The Vertical Flight Technical Society

35th Annual Student Design Competition

2017-2018 Request for Proposal (RFP)
Revision 1 to Section 2.2.4
(August 25, 2017)

for

A Reconfigurable VTOL Aircraft

Sponsored by

ARL

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1 Basic Proposal Information

The United States Army Research Laboratory (ARL) and the American Helicopter Society International invites you to participate in the 35th Student Design Competition (SDC). 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 ARL.

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 International 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: (1st, 2nd, 3rd)
- Graduate Student Category: (1st, 2nd, 3rd). 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: FLIGHTLAB Model: A bonus will be provided to one undergraduate and one graduate team that successfully meets the evaluation criteria stated in the optional Bonus Task Section 2.5 in addition to all other submission requirements.

1.1.4 Language of Proposal

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

1.1.5 Units Used in Proposal

All proposals shall provide answers in SI units. The use of units shall be consistent throughout all submitted materials. All engineering units should be expressed in the units of Newtons (force), kilograms (mass), seconds, minutes or hours as appropriate (time), meters (length), and kilometers per hour (velocity).

1.1.6 Proposal Format, Length and Medium

Two separate files comprise the Final Submittal for undergraduate and graduate teams. Both 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 the FLIGHTLAB Model task, an addendum to the Final Submittal and a separate file will be permitted. Each is described herein.

The first file is a PDF file 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. 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 (US letter paper size). Undergraduate submissions may have four (4) larger fold-out pages with a maximum size of 11 x 17 inches (US tabloid paper size), 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 landscape-orientation presentation, but it must still 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.

Students have the option to create a short video (with a 2 minute maximum length), in addition to the Executive Summary, which presents their design and its key features in a similar manner. The video should briefly describe the aircraft's unique design features, operation, and performance without technical jargon. No information or data should be included in this video that is not included in the Final Report. The video should be uploaded to YouTube and a link to the video should be included in the Executive Summary.

The third file is the optional FLIGHTLAB model:
Students participating in the bonus FLIGHTLAB task should provide all files necessary to run their model in the FLIGHTLAB environment, including but not limited to the vehicle model files (.fwm and .def), control system files (.csge, .configure, etc), and any tabular files for aerodynamic and structural properties. All FLIGHTLAB files should be compressed into a single .zip file and use the standard FLIGHTLAB file structure, which includes ctrl-eng, tables, trim, and usr folders. A results folder should include scripts used to run analyses and generate appropriate plots detailed in Section 2.5.

1.1.7 Signature Page

All submittals must include a signature page as the second page, immediately following 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; faculty and outside advisors may provide guidance but must not direct the work or ideas of the students. 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 POC in writing immediately.

1.1.9 Proposal Posting

AHS will post the winning entries in the undergraduate and graduate categories on its website. Other entries may also be posted. Each team must include written permission, which shall appear on a separate page immediately following the signature page. This permission page will not count against the page count. AHS may also link to or embed the Executive Summary video on its website.

1.2 Awards

ARL is very pleased to sponsor the AHS Student Design Competition this year. ARL will provide the funds for the awards and travel stipends through the AHS, as described below (all amounts in US Dollars). Awards are granted per team and can be made in one of three (3) categories, with a bonus also being offered:

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 FLIGHTLAB Model Bonus

- $500 (awarded to one *undergraduate* team successfully completing the FLIGHTLAB Model task, judged independent of the design portion)
- $500 (awarded to one *graduate* team successfully completing the FLIGHTLAB Model task, judged independent of the design portion)

AHS International will provide certificates of achievement to each member of the winning teams and their faculty advisors. A representative for each of the first place winners in the graduate and undergraduate categories will be expected to present a technical summary of their design at the May 2019 AHS International 75th Annual Forum in Philadelphia, Pennsylvania. These two presenters will each receive complimentary Forum registration, and each will be provided with $1,000 for reimbursement of 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 2017**
Submit Letter of Intent to Participate	NLT **5 February 2018**
Submit Requests for Information/Clarification	NLT **23 February 2018**
AHS Issues Responses to Questions	NLT **23 March 2018**
Teams submit Final Submittal (Final Proposal and Executive Summary)	NLT **31 May 2018**
Sponsor notifies AHS of results	**3 August 2018**
AHS announces winners	**17 August 2018**
Winning team presents at AHS Forum 75	**May 2019**

We reiterate: If you intend to participate, your Letter of Intent must arrive at the AHS International no later than (NLT) **5 February 2018**. The signature page must include all of the information specified in Section 1.1.7.

All questions and requests for information/clarification must be submitted by entrant teams to AHS no later than **23 February 2018**. All of the questions will be distributed to the judges on February 24th and all answers will be distributed collectively to all entrants no later than **23 March 2018**.

The Final Submittal must be received by 11:59 pm US Eastern Standard Time (GMT-5) **31 May 2018**.

1.4 Contacts

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: +1-703-684-6777 x103
E-mail: jmgibbs@vtol.org

1.5 Evaluation Criteria

The proposals will be judged on four (4) primary criteria with weighting factors specified below. Note that the FLIGHTLAB Model is not a criterion in determining the ranking of a team's 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 Originality (25 points)

The originality of the proposal shall be judged on:

- How innovative the solution is to achieve fixed wing like efficiency and vertical lift performance.
- How much originality the solution demonstrates and shows imagination.
- Vehicle/system aesthetics.
- How the design overcomes challenges that may have been previously unsolved.

1.5.3 Application & Feasibility (20 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 reliability and maintainability features influenced the design process.
- Discuss how manufacturing methods and materials were considered in the design process.
- Discuss how affordability was considered in the design process.
- Show an appreciation for the operation of the aircraft.

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.

2 System Objectives

2.1 Preface

The Sikorsky S-72/NASA Rotor Systems Research Aircraft (RSRA) research testbed was envisioned to test rotor systems independently from the fixed wing airframe and propulsion system they were attached to. This allowed the rotor speed to be varied and even stopped in flight while maintaining control of the aircraft, creating a "flying wind tunnel" that could test advanced rotor systems. (See www.vtol.org/RSRA for the AHS Vertipedia entries on the S-72.)

The DARPA / Lockheed X-Wing was a 4-bladed "circulation control rotor" intended to be tested on the RSRA. The X-Wing blades were designed with elliptical airfoil sections and air slots on the leading and trailing edges. When the rotor would be stopped in flight, the blown air could be switched from the trailing edge to the leading edge, effectively reversing the airfoil shape so that all four blades were "facing" forward.

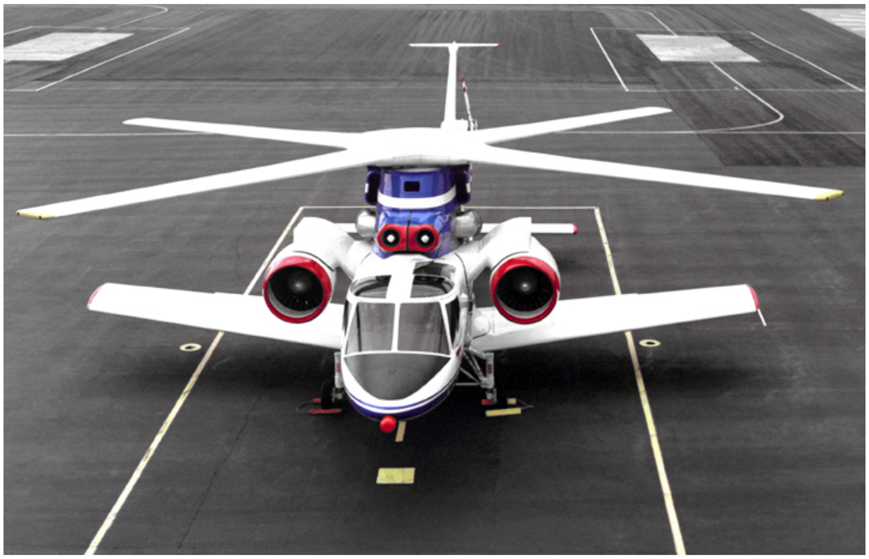

Figure 1. Sikorsky Rotor Systems Research Aircraft fitted with the Lockheed X-Wing circulation control rotor. [Igor I. Sikorsky Historical Archives]

In October 1976, the RSRA achieved its first flight without a rotor, using turbofans for propulsion and fixed wings for lift. Unfortunately, the combined RSRA/X-Wing vehicle never flew as the project was cancelled in 1987 when the government terminated the funding. The X-Wing stopped rotor concept—in its intended final form without fixed wings or turbofans—was a representation of aircraft designers' imagination of what reconfigurable aircraft might look like using 1980's technology.

The RSRA is the inspiration for this year's Student Design Competition. Students are asked to design a radical reconfigurable VTOL aircraft technology demonstrator incorporating today's technological advancements. What would it look like? Can it be useful? What technology would enable such a vehicle?

2.2 Specific Objectives

The goal of this year's competition is to design a Group 3 size unmanned VTOL aircraft that achieves high-speed forward flight (relative to current VTOL aircraft) and efficient hover through the use of novel reconfigurable propulsive and lifting devices. The aircraft should have superior performance over a comparably-sized aircraft that does not have reconfigurable systems.

2.2.1 Vehicle Design

The proposed aircraft design must have its main lifting device be a reconfigurable system. This is defined as a component or system of components which are designed to operate in two or more physical states. To transition between operating states, the system should reconfigure by changing shape, orientation, or location relative to a body fixed frame. Each operating state should provide a unique tradeoff or compromise in performance not achievable by another operating state. The selection of each operating state during flight corresponds to optimal performance for a specific flight condition. The reconfigurable system should be the key feature of the aircraft and should be a novel design.

For the X-Wing rotor system, its 4-bladed rigid rotor was designed to operate in two states with a transition period in between. The first being a rotating state similar to a traditional main rotor with air blown through the trailing edge slots on all 4 rotors for vehicle control. In the second operating state, the rotor was in a fixed position with air blown through the rearmost slots on all four blades.

2.2.2 Design Limitations

- The vehicle must be able to reconfigure on its own. Any effort exerted to change from one operating state to another shall be done by components which remain onboard the aircraft at all times. The reconfiguration must also be reversible, be able to be executed multiple times without external support, and must be able to take place during ground operations and during flight.
- No part of the vehicle can be removed or jettisoned.
- The aircraft must be controllable and stable at all times including during any transition period. (e.g. no tumbling maneuvers)
- Designs should be *new and novel*. Prior VTOL designs (see for example, the V/STOL Wheel and past SDC entries) should only be considered if performance can be improved upon through the use of new technology that was unavailable to the original design.

  Example: Traditional tiltrotors and tail sitters, including multi-rotors, do not meet the "new and novel" requirement. However, a multi-rotor rotor that transitions to axial flight, stows one or more rotors and unfolds fixed wings, to reduce drag in forward flight and increase efficiency is permissible.

2.2.3 Technology Limitations

Students are encouraged to conduct a literature review to find new technologies that may enable their aircraft design (see for example vtol.org/store and vtol.org/journal). However, any technology included in the design must have public documentation (conference proceedings, journal paper, technical report, etc) that describes its properties and performance. If any claim of improved performance, weight, efficiency, is used other than what is publicly documented, students must provide substantiation of these claims with analyses or testing.

A chosen technology should not be the focus of the design. Included technologies should be necessary to enable the novel reconfigurable design features. For example, the X-Wing used circulation control to enable the rotor to be stopped and produce lift in one operating state while also performing as a traditional rotor in another operating state. The key design feature of the X-Wing was the stopped rotor, the circulation control enabled it to function as desired.

Any powerplant and fuel type may be used, provided it meets the technology limitations. Energy may be harvested from natural sources in the environment such as solar or wind energy.

2.2.4 Vehicle Size

To increase the utility of the resulting vehicle, the aircraft must be able to operate in a megacity-type environment and fit down narrow streets and in confined spaces. When in hover configuration, its maximum horizontal dimension must be limited to no more than 3 m.

Maximum Gross Takeoff Weight (MTOW)	600 kg
Operating Altitude	3000 m standard atmosphere
Maximum Airspeed (V_{MAX})	333 km/h (180 knots) or greater
Payload	100 kg or greater
Maximum Vehicle Span (in a hover)	3 m

2.2.5 Performance Metrics

The performance of all proposed designs will be compared using 4 performance metrics.

1. Hover time in hours @ sea-level standard altitude (SLS) and at 3000 m standard atmosphere consuming 50% of energy capacity (fuel, batteries, etc)
2. Cruise range @ velocity for best range (V_{BR}) consuming 50% of energy capacity at SLS & 3000 m
3. Dash speed (V_{MAX}) at SLS & 3000 m
4. Estimated Drag Area which is defined as

$$Drag\ Area = \frac{Drag\ Force}{\frac{1}{2}\rho V_{MAX}^2}$$

For each flight condition, the vehicle will begin at MTOW with 100% energy storage (full fuel tank or fully charged batteries).

2.3 Deliverables

This section summarizes specific details which should be included in the final report. However, these are only a minimum set of requirements. Students are encouraged to conduct a thorough aerodynamic and structural analysis of the vehicle to validate claims of performance. In particular, an accurate estimation of the vehicles parasitic drag is critical to predict maximum level flight speed. Aeromechanical analysis of any rotor systems should ensure control authority and safety. A dynamic analysis of variable speed rotors can determine the quickness of rotor speed changes during maneuvers in acceptable. Loads analysis of any flexible, morphing, or variable-geometry surfaces or structural members should inform the selection of materials and mechanical design.

2.3.1 Vehicle Configuration Trade Studies

Students should perform a tradeoff analysis of several aircraft configurations, describe the strengths and weaknesses of each configuration considered, and justify the final selection chosen for the proposed vehicle. Include the specifications of the final proposed design in comparisons to provide a quantitative comparison to configurations not chosen.

2.3.2 Detailed Description of Reconfigurable Systems

A detailed description of the reconfigurable system, its enabling technologies, and its operation should be included in the report along with a justification of design choices and any supporting analyses and graphics. Comparisons should be made to traditional non-reconfigurable systems of a similar size to characterize benefits of the reconfigurable system. The section must clearly discuss knowledge of the aircraft controllability and operation in the transition phase (while reconfiguration takes place), including estimates of the time needed to reconfigure the aircraft.

Provide performance metrics such as power loading, Lift-to-Drag ratio, fuel or energy consumption rates, drag area, and other pertinent metrics which justify the use of the chosen reconfigurable design. An example would be the increase in range, maximum speed, or hover time specific to the added weight of the reconfiguration subsystem(s) in km/kg, (km/hr)/kg, or hr/kg.

2.3.3 Vehicle Weight Breakdown

Inboard and outboard profiles of the aircraft showing locations of major components are required as well as a weight breakdown in SAWE RP-A7 or RP-8 or similar format and a center of gravity (CG) analysis that ensures the aircraft is stable in flight if the CG locations shift.

2.3.4 Performance Calculations

Provide calculations to substantiate performance metrics of section 2.2.5 and reconfigurable subsystem metrics in section 2.3.2. Include calculations and a segment by segment summary of the aircraft performance for the chosen CONOPS in section 2.3.5 including flight speed, altitude, energy consumed, gross weight, and power required for the entire vehicle system.

2.3.5 CONOPS

Students should develop and present Concepts of Operations (CONOPS) for the proposed design which best displays the benefit of the vehicle's reconfigurable capabilities and completing useful work (payload delivery, SAR, etc). Standard equipment for all missions should include all necessary power and engine management and control units, communication equipment, and (unmanned) navigation equipment. Mission payloads may include cargo for transport, a sensor ball with Electro-optical/Infrared (EO/IR), Laser rangefinder/designation (LRF/D), SAR, moving target indicator, satellite communications relay, explosive hazards detection, and Chemical, Biological, Radiological, Nuclear, and Environmental (CBRNE) detection.

2.4 Additional Task for Graduate Teams

- A stress assessment to characterize the structural and aerodynamic loads acting on the reconfigurable system and lifting devices (wings, rotors, etc). In-flight aerodynamics loads (steady and vibratory) should be calculated and used in a structural analysis to ensure wings and rotors do not fail or fatigue and have acceptable safety margins.
    - Figures should include but not be limited to plots of maximum load factor versus airspeed (consider structural and power limitations), maximum steady airloads along a blade or wing span, and maximum steady structural loads along a blade or wing span.
- Identify aeroelastic stability boundaries and show that they fall outside of the aircraft's operating envelope.
- Develop flight control laws and simulate the vehicle during the reconfiguration process and show that the aircraft is controllable and stable throughout the reconfiguration process and that the reconfiguration can be reversed in flight.

2.5 Bonus Task – FLIGHTLAB Model

Advanced Rotorcraft Technologies Inc. (ART) will provide their FLIGHTLAB rotorcraft analysis package to all teams who wish to participate in this optional task in which teams should develop a FLIGHTLAB model of their proposed vehicle. The aircraft analysis model should consist of:

1. Rotor (if present) geometric, dynamic, and aerodynamic properties including but not limited to airfoil tables, chord distribution, twist distribution, inertias, and mass distributions.

2. Fuselage properties including but not limited to airloads (consistent with drag calculations from Section 2.3.3), control surfaces, and landing gear (if present).
3. Flight control system which enables the vehicle to be controllable and stable throughout its flight envelope.
4. Propulsion System of appropriate performance (lapse rates, torque limits, etc.)

The goal of this task is to have an accurate model of the vehicle which the judges will use to run analyses and test in the FLIGHTLAB flight simulation environment. All vehicle design parameters and performance metrics should match those stated in the Final Report.

Students should use their model to perform the following analyses and draw conclusions about the vehicle's flight characteristics:

1. Handling qualities assessment (roll, pitch, and yaw quickness)
2. Vehicle stability assessment (response to a step/ramp/impulse in roll, pitch, and yaw)
3. Center of gravity excursions (effects on stability and control power required when the CG moves)

Specific details for obtaining the necessary software license and support from ART will be provided to the Teams after receipt of the Letter of Intention to Participate.

ART will also provide a web-based training class on the use of FLIGHTLAB at the start of the competition, and students will receive FLIGHTLAB documentation and training material with their FLIGHTLAB distribution. ART will also provide some Help Desk support to the competing teams during the competition, but the teams should be aware that this support is limited.

REMINDERS

AHS International and ARL wish you success in your endeavors to meet the challenges of this RFP. Please remember the following important dates:

- To participate in the competition, AHS International **must** receive your Letter of Intent no later than **5 February 2018**.
- The deadline to submit all files for your proposal is **31 May 2018.**

No extensions will be given — please plan ahead!

All information on the competition is available at www.vtol.org/sdc.

Good luck!

The Vertical Flight Technical Society

www.vtol.org/sdc