flown with only 2 passengers (+ their baggage).
 1. Takeoff and post-takeoff hover: Vertical takeoff terminating in hover 50 ft above takeoff surface. Total time duration (takeoff + hover) – 30 seconds.
 2. Transition (if applicable) and climb: Minimum level-off altitude of 1,500 ft MSL. Credit may be taken for distance traversed during transition (if applicable) and climb. Average rate of climb: 500 feet/minute minimum.
 3. Cruise to destination: Distance between origin and destination site: 30 statute miles (note the unit). Minimum cruising altitude 1,500 ft MSL.
 4. En-route descent: No distance credit. Descent terminates 50 ft above landing surface. Instantaneous descent rate not to exceed 1,000 feet/minute.
 5. Pre-landing hover and landing: Hover at 50 ft above landing surface followed by vertical landing. Total time duration (hover + landing) – 30 seconds.
 - Note: Average speed measured over Segments 2-4 must be minimum 150 mph.

- **Point performance requirements:**

- “High, hot” takeoff and hover: Demonstrate vertical takeoff and hover at 50 ft above a takeoff surface at 5,000 ft MSL elevation, with ISA + 10 degrees C temperature offset.
- “High, hot” transition (if applicable) and climb: With maximum payload, starting from hover at 50 ft above a takeoff surface at 5,000 ft MSL elevation, with ISA + 10 degrees C temperature offset, demonstrate transition (if applicable) and at least 500 feet per minute rate of climb.
- Maximum speed requirement: Demonstrate a maximum speed of at least 176 mph at 50% payload, in standard ISA + 0 still atmosphere, at a selected altitude between 1,500 – 3,500 ft MSL.

- Capable of VFR and IFR flight with an autopilot

- **Propulsion & Energy Systems Assumptions:**

1. Electric motors: Use of electric motor(s) that will be in service by 2028. Assumed electric motor state-of-the-art (e.g., power density in kW/kg) must be substantiated based on reasonable and referenced technology trends. Electric motor efficiency must be accounted for in vehicle sizing and mission analyses.
2. Power electronics: The same comment (as above) also applies for power electronics, power conversion devices, and controllers, as applicable.
3. Wiring/cabling: The weight of wiring/cabling should be calculated based on lengths, power being transferred, and voltage level. Power transmission efficiency through wiring/cabling should be accounted for in vehicle sizing and mission analyses.
4. Batteries: The EIS target of 2028 should be used for battery state-of-the-art assumptions. Gravimetric energy density (Wh/kg), volumetric energy density (Wh/L), power density (kW/kg), and efficiency assumptions must be substantiated based on reasonable and referenced technology trends. Assumed battery energy density must not exceed **450 Wh/kg – P x 85s**, where P is the peak specific power of the pack.
 1. Note: For maintaining battery health, 10% of the battery’s state-of-charge shall be deemed unavailable for supplying mission energy requirements (including those of reserve mission). In other words, no more than 90% of the battery’s energy capacity should be charged.
 2. The assumed life of the battery pack (in terms of cycles) must be clearly documented and based on reasonable and referenced figures/trends. The cost of replacement of the battery at the end of its life cycle must be accounted for in cost calculations.
 - Note: The weights of 1-4 above must appear as separate line items in the vehicle’s weight breakdown (weight statement).

- **Autonomous flight:**
 - If pursued, provide systems and avionics architecture that could enable autonomous flight
 - Provide a market justification for choosing to either provide or omit this capability

Design Objectives

Demonstrate design efforts aimed at minimizing the following:

- Propulsive power requirements: measured by the total installed power rating of the propulsion system (measured in shp or kW)
- Mission energy requirements: measured by required battery energy (kWh), as measured over the course of the typical/economic mission

Make the vehicle visually appealing so it will be marketable and identify what features are important to the operators for different missions.

Proposal and Design Data Requirements

The technical proposal shall present the design of this vehicle 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 vehicle are expected along with performance capabilities and operational limits. These include, at a minimum:

1. A complete 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 speed(s) supported by pertinent trade analyses and discussion. The vehicle's performance in each segment should also be summarized, including but not limited to equivalent segment duration, lift-to-drag ratio, mean propulsive power requirement (measured at battery output), and segment energy consumption.
2. Vehicle performance summaries should be documented, and the flight envelope shall be shown graphically.
3. Payload range chart(s) should be documented
4. 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 vehicle.

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5. Complete geometric description, including dimensioned drawings, and internal arrangement of the vehicle illustrating sufficient volume for all necessary components and systems.
 - Scaled three-views (dimensioned) and 3-D model imagery of appropriate quality are expected. The three-view must include at least:
 1. Fully dimensioned front, left, and top views
 2. Location of vehicle aerodynamic center (from nose)
 3. Location of average CG location (relative to nose)
 4. Control surface moment arms (if applicable)
 - Diagrams and/or estimates showing that internal volume requirements are met, including as a minimum the internal arrangements of the passenger, cargo and maritime surveillance variants.
 1. Cross-section showing passenger seats
 2. Layout of passenger cabin
 3. Layout of cockpit
 4. Layout of cargo and size and location of any unique cargo doors
 5. Fuselage centerline diagram
 - Diagrams showing the location and functions for all vehicle systems.
6. Important aerodynamic characteristics and aerodynamic performance for key mission segments and requirements
7. Vehicle weight statement, center-of-gravity envelope reflecting varying payloads. Establish forward and aft center of gravity (CG) limits for safe flight.
 - Weight assessment summary with at least at the following level of detail:
 1. Propulsion and energy (motors, batteries, power electronics, wiring, thermal management system, etc. as applicable)
 2. Airframe Structure – Applicants are expected to define major sub-categories under this category based on the specific configuration that they are proposing.
 3. Control system (including but not limited to flight controls linkages, hydraulics, wires, actuators bell-cranks, engine controls, etc.)
 4. Payloads (seats, seatbelts, cushions, and other cabin systems)
 5. Systems
 - Instruments and Avionics
 - Hydraulic/pneumatic/electrical systems (if chosen)
8. Propulsion and energy systems description and characterization including performance, dimensions, and weights. The selection of the propulsion and energy system(s) and their sizing based on constraining operating scenarios (sizing for propulsive power requirements as well as sizing for mission energy requirements) must be clearly documented. In sizing of propulsion and energy systems, at least a

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basic analysis of redundancy and safe post-failure operability is expected. Airframe integration must be supported by analysis, trade studies, and discussion.

9. Summary of basic stability and control characteristics; this should include, but is not limited to calculation of aerodynamic center, static margin, pitch, roll and yaw derivatives. Sufficient stability & control analysis should be included to demonstrate that the proposed concept is stable and controllable over its flight envelope.

10. 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 costs.
 - Estimate the non-recurring development costs of the vehicle, including engineering, production tooling, facilities and labor

 - Estimate the fly away cost of the vehicle

 - Estimate the trip cost for performing the typical/economic mission and compare with other transportation modes over the same distance.

 - Estimate the selling price needed to generate at least a 15% profit
 - Show how the vehicle could be produced profitably at a production rate that is supported by a brief market analysis

 - Estimate of direct operating cost per flight hour, including
 - Cost associated with any consumable items

 - Estimate of maintenance cost per flight hour

 - Pilot/operator costs per flight hour

 - Cost associated with battery recharging, or swap-outs, as applicable

11. The proposal response will include the trade documentation on the two major aspects of the design development, a) the concept selection trades, and b), the concept development trade studies. The students 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

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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.

12. 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 comprise that best achieves the RFP.

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.

Additional Contacts

All technical questions pertaining to this RFP should be directed to Imon Chakraborty via email at: imonchakraborty@gatech.edu

Any updates to this RFP will be posted on the AIAA Design Competitions web site <http://www.aiaa.org/DesignCompetitions/>

Reference Material

- FAA Part 23: https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title14/14cfr23_main_02.tpl
- Uber Elevate website: <https://www.uber.com/info/elevate/>
- Uber Elevate whitepaper: <https://www.uber.com/elevate.pdf>

Design Competition Rules

Eligibility Requirements

- All AIAA Student members are eligible and encouraged to participate. Membership with AIAA must be current to submit a report and to receive prizes.
- Students must submit their letter of intent and final report via the online submission to be eligible to participate. **No extensions will be granted.**
- More than one design may be submitted from students at any one school.
- If a design group withdraws their final report from the competition, the team leader must notify AIAA Headquarters immediately.
- Design projects that are used as part of an organized classroom requirement are eligible and encouraged for competition.

Schedule

- Letter of Intent — 10 February 2019 (11:59 pm Eastern Time)
- Proposal delivered to AIAA Headquarters — 10 May 2019 (11:59 pm Eastern Time)
- Announcement of Winners — 31 August 2019 (11:59 pm Eastern Time)
 - Engine Design Competition dates
 - Letter of Intent – 14 February 2019 (11:59 pm Eastern Time)
 - Proposal submitted, via online submission site to AIAA Headquarters – 16 May 2019 (11:59 pm Eastern Time)
 - Round 1 evaluation completed – 30 June 2019 (11:59 pm Eastern Time)
 - Round 2 presentations at AIAA Propulsion and Energy Forum 2019

Categories/Submissions

- Team Submissions
 - Team competitions will be groups of not more than ten AIAA Student Members per entry.
- Individual Submissions
 - Individual competitions will consist of only one AIAA Student member per entry.
- Graduate
 - Graduate students may participate in the graduate categories only.
- Undergraduate
 - Undergraduate students may participate in the undergraduate categories only.
- Letter of Intent (LOI)
 - A Letter of Intent indicating interest in participating in the design competitions is required before submitting a final report.
 - All Letters of Intent must be submitted through the online submission system.
 - Letter of Intent must include student's names, emails, AIAA membership numbers, faculty advisor(s) names, emails, and project advisor(s) names and emails. Incomplete LOI's will result in the Team or Individual being ineligible to compete in the competition.
- Submission of Final Design Report

Each team or individual must provide an electronic copy their design report as outlined below to the online Submission site

 - An electronic copy of the report in Adobe PDF format must be submitted to AIAA using the online submission site. Total size of the file cannot exceed 25 MB.
 - Electronic report files must be named: "2019_[university]_DESIGN_REPORT.pdf"
 - A "Signature" page must be included in the report and indicate all participants, including faculty and project advisors, along with students' AIAA member numbers and signatures.
 - Electronic report should be no more than 100 pages, double-spaced (including graphs, drawings, photographs, and appendices) if it were to be printed on 8.5"x11.0" paper, and the font should be no smaller than 10 pt. Times New Roman.

Copyright

All submissions to the competition shall be the original work of the team members.

Authors retain copyright ownership of all written works submitted to the competition. By virtue of participating in the competition, team members and report authors grant AIAA non-exclusive license to reproduce submissions, in whole or in part, for all of AIAA's current and future print and electronic uses. Appropriate acknowledgment will accompany any reuse of materials.

Conflict of Interest

It should be noted that it shall be considered a conflict of interest for a design professor to write or assist in writing RFPs and/or judging proposals submitted if (s)he will have students participating in, or that can be expected to participate in those competitions. A design professor with such a conflict must refrain from participating in the development of such competition RFPs and/or judging any proposals submitted in such competitions.

Awards

The prize money provided for the competitions is funded through the AIAA Foundation. The monetary awards may differ for each competition, with a maximum award of \$1,000. The award amounts are listed below.

The top three design teams will be awarded certificates. One representative from the first place team *may be* invited by the Technical Committee responsible for the RFP to make a presentation of their design at an AIAA forum. A travel stipend *may be* available for some competitions, with a maximum travel stipend of \$1,000 which may be used to help with costs for flight, hotel, or conference registration to attend an AIAA forum.

Aircraft Design Competitions

- Graduate Team Aircraft – Electric Vertical Takeoff and Landing (E-VTOL) Aircraft
- Undergraduate Team Aircraft – Thin Haul Transport and Air Taxi
 - 1st Place: \$500; 2nd Place: \$300; 3rd Place: \$250
- Undergraduate Individual Aircraft – Power Line Survey Unmanned Aircraft Systems
 - 1st Place: \$1,000; 2nd Place: \$500; 3rd Place: \$300

Engine Design Competition

- Undergraduate Team Engine –Candidate Engines for Hybrid Electric Medium Altitude Long Endurance Search and Rescue UAV
 - 1st Place: \$500; 2nd Place: \$300; 3rd Place: \$250

Space Design Competition

- Undergraduate Team Space Design – Reusable Lunar Surface Access Vehicle
 - 1st Place: \$500; 2nd Place: \$300; 3rd Place: \$250

Structures Design Competition

- Graduate Team Structures – Design of the Structure for a VTOL Taxi
- Undergraduate Team Structures – Design of Deployable Solar Array Structure
 - 1st Place: \$500; 2nd Place: \$300; 3rd Place: \$250

Missile Systems Design Competition

- Undergraduate Team Missile Systems - Design of a Long Range Strategic Missile
 - 1st Place: \$500; 2nd Place: \$300; 3rd Place: \$250

Proposal Requirements

The technical proposal is the most important factor in the award of a contract. It should be specific and complete. While it is realized that all of the technical factors cannot be included in advance, the following should be included:

- Demonstrate a thorough understanding of the Request for Proposal (RFP) requirements.
- Describe the proposed technical approaches to comply with each of the requirements specified in the RFP, including phasing of tasks. Legibility, clarity, and completeness of the technical approach are primary factors in evaluation of the proposals.
- Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, systems analysis, method of attack, and discussions of new techniques should be presented in sufficient detail to permit engineering evaluation of the proposal. Exceptions to proposed technical requirements should be identified and explained.
- Include tradeoff studies performed to arrive at the final design.
- Provide a description of automated design tools used to develop the design.

Basis for Judging

The AIAA Technical Committee that developed the RFP will serve as the judges of the final reports. They will evaluate the reports using the categories and scoring listed below. The judges reserve the right to not award all three places. Judges' decisions are final.

1. Technical Content (35 points)

This concerns the correctness of theory, validity of reasoning used, apparent understanding and grasp of the subject, etc. Are all major factors considered and a reasonably accurate evaluation of these factors presented?

2. Organization and Presentation (20 points)

The description of the design as an instrument of communication is a strong factor on judging. Organization of written design, clarity, and inclusion of pertinent information are major factors.

3. *Originality (20 points)*

The design proposal should avoid standard textbook information, and should show the independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the method show an adaptation or creation of automated design tools?

4. *Practical Application and Feasibility (25 points)*

The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or insolvable problems.