34th Annual
AHS International
Student Design Competition

2016-2017 Request for Proposals (RFP)

24 Hour Hovering Machine Conceptual Design

Sponsored by

August 9, 2016

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1 Basic Proposal Information

Sikorsky, A Lockheed Martin Company, extends greetings and invites you to participate in the 34th Student Design Competition (SDC) of the American Helicopter Society (AHS) International — *The Vertical Flight Technical Society*. This Request for Proposal (RFP) is divided into two sections. Section 1 (this section) provides a general description of the competition and the process for entering. This section covers the rules (both general and proposal specific) and schedules that the sponsor requires of the participants. It also describes the awards and provides contact information. Section 2 describes the specific challenge presented by Sikorsky and AHS International.

1.1 Rules

1.1.1 Who May Participate

All undergraduate and graduate students from any school (university or college) may participate in this competition, ***with the exception of countries or persons prohibited by the United States Government***. A student may be full-time or part-time; their education level will be considered in the classification of their team (see Section 1.1.3).

1.1.2 Team Size and Number of Teams

We encourage the formation of project teams. The maximum number of students on a team is ten (10), with the exception described below; the minimum team size is one (1), an individual. Schools may form more than one team, and each team may submit a proposal. A student can be a member of one team only.

We look favorably upon the development of multi-university teams for the added experience gained in collaboration and project management. The maximum number of students for a multi-university team is twelve (12), distributed in any manner over the multi-university team.

The members of a team must be named in a Letter of Intent. The Letter of Intent is submitted by the captain of a team and sent to AHS headquarters by the date specified in Section 1.3. Information in the Letter of Intent must include the name of the university or universities forming the team, the name of the team, the printed names of the members of the team from all the universities in the team, the e-mail addresses and education level (undergraduate or graduate) of each team member, the affiliation of each student in the case of a multi-university team, and the printed names and affiliations of the faculty advisors, as well as contact information for the team captain.

1.1.3 Categories and Classifications

The competition has three categories that are eligible for prizes, as well as a bonus category. They are:

- Undergraduate Student Category: (1^{st}, 2^{nd}, 3^{rd})
- Graduate Student Category: (1^{st}, 2^{nd}, 3^{rd}). NOTE: The classification of a team is determined by the highest educational level currently pursued by any member of the team.
- New Entrant Category: A new entrant is defined as any school (undergraduate or graduate) that has not participated in the last three prior competitions.
- Bonus: Hardware Validation: A bonus will be provided to each of the undergraduate and graduate 1^{st} place teams if they successfully meet the evaluation criteria stated in the optional Hardware Validation section described in Section 2.5.1.

1.1.4 Language of Proposal

Regardless of the nationality of the teams, all submittals and communications to and from AHS must be in English.

1.1.5 Units Used in Proposal

All proposals shall provide answers in English and SI units. The primary units are to be English, followed by the secondary units in parentheses. The use of units shall be consistent throughout the proposal.

1.1.6 Proposal Format, Length and Medium

Two (three including the optional Hardware Validation video file) separate files comprise the Final Submittal for undergraduate and graduate teams. All must be present for a submission to be considered complete. The judges shall apply a significant penalty if either file is missing. The two files are the Executive Summary and Final Proposal. If a team completes Hardware Validation, an addendum to the Final Submittal and a separate video file will be permitted. Each is described herein.

The first file is called the Final Proposal.
It is the complete, self-contained proposal of the team. It shall be submitted in PDF form readable with Adobe Acrobat. Exceptions will be considered with advance request.

Undergraduate category Final Proposals shall be no more than 50 pages, and graduate category Final Proposals shall be no more than 100 pages. Note that a 15-page addendum is permitted for teams completing the Hardware Validation task. The addendum should be a standalone section attached to the end of the Final Proposal and unused pages (i.e., if all 15 pages are not used) cannot be added to the page count for the Final Proposal itself. All pages are to be numbered. This page count includes all figures, diagrams, drawings, photographs and appendices. In short, anything that can be read or viewed is considered a page and subject to the page count, with the following exceptions. The cover page, acknowledgement page, signature page, posting permission page (see Section 1.1.9), table of contents, list of figures, list of tables, nomenclature, reference pages and the Executive Summary are excluded from the page count for the Final Proposal. See Section 1.1.7 for specific information about the signature page.

Pages measure 8 ½ x 11 inches. Undergraduate submissions may have four (4) larger fold-out pages with a maximum size of 11 x 17 inches, and graduate submissions may have eight (8) larger fold-out pages with a maximum size of 11 x 17 inches. If a submission exceeds the page limit for its category, the judges will apply a penalty equal to ¼ point per page over the limit.

All proposals and summaries shall use a font size of at least 12 point and spacing that is legible and enhances document presentation.

The second file is a PDF file called the Executive Summary.
This is a self-contained "executive" briefing of the proposal. Both undergraduate and graduate category Executive Summaries are limited to twenty (20) pages measuring 8 ½ x 11 inches, with no more than four (4) larger fold-out pages of a maximum size of 11 x 17 inches. The Executive Summary can take the form of a viewgraph-style presentation, but it must be a PDF file readable with Adobe Acrobat. No additional technical content may be introduced in the Executive Summary. The judges shall apply the same page count penalty to the Executive Summary score as with the Final Proposal. The Executive Summary shall account for no more than 10% of the total score of the complete submission.

Hardware Validation video file (optional).
Teams that complete the optional Hardware Validation task may submit a video (less than 5 minutes) of the experiment/test. Video format must be PC compatible. The file name must clearly indicate the team name.

All submissions shall be made via e-mail, FTP or other electronic submittal program to AHS.

1.1.7 Signature Page

With the exception of the optional Hardware Validation video, all submittals must include a signature page as the second page, following immediately after the cover page. The signature page must include the printed name, e-mail addresses, education level, (undergraduate or graduate), and signature of each student that participated. In the case of a multi-university team, the page must also indicate the affiliation of each student.

The submittals must be wholly the effort of the students, but faculty advisors may provide guidance. The signature page must also include the printed names, e-mail addresses and signatures of the faculty advisors.

Design projects for which a student receives academic credit must be identified by course name(s) and number(s) on the signature page.

1.1.8 Withdrawal

If a student withdraws from a team, or if a team withdraws from the competition, that team must notify the AHS International point of contact in writing immediately (email preferred).

1.1.9 Proposal Posting

AHS International will post at least the Executive Summaries of each of the winning entries on its website at www.vtol.org/sdc. The written permission shall appear on a separate page immediately following the signature page. This permission page will not count against the page count. Specific permission must also be provided for the optional Hardware Validation video files to be posted (if submitted).

1.2 Awards

Sikorsky is very pleased to sponsor the AHS Student Design Competition this year. Sikorsky will provide the funds for the awards and travel stipends through AHS International. Submittals are judged in four (4) categories. Awards are granted per team.

1.2.1 Undergraduate category

- 1st place: $1,850
- 2nd place: $1,200
- 3rd place: $500

1.2.2 Graduate category

- 1st place: $2,500
- 2nd place: $1,750
- 3rd place: $950

1.2.3 Best first time entrant

- $500 (undergraduate)
- $750 (graduate)

1.2.4 Hardware Validation Bonus

- $500 (awarded to one graduate and one undergraduate team successfully completing the Hardware Validation task independent of the design portion).

Certificates of achievement will be presented to each member of the winning teams and to their faculty advisors for display at their school. The first place winner or team representative for the graduate and undergraduate categories will be expected to present a technical summary of their design at the AHS International 74th Annual Forum, 15-17 May 2018, in Phoenix, Arizona, USA. Presenters receive complimentary registration and each team will be provided up to $1,000 in expenses to help defray the cost of attendance.

1.3 Schedule

Schedule milestones and deadline dates for submission are as follows:

Milestone	**Date**
AHS Issues a Request For Proposal	August 2016
Submit Letter of Intent to Participate	No Later Than (NLT) 3 February 2017
Submit Requests for Information/Clarification	Continuously, but NLT 24 February 2017
AHS Issues Responses to Questions	NLT 24 March 2017
Teams submit Final Submittal (Final Proposal and Executive Summary)	NLT 31 May 2017
Sponsor notifies AHS of results	4 August 2017
AHS announces winners	18 August 2017
Winning teams present at AHS Forum 74	15-17 May 2018

We reiterate: If you intend to participate, your Letter of Intent must arrive at AHS International headquarters no later than **3 February 2017**. The signature page must include all of the information requested in Section 1.1.7. Email submissions are preferred.

All questions and requests for information/clarification that are submitted by teams to AHS International headquarters will be distributed with answers to all participating teams and judges. Entrants' requests for information/clarification (questions) will be answered as soon as possible. All of the questions and answers will also be distributed collectively to all entrants no later than 24 March 2017.

The Final Submittal must be received by 11:59 pm (GMT-5) on Wednesday, **31 May 2017**.

1.4 Point of Contact

All correspondence should be directed to:

Ms. Julie M. Gibbs, Technical Programs Director
AHS International
2701 Prosperity Ave., Suite 210
Fairfax, VA. 22031 USA
Phone: (703) 684-6777 x103
E-mail: jmgibbs@vtol.org

1.5 Evaluation Criteria

The proposals shall be judged on four (4) primary categories with weighting factors specified below. Note that Hardware Validation is not a criterion in determining the ranking of the teams' performance.

1.5.1 Technical Content (40 points)

The Technical Content of the proposal requires that:

- The design meets the RFP technical requirements.
- The assumptions are clearly stated and logical.
- A thorough understanding of tools is evident and their use is appropriate and sufficient for the application.
- All major technical issues are considered.
- Appropriate trade studies are performed to direct/support the design process.
- Well balanced and appropriate substantiation of complete aircraft and subsystems is present.
- Technical drawings are clear, descriptive, and accurately represent a realistic design.

1.5.2 Application & Feasibility (25 points)

The proposals will be judged on the appropriateness of the proposed aircraft to the mission requirements, how well current and anticipated technologies are applied to the problem, and on the feasibility of the solution. The proposals must:

- Defend the choice of the aircraft based on the mission requirements
- Justify and substantiate the technology levels that are used or anticipated
- Direct appropriate emphasis and discussion to critical technological issues
- Discuss how affordability considerations influenced the design process
- Discuss how reliability and maintainability features influenced the design process
- Discuss how manufacturing methods and materials were considered in the design process
- Show an appreciation for the operation of the aircraft

1.5.3 Originality (20 points)

The originality of the proposal shall be judged on:

- How innovative the solution is
- How much originality the solution demonstrates and shows imagination
- Vehicle/system aesthetics

1.5.4 Organization & Presentation (15 points)

The organization and presentation of the proposal requires

- A self-contained Executive Summary that contains all pertinent information and a compelling case as to why the proposal should win. It must be a separate file.
- An introduction that clearly describes the major features of the proposed system
- A well-organized proposal with all information presented in a readily accessible and logical sequence
- Clear and uncluttered graphs, tables, drawings and other visual elements
- Complete citations of all previous relevant work (the State of the Art)
- Professional quality and presentation
- The proposal meets all format and content requirements.

The RFP describes the contest and the requirements. Schedule, page count and other limits, and the basic rules are part of the RFP and will be judged under Section 1.5.

1.6 Proposal Requirements

The Final Submittal needs to communicate a description of the design concepts and the associated performance criteria (or metrics) to substantiate the assumptions and data used and the resulting predicted performance, weight, and cost. Use the following as guidance while developing a response to this Request for Proposal (RFP):

a. Demonstrate a thorough understanding of the RFP requirements.

b. Describe how the proposed technical approach complies with the requirements specified in the RFP. An explanation of the choice of the type of aircraft being offered is expected. Technical justification for the selection of materials and technologies is expected. Clarity and completeness of the technical approach will be a primary factor in evaluation of the proposals.

c. Identify and discuss critical technical problem areas in detail. Present descriptions, method of attack, system analysis, sketches, drawings, and discussions of new approaches in sufficient detail in order to assist in the engineering evaluation of the submitted proposal. Identify and justify all exceptions to RFP technical requirements. Design decisions are important, but so are process and substantiation.

d. Describe the results of trade-off studies performed to arrive at the final design. Include a description of each trade and a thorough list of assumptions. Provide a brief description of the tools and methods used to develop the design and an explanation of why you chose the particular tools and methods.

e. Section 1.1.6, titled "Proposal Format, Length and Medium" describes the data package that a team must provide in the Final Submittal. Specifically, the Final Submittal must contain two files transmitted electronically. The first file is the Final Proposal, which is the full length, complete and self-contained proposed solution to the RFP. By self-contained, we mean that the proposal does not refer to and does not require files other than itself. The second file is an Executive Summary, which presents a compelling story why the sponsor should select your design concept. The Executive Summary should highlight critical requirements and the trade studies you conducted, and summarize the rotorcraft concept design and capabilities.

f. Judging will focus on innovative solutions, system performance, and system value.

g. Unless otherwise specified, all engineering units should be expressed in the English units of pounds (force), slugs (mass), seconds, minutes or hours as appropriate (time), feet or inches as appropriate (length).

2 System Objectives

2.1 Operating Concept

At the 72nd Annual Forum in May 2016, AHS International announced the Igor I. Sikorsky 24 Hour Hover Challenge (www.vtol.org/challenge) to inspire innovative thinkers with the follow-on challenge to the AHS Igor I. Sikorsky Human Power Helicopter Competition: to build and fly a heavier-than-air flying machine that can hover for 24 hours while still demonstrating other typical helicopter attributes. [NB: while the rules are very similar, only the guidelines in this RFP are applicable here, and vice-versa.]

A top-level analysis of the design space is for a vehicle that can hover for 24 hours while carrying 176.4 lbs (80 kgs) of payload reveals that step-changes in structural, propulsion system and rotor aerodynamic efficiency are required to meet this challenge. Figure 1 illustrates the impact of disk loading and weight empty fraction for a notional coaxial rotor helicopter with a constant propulsion system Specific Fuel Consumptions (SFC) of 0.35 lb/hp/hr. Pushing all three vehicle design parameters to their most optimistic values, one can quickly see that the result is a vehicle between 2,000 and 5,000 lb. At nominal state-of-the-art values, vehicle size grows exponentially. Thus, the AHS Sikorsky Hover Conceptual Design is meant to drive fundamental improvements in rotary wing technology.

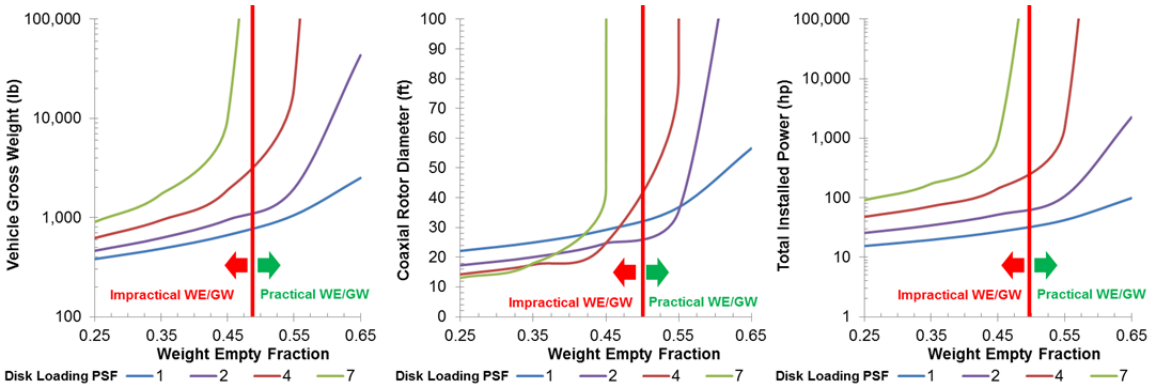

Figure 1: 24 Hour Hover Challenge Design Space

Some key takeaways emerge:

Weight Empty Fraction
The lowest weight empty (WE) fraction on a real helicopter is 50% (Mosquito Aviation XE). The Atlas Human Powered Helicopter (HPH), which won the AHS Sikorsky Prize in 2013, had a peak power of 1-2 hp, and a WE fraction of ~50%. The lightweight structure used broke apart on several occasions, and maximum flight time was under 60 seconds. An invention is necessary to get the high-strength, lightweight structure that can withstand a helicopter operating environment for 24 hours to meet the WE fraction required.

Propulsion System Efficiency
Diesel engines with SFCs of 0.35 lb/hp/hr have power-to-weight (P/W) ratios of 0.5-1.0 hp/lb, while gas turbine engines with SFCs of 0.45-0.65 lb/hp/hr have power to weight ratios of 4-6 hp/lb. A propulsion system invention is necessary to get the SFC and P/W to match the WE fraction required. As an example, the Altas HPH propulsion system (the pilot, T. Weichert) included both the energy and the motive system.

Rotor Aerodynamic Design
To minimize power, it is convenient to lower disk loading. Conventional helicopters do not have disk loadings below 2-4 lb/ft^2. Lower disk loading requires lower rotor speeds, which has an adverse effect on rotor Figure of Merit and makes rotor controllability very challenging.

2.2 Aircraft Requirements

The aircraft shall be unoccupied, i.e., fly autonomously or receive commands from a Ground Controller.

The aircraft shall carry a Non-Productive Payload with ground weight no less than 176.4 lb (80 kg) for the duration of flight. Non-Productive Payload is defined as an object or material that does not aid in the systems necessary for creating lift or control in an aircraft, or provide structural support for the aircraft.

Energy, whether chemical or electro-magnetic radiation, shall not be collected by the aircraft from man-made sources separate from the aircraft except for the purpose of flight control and telemetry communication during flight. An exception to this rule shall be solar irradiation and atmospheric gases collected for the purpose of combustion or electrolysis.

The aircraft shall not trap gasses that have density lower than ambient air. All closed cavities of the aircraft must be vented to the atmosphere.

No part of the machine may be jettisoned during flight.

The use of newer technologies (e.g., distributed systems, electric motors, hybrid and/or heterogeneous concepts, solar power) is welcomed, as long as it is explained how these technologies are sufficiently mature to lead to a vehicle that can be designed, built and tested within the next 3-5 years.

2.3 Mission Requirements

The aircraft is required to hover for a cumulative duration of 24 hours inside three separate Hover Stations following takeoff without landing, as depicted in Figure 2. Assume sea level standard conditions.

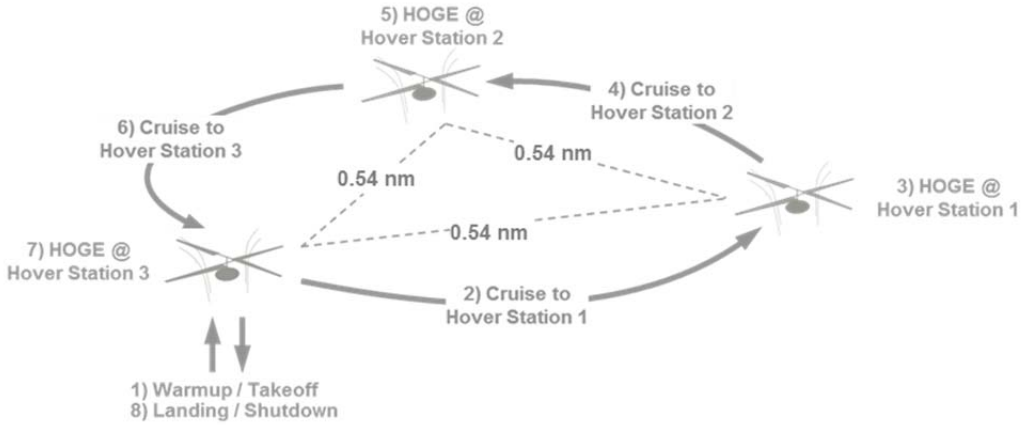

Figure 2: 24-Hour Hover Challenge Mission Profile

Hover shall be defined as a condition when the aircraft is supported exclusively by aerodynamic forces, has zero relative velocity with respect to a ground observer station, both longitudinally and laterally, and has no change in altitude. Furthermore, hover shall be defined as out-of-ground-effect (OGE) at an altitude at least twice the largest vehicle dimension. Lastly, hover shall be defined as flight time during which wind speeds do not exceed 9.71 kt (5 m/s).

The duration of time spent in each Hover Station is measured with respect to the difference in time between entering and exiting the hover station volume. The Hover Station volume shall be a 20 m radius sphere. The three Hover Stations shall be no less than 0.54 nm (1 km) apart, as measured from their respective centroids.

2.4 Documentation Requirements

2.4.1 Conceptual Design Trade Studies

The teams shall provide a conceptual design trade study to substantiate their design. The trade study should document the types of vehicle configurations explored (open vs. ducted rotor, single vs. multi-rotor, etc.), propulsion systems explored (electric, fuel cell, solar, thermal engine, etc.) and general vehicle attributes varied/optimized (disk loading, rotor speed, etc.).

The hover time objective is 24 hours, and the final assessment of the design will be based on whichever design meets the objective. If the design falls short of the 24-hr requirement, the teams are encouraged to present rationale for the lower hover time.

2.4.2 Vehicle Description

The teams shall provide a general description of the vehicle which highlights how it meets the stated requirements.

2.4.3 Propulsion System Data

The teams shall provide installed propulsion system performance estimates including: power available at engine output shaft; and energy consumption characteristics such as fuel flow per power setting at static conditions between idle and Maximum Rated Power (MRP).

2.4.4 Hover Performance Data

The teams shall provide hover performance estimates including: Total Aircraft Power Required; total air vehicle Figure of Merit vs gross weight; and download as a percentage of gross weight.

2.4.5 Forward Flight Performance Data

The teams shall provide forward flight performance estimates including total power required versus airspeed from hover to maximum continuous power speed.

2.4.6 Mission Performance Data

The teams shall provide a segment-by-segment mission profile description that includes the following for each mission segment (assume sea level standard conditions):

a. Type of mission activity (HOGE, HIGE, Cruise, Reserve etc.)
b. Atmospheric condition (pressure altitude and free air temperature)
c. Average Gross Weight of mission leg start and end.
d. Airspeed
e. Distance or time.
f. Fuel flow or energy consumption and specific range/endurance.

g. Total power required and power available.

2.4.7 Air Vehicle Design & Subsystem Drawings

The teams shall provide the following drawings:

a. General Arrangement: Three-view representation that defines the external geometry and design of the vehicle. Includes principal dimensions and general data table (surface area, span, chord sweep angles, etc.)
b. Inboard Profile: Defines the internal geometry and design of the vehicle. Includes propulsion, drive system, landing gear, Vehicle Management System (VMS), payload systems, etc.
c. Structural Arrangement: Three-view and isometric representations of the CATIA model that defines the internal structural arrangement of the product. Includes propulsion, drive system, landing gear, VMS, payload systems, etc.
d. Subsystem Functional Schematics: Clarifies the components of a system as well the system spacial relationship and interface within the vehicle. Included, as appropriate, are weight and power attributes, kinematics, dynamics and loads.

2.4.8 Aerodynamic Data

The teams shall provide isolated non-dimensional main rotor flight performance, including:

a. Vertical Flight: The ratio of ideal Hover Out-of-Ground-Effect (HOGE) power to actual HOGE power required, main rotor Figure of Merit (FM), vs. blade-loading coefficient (C_T/σ).
b. Forward Flight Edgewise Mode: The ratio of main rotor lift to equivalent main rotor drag (L/De) as a function of rotor advance ratio, (μ). The rotor Lift (L) and details of the rotor drag (De) calculation shall be documented in tabular form.
c. Forward Flight Axial Mode (if applicable): The propulsive efficiency (η) as a function of propeller advance ratio, (J).

The teams shall provide the aerodynamic data describing the airframe. The airframe excludes all items in the rotor system and aerodynamic surfaces (such as wings, if any). The following airframe equivalent areas (normalized by the freestream dynamic pressure, q) shall be documented:

a. Equivalent parasite lift area (L/q) at zero degrees of vehicle pitch and yaw.
b. Equivalent parasite drag area (D/q) at zero degrees of vehicle pitch and yaw.
c. Equivalent pitching moment volume: (M/q) at zero degrees of vehicle pitch and yaw.
d. Equivalent parasite side force area (Y/q) at zero degrees of vehicle pitch and yaw.

The teams shall provide a component drag build-up. A table shall be provided which includes a list of the drag items, their horizontal and vertical drag coefficients (Cd), an equivalent flat-plate drag area, and an indication of the source of the drag estimate.

2.4.9 Loads & Criteria Data

The teams shall provide the following:

a. Limit load factor structural and aerodynamic envelope at structural design gross weight and maximum gross weight
b. V-Nz diagrams

c. Component design loads

2.4.10 Mass Properties Data

The teams shall provide the following:

a. Weight Empty Derivation (methods, fixed equipment lists, etc.)
b. Mission Weight Build-up
c. SAWE RP8A Part I Group Weight Statement.
d. Center of Gravity Analysis (laterally and longitudinally)

2.4.11 Manufacturing & Cost Data

The teams shall provide an estimate of the cost and schedule required to produce the vehicle based on assembly labor and bill of materials. These estimates shall be part of the trade studies discussed in Section 2.4.1.

2.5 Additional Tasks for Graduate Students Only

For the graduate category, a deeper technological investigation of the aircraft key elements is required. The Graduate Student Design Teams are required to complete one of the following tasks:

a. Simulation & Flight Control Laws Development: The graduate design teams will be required to create a flight simulation of the aircraft so that a pilot may fly it in a simulator and give feedback to the team. X-Plane, FLIGHTLAB or a similar software package may be used. This includes the development of flight control laws to demonstrate the vehicle is stable and controllable in hover and forward flight throughout the duration of the mission.
b. Stress Analysis & Fatigue Substantiation: This will entail a Preliminary Design stress level assessment and static and/or fatigue substantiation of the critical elements. The objective is to demonstrate, on a few selected cases, that the students master the stress substantiation tasks, including FAR requirements. The teams should select at least one dynamic system component (blade, hub, or transmission) and one airframe component (frame, tail boom, etc.).
c. Aerodynamic Design Substantiation: The teams shall provide design substantiation of the rotor system and the airframe to meet the performance objectives of the RFP.
d. Propulsion System Details: The teams shall provide design substantiation of the propulsion system (energy collection and storage mechanism, power conversion device, thermal management systems, etc.) to meet the performance objectives of the RFP.

2.5.1 Hardware Validation (Optional)

Both the undergraduate and graduate teams are given the opportunity to develop a hardware validation test to help substantiate the validity of the claims made regarding their design. The details of the test activity are left to each team to determine, but should address the criteria set forth in the evaluation guidelines presented in Section 2.2 and Section 2.3. Those teams choosing to participate in this task shall develop a test plan, identify pre-test predictions and submit them ahead of testing, perform data reduction, and report on the results.