2001 Request For Proposal (RFP)

For

Advanced Rotor Control Concepts

18th Annual Student Design Competition

For

Undergraduate And Graduate Students

Sponsored by:

BOEING

And

AMERICAN HELICOPTER SOCIETY

AHS International

The Vertical Flight Society

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Section 1.0 Basic Proposal Information

I. Rules

1. Competition categories include:

   Graduate For-Credit (as a part of a Design Course or Independent Study)

   Undergraduate For-Credit (as a part of a Design Course or Independent Study)

   Not-For-Credit (not a part of a Design Course or Independent Study)

2. Schools are encouraged to form project teams. The number of students on each team may be determined by the school.

3. All undergraduate and graduate students may participate in this competition. For submittals in the For-Credit categories, the classification of a team is determined by the highest education level of any member of the team. Part time students may participate at the appropriate graduate or undergraduate level. In the Not-For-Credit category, both graduate and undergraduate students may participate.

4. Only one design proposal may be submitted by each student or team; however, any number of design proposals are permitted from a university or college.

5. The competition consists of a written Proposal Outline, a written Final Proposal, and an oral presentation (for finalists selected after judging of the written proposals). As in industry, after review of the Proposal Outline the AHS may provide each team with requests for clarification specific to its Outline. Responses to the requests could be submitted separately, or could be included in the Final Proposal. Final presentations will be given at the AHS Mideast Region Specialist Meeting on Crewstations and Flight Controls in Philadelphia in October, 2001, for which travel stipends of approximately $1000 will be made available.

6. Documents must be submitted to the AHS in digital format readable using Microsoft Word 97, PC format. (Requests for exceptions will be considered in advance). All documents submitted shall be double-spaced with a font of at least 10 point. All material must be legible.

   The written proposal outline will be due on March 30, 2001. It shall be limited to no more than 20 pages (including all graphs, drawings and photographs).

   The Final Proposal will be due June 22, 2001. It shall be limited to no more than 75 pages (including all graphs, drawings, photographs, and appendices). Up to 8 of the 75 pages may be larger than 8½”x11”, such as fold-outs up to a maximum size of 11”x22”.

   The Final Proposal document must include a self-contained Executive Summary, limited to no more than 7 pages including all graphics. This summary is not to be considered a part of the 75 page limit.

7. Presentations must be submitted to the AHS, in advance of the Specialists Meeting, in digital format readable using Microsoft PowerPoint 97, PC format. (Requests for exceptions will be considered in advance).

8. For all submittals, an inside cover page must include the printed name, educational level and signature of each student who participated. Submittals ***must*** be the work of the students, but guidance may come from Faculty Advisor(s), and must be acknowledged on this signature page. Design projects for which any student receives academic credit must be identified as such on this signature page, and will be considered in one of the For-Credit categories.

9. All Submittals are to be provided to:

    Kim Smith, Deputy Director
    American Helicopter Society (AHS)
    217 N. Washington Street
    Alexandria, Virginia 22314
    Tel. # ....(703) 684-6777
    Fax # ....(703) 739-9279
    Email ....AHS703@aol.com

10. The Awards shall be:

    Graduate For-Credit Category

    1st Place $750
    2nd Place $250

    Undergraduate For-Credit Category

    1st Place $750
    2nd Place $250

    Not-For-Credit Category

    1st Place $750
    2nd Place $250

11. Certificates will be presented to each member of the winning teams, and to their Faculty Advisors for display at their school.

12. A representative of each winning team in the Graduate and Undergraduate Categories will be expected to present a technical summary of their air vehicle design at the AHS Annual Forum 58, in May of 2002. A stipend of $1000 will be provided for each first place team in the Graduate and Undergraduate category to help defray the costs of attending the Forum. The first place winners or members of the winning teams will receive complimentary registration to the 2002 AHS Annual Forum.

13. If any student or design team withdraws their project from the competition, the student or team leader must notify the AHS National Headquarters Office immediately in writing.

II. Schedule & Activity Sequences

Scheduled milestones and deadline dates for submission of the proposal and related material are as follows:

A. AHS Issue of Request for Proposal (RFP)... August 21, 2000
B. Teams Submit Requests for Information/Clarification................ by February 15, 2001
C. Teams Submit Proposal Outline due to AHS .... by March 30, 2001
D. AHS Issue Responses to Questions & Requests for Clarifications ..... by May 15, 2001
E. Teams Submit Final Proposals.. by June 22, 2001
F. AHS Notifies Finalists .... August 1, 2001
G. Teams Submit Presentation Material to AHS.................................. September 8, 2001
H. Teams Present at AHS Specialists Meeting (Philadelphia)......................October, 2001
I. AHS Announces Winners .... December 1, 2001
J. Winners Present Designs at AHS Forum 58.. May, 2002

All questions by teams put forward to the AHS before submittal of the Proposal Outline will be distributed with answers to all participating teams. Any Questions or Requests for Clarifications from the judges after review of a team's Proposal Outlines will not be provided to other teams.

All submittals must be postmarked on or before the dates specified in Items C, E and G.

III. Proposal Requirements

The content of the proposal 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. The following should be used as guidance while developing a response to the Request For Proposal (RFP).

1. Demonstrate a thorough understanding of the RFP requirements.
2. Describe the proposed technical approach that complies with the requirements specified in the RFP. 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
3. Identify and discuss critical technical problem areas in detail. Descriptions, method of attack, system analysis, sketches, drawings, and discussions of new techniques should be presented in sufficient detail to assist in the engineering evaluation of the submitted proposal. Exceptions to RFP technical requirements must be identified and justified.
4. Describe the results of tradeoff studies performed to arrive at the final design. Include a description of each trade and the list of assumptions. Provide a brief description of the tools and methods used to develop the design.
5. The data package which must be provided in the proposal is described in Section 2.0, IV.

IV. Basis For Judging (Weighting Factors)

1. Technical Content (40 points)
    - Design meets RFP technical requirements
    - Assumptions clearly stated and logical
    - Major technical issues considered
    - Appropriate trade studies performed to direct/support the design process
    - Well balanced and appropriate substantiation of complete system
    - Technical drawings accurately describe the complete aircraft and its subsystems
2. Organization & Presentation (15 points)
    - Self contained Executive Summary which contains all pertinent information and makes a compelling case for why the proposal should win.
    - Introduction clearly describes the major features of the proposed aircraft
    - All pertinent and required information included and easy to find
    - Continuity of topics
    - Figures, graphs and tables are uncluttered and easy to read and understand
    - All previous relevant work cited
    - Overall neatness of report
3. Originality (20 points)
    - Treatment of problem shows imagination
    - Concepts show originality
    - Unique vehicle attributes and subsystem integration show innovative thinking
    - Vehicle aesthetics
4. Application & Feasibility (25 points)
    - Current and advanced technology levels used are justified and substantiated.
    - Particular emphasis should be directed at identification of critical technical problem areas.
    - How affordability considerations influenced the design process.
    - How reliability and maintainability features influenced the design process.
    - Manufacturing methods and materials are considered in the design process.
    - Proposal shows an appreciation of how the vehicle will be used by the operator.
    - Consideration of additional applications and capabilities other than those in the RFP.

Section 2.0 Design Objectives and Requirements

I. Program Objectives

The topic for this project is the development of a VTOL platform with an innovative method of controlling the cyclic pitch of rotor blades. Methods that do not depend upon the use of traditional swashplate mechanisms are sought. Traditional tiltrotor and helicopter rotors use a swashplate mechanism to transfer rotor control inputs from the fixed frame of reference to the rotating frame of reference. This mechanism has proved to be reliable over time, however, it presents several limitations to the designer in that blade control inputs are limited by the physical constraints of the swashplate. Attempts have been made to develop alternative means of rotor blade control without conspicuous success. It is believed that the latest developments in materials and controls technology and advanced actuators, especially smart metal technologies, may offer a new opportunity to investigate advanced rotor blade control methods.

II. Project Objectives

The objective of this design competition is to develop the conceptual design of a modern civil search and rescue (SAR) VTOL rotorcraft. The vehicle must incorporate new and innovative methods of controlling the pitch of rotor blades. A balanced approach to risk is desired to optimize investment and qualification/certification costs.

The primary challenge is to produce the design for an advanced, high performance, rotor control mechanization that is affordable and capable of being developed to meet flight safety qualification and all other airworthiness requirements. The design is required to address the following topics: design of reliable actuation technologies and methods that are capable of providing the necessary control forces; design of reliable and accurate means of measuring rotor states for all degrees of freedom, including flapping, feathering, and lead-lag motions; and design of reliable methods of transitioning all required information across the boundary between the fixed and rotating frames of reference, including the required sources of actuator motive power. Emphasis must be placed on developing a safe and reliable mechanization, such that analysis of failure causes and effects must be considered in the design process. Provide actuator power required, failure modes of the chosen technology/design, maturity of the technology (present and future), and future research required. This portion of the effort is worth 40% of the total points available.

The proposals shall also provide design definition and estimates of performance attributes for three separate areas; the aircraft configuration design and sizing, the crew station definition, and the flight control system to support the innovative rotor control system. Each of the areas is worth 20% of the total points available.

1. Aircraft Configuration Design, Mission Specification and Sizing Groundrules

The aircraft is required for Search-and Rescue (SAR) mission in adverse weather conditions. The objective of this effort is to perform trade study evaluations of vertical take-off & landing aircraft (helicopter, tiltrotor, other) for a representative search and rescue mission. The mission specification is provided in Section 2.0. Assess the benefits and drawbacks of utilizing a "swashplateless" rotor.

2. Crew Station

A key aspect of any aircraft design is it's interface with the crew. The objective of this design effort is to design a cockpit / crew station that enables the crew to address the unique requirements of the SAR mission. The design should address both the cockpit and cabin crew stations.

The cockpit crew interface shall include interfaces to enhance the situational awareness of the crew. The interface should highlight unique features of your design and / or unique interfaces required to support the SAR mission in adverse weather. Drawings must be included, as well as a description of the interfaces. Human Engineering principals and practices shall be used in the design process. Unique features of your display and inceptor design should be highlighted. Special attention should be paid to adding capability which reduces pilot workload without adding significant cost to the design.

The cabin crew station shall include interfaces necessary for the para-rescuers to perform their mission and keep the aircrew informed of status. The interface should highlight unique features of your design and /or unique interfaces required to support the SAR mission. Drawings should be included, as well as a description of the interfaces.

3. Flight Control System

For mechanical controls, a description of the kinematics, inceptor forces and anti-control jam design must be included. A list of flight control parts must be identified. The design criteria for loads, dynamic performance and life must be addressed. Qualification methods for the FCS shall be described, including identification and justification of pass/fail criteria.

For electronic flight control components, a description of the architecture of the flight control system (FCS) and its theory of operation must be presented. A description of the flight control computers, sensors, inceptors and actuators shall be presented.

For software used, the proposal shall include a description of software development, including development processes, software architecture, special sampling requirements, and discussion of failure management and fault isolation.

The FCS should have a reliability of less than one failure in 10^7 flight hours. Redundancy to meet this requirement shall be described and justified by analysis.

III. Requirements and Constraints

1.0 General Requirements

The market requires a dual-piloted, vertical takeoff and landing (VTOL) rotorcraft. The aircraft shall incorporate high value technologies in airframe, propulsion, and aircraft human factors engineering. The new system will provide dramatic improvements in performance, and system commonality.

The aircraft must provide search and rescue service in IFR conditions at a range of 300 nm. The mission includes fly-out, loiter, perform a rescue of 2 people and return to base.

It is anticipated that launch of the configuration will lead to delivery of the first aircraft in the year 2015. An average production rate of four aircraft per month should be used.

2.0 Mission Profile Requirements

Perform sizing trade studies for a "range mission" and an "endurance mission" as given below. Choose a suitable configuration that meets each of these requirements.

Range Mission -

basic requirement is 600 nm range at an altitude of 500 ft @ ISA +/- 15 deg. C conditions.

Endurance Mission -

basic requirement is 5 hrs at no speeds no less than 60 knots, not greater than 120 knots @ 500 ft PA, in ISA conditions.

Final evaluation mission -

This is the primary mission for the design competition. It is meant to be loosely based upon the mission flown in the novel <u>The Perfect Storm</u>, by Sebastian Junger (see http://www.aperfectstorm.com/#).

Segment	Profile (all at normal SAR weight)
A	10 min. warmup @ idle (25% MCP) @ 0 ft, ISA day
B	Take-off and climb at max. climb rate to 500 ft PA, at max. fuel
C	Cruise at 99% best range speed for 300 nm (refueling optional), (appropriate or max fuel)
D	loiter in hover for 15 minutes on station in 30 knot cross wind with 50% gusts (at 60% fuel) while evacuating 2 from a sinking boat.
E	Return cruise for 300 nm (headwind = 60 knots 0-10K, 40 knots 10K-15K) (appropriate or 50% fuel - refueling at altitudes above 10Kft only)
F	Land with 15 min. IFR reserve @ 500 ft PA

Fixed Useful Load Evaluations -

The "normal" SAR crew will consist of 4 crew @ 200 lb each; 2 flight crew and 2 pararescuers.

Tasks 2 & 3 will define the requirements for the remainder of fixed useful load. Fixed useful load should be itemized and specifications must be provided for :

a) communications, for the aircraft and crew
b) mission system equipment including navigation, weather aids, night vision, FLIR
c) rescue/survival gear for aircraft, crew and passengers
d) refueling kits, if it required to meet the mission requirements (this is part of the configuration trade)
e) medical/EMS equipment
f) heating/de-ice systems and sensors for the aircraft
g) crew, crew safety and crew's personal equipment

An estimate of the cost, weight and drag implications for each of the equipment listed above must be provided. Costs should consider both recurring cost (equipment, installation, maintenance) and non-recurring cost (qualification testing, design/development, redundancy/integration provisions). Weight and drag should consider internal vs. external requirements (fasteners, holes, braces).

Notes:

- Fuel type – assume NATO F40 (JP4), 6.693 lb/US-gal. Or alternate
- De-ice equipment must be on in known icing conditions per Air Weather Service Manual (AWSM 105-39), 5 January 1969.

3.0 System Capabilities Required

- The aircraft must also be capable of power-off glide/autorotation to a survivable emergency landing.
- Manual rotor blade folding is desired to minimize hangar requirements.
- Cabin storage capacity is 1 patient, 2 crew and equipment (2ft D x 6ft W x 4ft H).
- Authorized flight envelope must be consistent with appropriate FARs for the design gross weight and should be capable of a transient turn capability (loss of airspeed and/or altitude allowed) at cruise speed equal to a standard rate turn (Minimum capability = 30° bank turn).
- For maximum takeoff and landing safety, the aircraft must provide a one engine inoperative (OEI), hover-out-of-ground-effect (HOGE) capability at 60% fuel and

full payload capacity using no more than Emergency power at sea level, ISA+20°C ambient conditions. For scaleable or developmental engines, consider emergency power to be 25% above the takeoff power rating.

- A flight crew of four is required, with side-by-side cockpit (pilot and copilot) seating, and cabin seating for a flight surgeon and a flight nurse.

- No cabin pressurization is required.

- The aircraft must be capable of reliable unassisted self-starting.

- The design must include the mission equipment (navigation, sensors, communication gear, etc.) required to perform the SAR mission in adverse weather conditions and night operations.

- The aircraft must be designed to facilitate basic aircraft maintenance. The design must facilitate access for inspection and rapid repair/replacement of all aircraft components (engines, transmission(s), avionics, hydraulic/electrical/fuel/cooling systems, flight controls, etc.).

- The design must consider the elements of good crashworthiness design per FAR Part 29, including:

    - Landing gear struts that do not penetrate the cabin area
    - High mass items (engine and transmissions) that have adequate crash protection to prevent entry into the cabin areas
    - Crashworthy fuel tanks,
    - Adequate seat stroke (at least 8 inches).

- Designs for low noise are required to minimize external noise (community impact) and internal noise. Since rotor advancing tip Mach number is a significant noise source, it is suggested that advancing tip Mach number be limited to 0.87 for cruise conditions. In addition, 1% of the design takeoff gross weight should be allocated for internal noise reduction treatments.

- Emerging turboshaft engine technology levels should be assumed, including IHPTET technologies. Other engine types may use similar factors on SFC and weight. If data are not available, use the scaleable turboshaft data provided in the data package.

4.0 Data Package

These data are provided as reliable estimates but should be afforded some level of scrutiny in any rigorous analysis. Changes are acceptable with supporting technical data.

Weights

Fixed Equipment Weights (as required)

Avionics	650 lb

Payload Characteristics

Crew	200 lb
Patient	190 lb

Scaleable State-of-the-art Engine Characteristics

Scaleable turboshaft engine SFC characteristics are provided here. Data are static, uninstalled. If existing engine data are used, assume a 25% reduction in SFC and a 40% improvement in power to weight ratios, representing IHPTET improvements.

Engine Rating Ratios		Duration	$SFC/\delta\theta^{0.5}$ (lb/hr/hp)
1.250	(OEI, Emergency)	30 sec.	0.302
1.000	(Takeoff or MAX)	2 min	0.305
0.924	(IRP)	30 min	0.309
0.791	(Cruise or MCP)	Continuous	0.328
0.5	(partial power)	-----	0.400
0.2	(Idle)	-----	1.000

Engine Weight, lb = 160 + 0.05539 * (Design SHP)
Engine Diameter, ft = $0.017 * (\text{Design SHP})^{0.5}$
Fuel Density, lb/gal = 6.75 (Jet A)

Ram power increase with speed may be assumed to follow:

$$[\Delta SHP/(SHP\ @\ V=0)] = 0.00016 - 4.63\times10^{-5}\,(V/\theta^{0.5}) + 2.32\times10^{-6}\,(V/\theta^{0.5})^2$$

where, SHP is in Hp, V is in knots and θ is the absolute temperature ratio, (459.7+T°F)/518.7°R.

IV. Proposal Data Package Requirements

The design proposed must meet the above stated objectives, requirements, and constraints. The following data shall be furnished:

1. Justification for the air vehicle design submitted. Include discussion of the tradeoff studies (describe analysis methods and tools) that were performed to arrive at the proposed design. Present the performance, weight, handling qualities, reliability and maintainability, manufacturing materials and techniques, and cost criteria by which the final designs were chosen. Include the sizing trade study results to show how the pertinent vehicle configuration parameters were chosen, such as rotor system size, type of anti-torque system, wing span and aspect ratio, engine size, etc. If multiple vehicle types were initially considered, describe the rationale for the vehicle type selection.

2. A set of drawings which depict the air vehicle and includes, but is not limited to:
    - Fully dimensioned three view drawings
    - A dimensioned system integration/general arrangement(inboard profile) which shows the location and arrangement of the major subsystems.

3. The structural design, including materials, must be described. Weight breakdowns for the vehicles shall be provided in MIL-STD-1374, Part I format. Weight and balance charts must be provided with the weight statement. The center of gravity and it's allowable travel shall be indicated on the three-view drawings, along with tip-over and tip-back angles.

4. Describe the analysis methods and the results of the flight performance (including rotor performance), stability and control, and handling qualities evaluations of the design. A description of the flight control system shall be provided.

5. A description of the engine installation and drive system shall be provided, along with tables or graphs of performance (installed engine power and/or thrust available as appropriate for the aircraft concept, drag/download analyses, fuel flow, etc.). If the engines selected are not existing engines, provide a discussion of the technology involved and the current state of development of such engines. Data tables or charts must be provided which specifically indicate the proposed aircraft designs will meet the flight performance and mission requirements.

6. If the proposed aircraft concept requires conversion between rotor and wing borne flight, a description of the means to provide this shall be provided. Also, the flight performance, stability and control, and handling qualities aspects of conversion shall be addressed and described.

7. A description and associated drawings of both the cockpit and cabin crew areas.

8. A description of the mission systems (avionics) suite. Existing equipment (off-the-shelf) as well as equipment with new/unique requirements shall be described.

9. Reliability and maintainability aspects of the air vehicle design shall be addressed. Configuration and other features such as easy access to avionics, quick engine removal, minimum of special tool, unique designs, etc.

10. Acquisition and operating cost of the air vehicles shall be addressed, including manufacturing cost and direct and indirect operation costs. Assume a production run of 300 aircraft and a use of 2000 flight hours per aircraft per year. Include a description of the methods and data used for cost analysis.

11. Manufacturing approaches and risks for non-traditional hardware designs shall be addressed. Identify specific material handling, manufacturing tolerance or other unique concerns introduced.

Note: Any additional data or analysis which can be provided to add to your design's credibility within the page count constraint is welcome.