2012-2013 AIAA Foundation Undergraduate Team Aircraft Competition

Design of a 2030 Regional Airliner Considering Hybrid Electric Propulsion

I. Rules – General

1. All undergraduate AIAA Student Members are eligible and encouraged to participate.

2. An electronic copy of the report in MS Word or Adobe PDF format must be submitted on a CD or DVD to AIAA Student Programs. Total size of the file(s) cannot exceed 20 MB.

Students may submit their final report via email to the AIAA Student Programs Coordinator (Rachel Andino, rachela@aiaa.org).

A "Signature" page must be included in the report and <u>indicate all participants, including faculty and project advisors, along with students' AIAA member numbers and signatures</u>. Designs that are submitted must be the work of the students, but guidance may come from the Faculty/Project Advisor and should be accurately acknowledged.

Each proposal should be no more than 100 double-spaced pages (including graphs, drawings, photographs, and appendices) if it were to be printed on 8.5" x 11.0" paper, and the font should be no smaller than 10 pt. Times New Roman. Up to five of the 100 pages may be foldouts (11" x 17" max).

3. *Design projects that are used as part of an organized classroom requirement are eligible and encouraged for competition.*

4. The prizes shall be: First place-$1,500; Second place-$750; Third place-$500 (US dollars). Certificates will be presented to the winning design teams for display at their university and a certificate will also be presented to each team member and the faculty/project advisor. One representative from the first place design team may be expected to present a summary paper at the 2013 Aviation Conference.

Reasonable airfare and lodging will be defrayed by the AIAA Foundation for the team representative.

5. More than one design may be submitted from students at any one school.

6. If a design group withdraws their project from the competition, the team leader must notify AIAA Headquarters immediately!

7. Team competitions will be groups of not more than ten AIAA Student Members per entry. Individual competitions will consist of only 1 or 2 AIAA Student Member per entry.

II. Copyright

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

Any submission that does not contain a copyright notice shall become the property of AIAA. A team desiring to maintain copyright ownership may so indicate on the signature page but nevertheless, by submitting a proposal, grants an irrevocable license to AIAA to copy, display, publish, and distribute the work and to use it for all of AIAA's current and future print and electronic uses (e.g. "Copyright © 20__ by _____. Published by the American Institute of Aeronautics and Astronautics, Inc., with permission.).

Any submission purporting to limit or deny AIAA licensure (or copyright) will not be eligible for prizes.

III. Schedule and Activity Sequences

Significant activities, dates, and addresses for submission of proposal and related materials are as follows:

A. Letter of Intent – 22 March 2013
B. Receipt of Proposal – 14 June 2013
C. Announcement of Winners – August 2013

Groups intending to submit a proposal must submit a Letter of Intent (Item A), with a maximum length of one page to be received with the attached form on or before the date specified above. LOI may be emailed to Rachel Andino (rachela@aiaa.org). If you chose to mail your forms, they must be typed or clearly printed and mailed to:

AIAA Student Programs
Attn: Student Programs Coordinator
1801 Alexander Bell Drive, Suite 500
Reston, VA 20191-4344

The CD containing the finished proposal must be received at the same address on or before the date specified above for the Receipt of Proposal (Item B).

IV. 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 and keyed accordingly:

1. Demonstrate a thorough understanding of the Request for Proposal (RFP) requirements.

2. 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.

3. 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.

4. Provide a description of automated design tools used to develop the design.

5. The students, in writing their proposal, must justify and document the configuration selection and design processes they used to determine the most cost effective and technically feasible solution.

As a team the students are required to: Evaluate the effectiveness of at least three air vehicle configurations* at meeting the required capabilities listed in this RFP (using weighted objectives or a similar method – see Table 1) and down select to one preferred configuration with detailed justification; Perform a comprehensive trade study analysis on the preferred configuration and be able to explain the motivations behind design choices with logical supporting rationale; Propose a final, optimized conceptual air vehicle design.

* As there are a variety of configurations that could be utilized to achieve this capability, no specific one is prescribed as a preferred solution to the students. (NOTE: Three different fixed wing configurations would be just as acceptable to evaluate as would a combination of fixed wing and rotorcraft configurations).

Capabilities	Priority Weighting	Configuration A	Configuration B	Configuration C
Short Landing Area Operations				
Autonomous Flight				
Payload Carriage & Useful Load				
Speed & Altitude				
Payload & Range				
Affordable & Supportable				
Transportable				
SCORES				

Table 1: Weighted Objectives Method Example

V. Basis for Judging

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.

VI. Request for Proposal

Design of a 2030 Regional Airliner Considering Hybrid Electric Propulsion

Background

Fuel consumption of ground vehicles can be reduced with plug-in hybrid propulsion, where both petroleum and electricity is stored on the vehicle. This has been enabled by recent advancements in battery technology, but it hasn't reached a level where enough energy per pound can be stored for commercial airliners to get a similar benefit. However, batteries have been improving rapidly, and may reach a point where they can be useful on aircraft, especially for short missions.

Recent NASA funded research into technologies for commercial aircraft in the 2030-2035 timeframe has identified hybrid electric propulsion as a potentially "game-changing" technology. A hybrid propulsion system combines the best features of gas turbine (high thrust/weight, high energy density Jet-A fuel) with the best features of electric propulsion (high efficiency over a wide range of operating speeds, no local emissions, potentially lower noise).

Airliners typically fly much shorter ranges than their maximum range capability. Especially at these shorter ranges, electric propulsion has a greater potential benefit. Hybrid propulsion, where some of the energy stored on the aircraft is jet fuel, and some is electricity in batteries, can allow aircraft to efficiently fly a wide range of missions, by varying the ratio of electrical energy (batteries) to chemical energy (jet fuel) loaded on the aircraft.

Future Scenario:

Assume that in the year 2030, FAA certified batteries are available for flight operations at many airports across the US. Airports will still have jet fuel that can be pumped to aircraft similar to what is done today. The batteries take two hours to charge, so a battery rental service is used to charge batteries outside the aircraft at airports. Battery packs are a standard size and can be unloaded and swapped for charged ones. The aircraft pay a rental fee for the battery and the electricity that is used to charge the battery.

Project Objective:

Considering hybrid electric propulsion and advanced modular batteries, design a regional-sized commercial airliner with the lowest operating cost per seat-mile for the economic mission of 400 NM. Determine if hybrid electric technology offers fuel burn, cost, noise, or emissions advantages over conventional propulsion.

General Requirements:
This aircraft is representative of the Q400 / ATR-72 class aircraft.
Safety & Airworthiness Regulations: FARs, but identify any exceptions needed due to the introduction of new technologies.
Crew: 2
Passengers: 70 (1 Class)
Seating: Pitch 32", Width 17.2"
Cargo Volume: 280 ft^3 for passenger baggage. (4ft^3 per passenger)
Cargo Weight: 2450 lbs (35 lbs per passenger)
Revenue Cargo: none
Full Payload Weight: 16,450 lbs. (200 lbs per pax plus 35lbs of baggage)
Balanced Field Length: 4000-ft Sea level standard day
Minimum Cruise Speed: Mach 0.45
Initial Cruise Altitude: >20,000 ft
Maximum Cruise Altitude: 45,000 ft
Maximum Range with full payload: 1200 NM
Economic Mission: 400 NM with full payload

Battery Module Properties:
Dimensions: EH Container with hard points on each corner for securing to the aircraft
http://www.unitedcargo.com/shipping/container_aircraft.jsp?name=EH&type=container
Battery Volume: 9 ft^3
Battery Weight: 360 lbs
Useful Energy: 122,471 Wh (750 Wh/kg) (investigate +/- 33% of this value)
Battery energy cost (includes battery rental): $0.05 per kWh
CO2 of battery electricity and battery use: 10 g CO_2 / kWh
Battery Discharge Rate: 10 C
The battery is a sealed unit with the following environmental requirements: pressure altitude between 0 and 10,000-ft; temperature between 130 and -50 degrees F during operation. Five of the six sides of the

battery modules need 2-inches of clearance from each other or surrounding structures. Note: The Team may use other values if research substantiation is provided.

Other Electric System Properties:
Electric motor system (motors + motor controllers) power density: 3 hp/lb
Electric motor and controller combined system efficiency: 95%
Generator power density: 3 hp/lb
Generator efficiency: 96%
Note: The Team may use other values if research substantiation is provided.

Fuel and Energy Storage:
Only Jet fuel and Batteries are allowed for energy storage on the aircraft. Any amount of jet fuel and number of battery packs (including zero) can be used depending on the length of the mission and weight of the payload. For jet fuel, only conventional petroleum-based jet fuel or "drop-in" fuels, such as blended biofuel or blended synthetic fuel can be used.

Economics:
The design metric is to minimize operating cost per seat-mile for the economic mission of 400 NM. Assumptions:
Jet fuel price: $5.00 per gallon (includes carbon tax)
Electricity price including battery rental fee: $0.05 per kWh (includes carbon tax)
The value of passenger time can also be considered in the economic analysis.

Projected aircraft and engine technology and assumptions:
Many potential 2030 propulsion, structures, aerodynamics, subsystems, and operations technologies were identified in recent FAA and NASA studies (see References) and can be applied to this design study.

Data Requirements

The technical proposal must convincingly demonstrate that the design can satisfy the design mission performance requirements will achieving the best possible cost and environmental impact with the nominal mission. The proposal should satisfy the following tasks to show how the design would be developed:

1. Justify the final design, and describe the technologies, gas turbine engine selection, electric motor and controller selection, and technical approach used to meet the mission requirements.
2. Provide carpet plots used to finalize the final selected design
3. Provide subsystem architecture trade studies
4. Include a dimensioned 3-view general arrangement drawing
5. Include an inboard profile showing the general internal arrangement
6. Include an illustrated description of the primary load bearing airframe structure, and state rational for material selection
7. Show an estimated drag build-up and drag polar for the cruise configuration, the take-off configuration, and the landing configuration
8. Show a weight breakdown of the major components and systems and center of gravity travel
9. Provide an estimate of community noise and compare to standards

10. Provide an estimate of CO_2 emissions from the aircraft, as well as electricity generation
11. Provide an estimate of landing and takeoff NOx and compare to standards
12. Demonstrate aircraft stability for all flight and loading conditions
13. Describe any advanced technologies or design approaches and their relative benefits as used to obtain performance improvements. For advanced batteries, describe impact if this technology achieves +33% or -33% relative to the stated values, including cost and/or performance changes. Determine level of battery performance where cost is the same for a hybrid electric and conventional aircraft.
14. Provide flyaway cost and life cycle cost estimate for a production run of 500 and 1000 units. Carbon taxes, fuel cost, and electricity cost are specified above. Estimate the sensitivity of the total costs to the assumption for electricity price (for example, what is the impact if the electricity price is $0.10 instead of $0.05 per kWh).

References:

1) FAA CLEEN – The FAA CLEEN project is looking at a variety of near term technologies that could be applied to this design study.
2) NASA ERA – The NASA Environmentally Responsive Aviation program has funded multiple contractor teams that have reported on technologies that could be applied to this design study.
   http://www.aiaa.org/KeySpeeches2012/ (see 50th Aerospace Sciences meeting)

3) NASA SFW – The NASA Subsonic Fixed Wing program has funded multiple contractor and NASA teams working on concepts and technologies that could be applied to this design study.
   http://www.aeronautics.nasa.gov/fap/subfixed.html
   http://www.nasa.gov/topics/aeronautics/features/future_airplanes.html

   Of particular relevance is the work reported by the Boeing and General Electric related to hybrid electric propulsion.
   http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110011321_2011011863.pdf

Intent Form

AIAA
Undergraduate Team Aircraft Design Competition
Request for Proposal: **Design of a 2030 Regional Airliner Considering Hybrid Electric Propulsion**

Title of Design Proposal: ____

Name of School: ____

Designer's Name	**AIAA Member #**	**Graduation Date**	**Degree**
______________ Team Leader	______________	______________	______________
______________ Team Leader E-mail			
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In order to be eligible for the 2012-2013 AIAA Undergraduate Team Aircraft Design Competition, you must complete this form and return it to AIAA Student Programs (rachela@aiaa.org) ***before 22 March 2013***, at AIAA Headquarters to satisfy Section IV, "Schedule and Activity Sequences" of the competition. For any nonmember listed above, a student member application and member dues payment should also be included with this form.

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Signature of Faculty Advisor | Signature of Project Advisor | Date

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Faculty Advisor – Printed | Project Advisor – Printed | Date