41st Annual Student Design Competition

2023-2024 Request for Proposal (RFP)

Multi-Mission Modular UAS for Disaster Relief

Sponsored by

Table of Contents

1. Basic Proposal Information

The DEVCOM Army Research Laboratory extends greetings and invites you to participate in the 41st Annual Student Design Competition (SDC) of the *Vertical Flight Society* (VFS).

This Request for Proposal (RFP) is divided into two sections. Section 1 (this section) provides:

- General description of the competition
- Process for entering
- Rules (both general and proposal specific)
- Schedules
- Award description
- Contact information

Section 2 describes the specific challenge by the **DEVCOM Army Research Laboratory** and VFS.

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 1.1.3).

1.1.2 Team Information: Roles, Size and Number of Teams

The formation of project teams is encouraged and must follow these rules:

- **ALL teams MUST name at least one (1) faculty advisor to compete.**
- The maximum number of students on a single-university team is ten (10).
- Minimum team size is one (1), an individual, in addition to at least one faculty advisor.
- Schools may form more than one team, and each team may submit a proposal, but each team is limited to a maximum of ten (10) students.
- A student may be a member of one team only.
- **Teams are allowed to include up to two (2) industry and/or two (2) government advisors to mentor/advise on the design.**

We look favorably upon the development of collaborative, multi-university teams for the added experience gained in education 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 the Letter of Intent (LOI). The LOI is drafted by the team captain and emailed to the Vertical Flight Society contact by the date specified in section 1.3.
Information in the Letter of Intent must include:

- **Name of the university or universities forming the team**
- Name of the team

- **Printed name of each student member of the team including**
  - Email
  - Education Level (Undergraduate or Graduate)
  - Affiliation of each student in the case of multi-university team
- **Identify the team captain and faculty advisor(s):** ***the team captain and faculty advisor will be the POC for all SDC communications.***
- Printed name, affiliation and email address of any industry or government advisors

1.1.3 Categories and Classifications

The competition has two award categories, which are:

- Undergraduate Student Category (1st, 2nd, 3rd)
- Graduate Student Category (1st, 2nd, 3rd)

NOTE: The classification of the team is determined by the highest educational level currently pursued by any member of the team.

There is a third category awarded to team(s) that meet the criteria, which is:

- New Entrant Category: A new entrant is defined as any school (undergraduate or graduate) ***that has <u>not</u> participated in the last three competitions***.

1.1.4 Language of Proposal

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

1.1.5 Units Used in Proposal

All teams must submit using SI units as the primary units, with English units in parentheses (optional). The use of units shall be consistent throughout the proposal. All engineering units should be expressed in the units of:

- Newtons, N (Force)
- Kilograms, kg (Mass)
- Seconds, minutes, or hours as appropriate (Time)
- Meters, m, or kilometers, km, as appropriate (Length)
- Meters per second, m/s (Velocity/Speed)
- Watts, W, or Kilowatts, kW as appropriate (Power)
- Gross Takeoff Weight (GTOW) and Payload Weight may be expressed in kilograms

1.1.6 Proposal Format, Length and Medium

Two mandatory files comprise the Final Submittal and both files must be present for a submission to be considered complete. The judges shall apply a penalty if a file is missing.

Third File (Graduate Teams): ***Gust Rejection Animation*** **–** see section 2.4.6 Additional Tasks for Graduate Teams.

Optional File: A maximum of two video files can be submitted as part of a team's proposal as separate MP4 file(s).

The two mandatory files are the Final Proposal and Executive Summary. Each is described herein.

The first file is called the Final Proposal. It is the complete, self-contained proposal of the team and must be submitted in Adobe PDF and follow these guidelines:

- Undergraduate category Final Proposals shall be no more than 50-pages.
- Graduate category Final Proposals shall be no more than 100-pages.
- All pages are to be numbered.
- Page count includes all figures, diagrams, drawings, photographs, and appendices.
- Pages should measure 8 ½ x 11 inches.
- Use of font size of at least 10-points and spacing that is legible.
- 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.

In short, anything that can be read or viewed is considered a page and subject to the page count, with the following exceptions:

- Cover page
- Acknowledgement page
- Signature page (see Section 1.1.7)
- Posting permission page (see section 1.1.10)
- Table of contents
- List of figures
- List of tables
- Nomenclature
- Reference pages
- Executive Summary

The second file is called the Executive Summary. This is a self-contained "executive" briefing of the proposal and must be submitted in Adobe PDF and follow these guidelines:

- Limited to twenty (20) pages for both undergraduate and graduate category and can take the form of a viewgraph-style presentation.
- No additional technical content should be introduced in the Executive Summary
- All pages are to be numbered.
- Pages should measure 8 ½ x 11 inches.
- Use of font size of at least 10-points and spacing that is legible.
- If a submission exceeds the page limit, judges will apply the same page count penalty to the Executive Summary score as the Final Proposal.
- The Executive Summary is not scored separately but contributes up to 10% of the total score of the complete submission.

All submissions shall be made via e-mail to the VFS contact or by upload to VFS (instructions will be provided by VFS).

1.1.7 Signature Page

All submittals must include a signature page as the second page, following immediately after the cover page. The signature page must include:

- Student name
- E-mail address
- Education level (undergraduate or graduate)
- Signature of each student
- 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 their project from the competition, the team captain must email the VFS SDC point of contact immediately.

1.1.9 Permission/Proposal Posting

VFS will publish the Executive Summaries of each of the winning entries in the undergraduate and graduate categories on the SDC website *hence written permission MUST appear on the signature page* – this permission page will not count against the page count. vtol.org/awards-and-contests/student-design-competition/past-student-design-winners

Therefore, neither the Executive Summaries nor the Final Proposals are considered confidential. The Society does not share or publish any of the non-winning proposals but does keep a record of all proposals.

VFS makes no claims on the Intellectual Property or ownership rights of the proposals, which remains with the student team members (or the university if it asserts rights to student products), who are free to republish or use all or part of the proposal in future works. The permission page merely gives VFS the right to publish the executive summary and other parts of the proposal (e.g., images of the proposed aircraft) for the press release and other promotional purposes.

1.2 Awards

DEVCOM Army Research Laboratory is pleased to sponsor the VFS Student Design Competition this year. **DEVCOM Army Research Laboratory** will provide the funds for the awards and travel stipends through VFS. Submittals are judged in three (3) categories.

Undergraduate category:

- 1st place - $2,000
- 2nd place - $1,200

- 3rd place - $750

Graduate category:

- 1st place - $2,500
- 2nd place - $1,800
- 3rd place - $1,000

Best New Entrant (as defined in section 1.1.3):

- Undergraduate - $500
- Graduate - $750

Certificates of achievement will be presented to each member of the winning team and to their faculty advisors for display at their school.

- Student representatives from the first-place graduate (up to two students) and undergraduate (up to two students) teams are expected to present a technical summary of their design at the Vertical Flight Society's 81st Annual Forum, May 13-14, 2025, in Virginia Beach during an Aircraft Design Technical Session.
- The student(s) presenting the winning design will receive complimentary registration to the Forum.
- In addition, the first-place graduate and undergraduate team's university will be provided a $1,000 stipend to help defray the cost of the team's Forum attendance – the additional travel stipend amount will be included in the first-place award disbursement to the school.

The Vertical Flight Society and the Student Design Competition Committee reserve the right to decline to make all the awards in the above categories if there are not enough submissions that meet the expectations of the judges. Proposals that do not, in the assessment of the judges, demonstrate an adequate understanding of the problem may be deemed ineligible for an award. In addition, any proposal that includes plagiarism or that copies substantial portions of prior proposals or publications will be disqualified.

1.3 Schedule

Schedule milestones and deadline dates for submission are as follows:

Milestone	Date
VFS Issues the RFP	August 2023
Teams Submit Letter of Intent (LOI) to Participate	February 1, 2024
Teams Submit Requests for Information (RFI)/Clarification **Note: questions/answers will not be communicated on a case-by-case basis. VFS will distribute ALL questions/answers collectively to all participating team captains by March 26, 2024.**	Continuously, but NLT February 23, 2024
Sponsor RFI/Questions Review	Feb. 26 to March 25, 2024
VFS Issues RFI/Questions Response to Teams	NLT March 26, 2024
Teams Submit Executive Summary and Final Proposal	NLT May 31, 2024
SDC Committee & Sponsor Reviews/Scores Final Proposals	June 1 to July 31, 2024
Sponsor/SDC Committee notifies VFS of results	August 2024
VFS announces winners	August 2024
Winning Graduate and Undergraduate Teams present at VFS Forum 81 (2025)	Forum 81: May 13-15, 2025, Virginia Beach, VA

1.4 Contacts

All correspondence should be directed to:
Julie M Gibbs, Technical Programs Director
VFS – *the Vertical Flight Society*
2700 Prosperity Ave., Ste. 275
Fairfax, Va. 22031
Phone: (703) 684-6777 x 103
E-mail: jmgibbs@vtol.org

1.5 Evaluation Criteria

The proposals shall be judged on four (4) primary categories with weighting factors specified below.

1.5.1 Technical Content (40 points)

The Technical Content of the proposal requires that:

- The design meets the RFP technical requirements.
- Assumptions are clearly stated and logical.
- A thorough understanding of tools is evident.
- 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 how well current and anticipated technologies are applied to the problem, and on the feasibility of the solution. The proposals must:

- 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:

- Innovation, simplicity, and elegance of the solution.
- Imagination and ingenuity of the ideas investigated with the trade studies.
- Vehicle/system aesthetics.

1.5.4 Organization & Presentation (15 points)

The organization and presentation of the proposal requires:

- Self-contained Executive Summary that contains all pertinent information and a compelling case as to why the proposal should win and 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 proposal requirements (Section 1.6) and design objectives (Section 2).

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):

1. Demonstrate a thorough understanding of the RFP requirements.
2. Describe how the proposed technical approach 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. 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 is the process and substantiation.
4. 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.

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 the primary two files submitted via email or upload.

1. 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.
2. The second file is an ***Executive Summary***, which presents a compelling story why the VFS evaluators 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.

2.0 Operating Concept

On 6 February 2023, a series of high-magnitude earthquakes struck southern and central Turkey and northern and western Syria. The epicenter of the first, M_w 7.8, earthquake was 37 km west-northwest of the Turkish city Gaziantep. A second, M_w 7.7, earthquake later struck with an epicenter 95 km north-northeast of the first. The earthquakes resulted in the confirmed deaths of 50,783 people in Turkey and 8,476 people in Syria. Relief efforts by the Turkish government in the days and weeks following the disaster were hampered by damaged roads, winter storms, and disruption to communications.

In the immediate time after a disaster, traditional means of ingress and egress for ground vehicles and fixed-wing air vehicles might be disrupted: roads may be damaged, airports may be flooded, runways might be destroyed or inoperable. **Therefore, we propose the design of a multi-mission, modular, VTOL UAS which can:**

1. **Take off and land vertically from the deck of a ship in high-winds and gusty conditions.**
2. **Cruise to and from the site of a disaster.**
3. **Serve as a long-endurance communications relay, OR land vertically to deliver relief supplies.**
4. To satisfy the requirements of both the long-endurance and supplies-delivery missions, the vehicle may be modified using a system of modular add-ons.

2.2 Aircraft Requirements

The vehicle shall meet the following requirements:

Table 1.

#	UAS Metric	Units	Long Endurance	Supplies Delivery
1	Gross Takeoff Weight (GTOW)	kg	160	160
2	Payload Weight	kg	20	50
3	Threshold Endurance at 185 km Mission Radius	Hours	10	0.33
6	Launch and Recovery Footprint	m	6 x 6	6 x 6
7	Minimal Launch & Recovery Equipment	---	Yes	Yes
8	Vehicle Storage in Hangar (4x12) m	# UAS	4	4
9	Spatial Accuracy of Aircraft Recovery	m	1	1
10	Wind Limits for Launch and Recovery (Head, Cross, Tail, Gust) *	m/s	15, 8, 3, 5	15, 8, 3, 5
11	Payload & Accessories Bus Power Required	W	800	400
12	Heavy Fuel (Jet-A fuel compatible) Required	---	Yes	Yes

*** Required for graduate teams only.**

In addition to the requirements enumerated in the table, the aircraft described above should:

- Be launched and recovered vertically from the deck of a ship.
- Be manoeuvrable by 2 people using minimal equipment while on deck.

- Must be either 100% electric or use an engine(s) compatible with Jet-A fuel. Engines should not use gasoline.
- Must include subsystem weight for optical navigation and avionics hardware.

2.2.1 Modular Add-on Specifications and Requirements

To meet the minimum mission requirements for both the long-endurance and supplies-delivery missions and to also maximize loiter time and payload weight respectively, the design teams will be allowed (but not required) to make one or more modifications to their UAS design. **The requirements having to do with modular add-ons are:**

- The vehicle modifications will take place between missions on the deck of a ship.
- The gross takeoff weight (GTOW) of the UAS must be equal to 160 kg in all configurations.
- The maximum weight of the add-on(s) must be no greater than 15% of the GTOW. In other words, UAS components weighing no more than 15% of the GTOW may be removed and replaced with a different set of components of the same weight.
- The modular add-on(s) must be swapped out and in by 2 people in less than 10 minutes. The design teams are expected to reasonably assess what is possible in a 10-minute time frame.
- The interface of the modular add-on(s) and the vehicle must be well-defined. The design teams should describe in detail the structural, aerodynamic, and aeromechanical implications of both their add-on(s) and the add-on interface.
- The vehicle storage requirements given in #8 of Table 1 must include the base vehicle as well as both sets of add-ons.
- Add-on weight MAY include additional energy weight (e.g., fuel, battery, fuel cell, etc.).

2.3 Mission Requirements

The purpose of the long-endurance mission is to serve as a communications relay to support the disaster relief effort. The vehicle will carry a 20 kg Mission Equipment Package (also called the payload) which will relay cell signals. For this mission the loiter time in Segment 5 should be maximized (given all other constraints and requirements), with a minimum value of 10 hours. **The requirements for the long-endurance mission are:**

1. 5-minute flight idle: $h_G = 0\ m$.
2. Vertical takeoff from a ship deck: $h_G = 10\ m$.
3. Climb to $h_G = 500\ m$ in no more than 4 minutes: $h_G = 500\ m$.
4. Fly 185 km in no more than 1.25 hr: $h_G \geq 500\ m$.
5. Loiter for no less than 10 hours: $h_G = 500\ m$.
6. Fly 185 km at any speed: $h_G \geq 500\ m$.
7. Descend to $h_G = 10\ m$ in no more than 4 minutes: $h_G = 10\ m$.
8. Vertical landing on ship deck: $h_G = 0\ m$.

Note the following:

- Range credit toward the 185 km requirement in segment 4 may be taken for ground covered in segment 3.
- Likewise for segments 6 and 7.

The purpose of the supplies-delivery mission is to provide disaster relief supplies to a helipad. For this mission, the weight of the payload should be maximized (given all other constraints and requirements), with a minimum value of 50 kg. **The requirements for the supplies-delivery mission are:**

1. 5-minute flight idle: $h_G = 0\ m$.
2. Vertical takeoff from a ship deck: $h_G = 10\ m$.
3. Climb to $h_G = 500\ m$ in no more than 4 minutes: $h_G = 500\ m$.
4. Fly 185 km in no more than 1.25 hr: $h_G \geq 500\ m$.
5. Loiter for 20 minutes: $h_G = 500\ m$.
6. Descend to $h_G = 10\ m$ in no more than 4 minutes: $h_G = 10\ m$
7. Vertical landing onto helipad, offload all payload: $h_G = 0\ m$.
8. Vertical takeoff from helipad: $h_G = 10\ m$.
9. Climb to $h_G = 500\ m$ in no more than 4 minutes: $h_G = 500\ m$
10. Fly 185 km at any speed: $h_G \geq 500\ m$.
11. Descend to $h_G = 10\ m$ in no more than 4 minutes: $h_G = 10\ m$
12. Vertical landing on ship deck: $h_G = 0\ m$.

Note the following:

- Range credit toward Segment 4 may be taken for ground covered in Segment 3
- Range credit for Segment 10 may be taken for ground covered in Segments 9 and 11
- Loiter time credit for Segment 5 may be taken for time taken in Segment 6

The details of the mission requirements have been left somewhat open-ended. Any aspect of how the vehicle flies, not explicitly specified in the enumerated lists above are at the discretion and judgement of the design team.

- Example 1: the vehicle may cruise at a higher altitude than $h_G = 500\ m$, but must start and finish the segment at $h_G = 500\ m$.
- Example 2: The design teams should use their best judgement when analysing the aerodynamic environment of shipboard and helipad VTOL. Any decisions made by the design teams of this kind should be thoroughly discussed and justified.

2.4 Document, Experimental or Other Requirement Task

For all analysis and quantitative metrics requested in this section, 2.4, design teams shall discuss the methods, techniques, models, and assumptions used to calculate the results.

2.4.1 Conceptual Design Trade Studies

The design teams shall provide conceptual design trade studies and associated analysis which substantiate their UAS design decisions. **Trade studies should include topics such as:**

- Vehicle configuration choice (e.g., tail sitter vs lift + cruise)
- Rotor/propeller design
- Powerplant selection
- Transmission design
- Wing design (if applicable)
- Fuselage design

- Any other analysis the design team used to come to its final design.

2.4.2 Vehicle Performance

The design teams shall provide vehicle performance analysis for both the long-endurance and supplies-delivery missions. **The analysis must include but is not limited to:**

- Vehicle total power required for all mission segments.
- Vehicle aerodynamic power required (e.g., for a helicopter this would be rotor shaft power required) for all mission segments.
- Vehicle transmission efficiency for all mission segments.
- Vehicle powerplant efficiency for all mission segments.

Graduate teams are required to:

- Provide an off-mission analysis of total power required vs airspeed (from 0 – 50 m/s in increments of 5 m/s) for the long-endurance UAS configuration using the assumption that $W = GTOW$.
- Include the corresponding graphs of pitch angle, flightpath angle, and wing lift fraction vs. airspeed.
- In addition, provide their trim solutions (i.e., control inputs and corresponding zero net forces/moments) for all mission segments.

2.4.3 Weight Breakdown

Design teams shall provide the following items related to the vehicle weight:

- A component-by-component weight breakdown for the vehicle in all add-on configurations (assuming $W = GTOW$).
- Vehicle weight at the beginning of each mission segment.
- A center of gravity analysis (laterally, longitudinally, and vertically).

2.4.4 Aerodynamic Metrics

Design teams shall include the following aerodynamic metrics describing the airframe. The airframe excludes rotors, wings, and empennage, but does include rotor hubs:

- Lift area (L/q) at zero degrees vehicle pitch and yaw angle.
- Drag area (D/q) at zero degrees vehicle pitch and yaw angle.
- Pitching moment volume (M/q) at zero degrees vehicle pitch and yaw angle.

In addition, a component-by-component drag breakdown—including rotors, wings, and empennage (if applicable)—shall be provided for the long-endurance mission Segment 5 and the supplies-delivery mission Segment 4.

2.4.5 Vehicle Drawings

Design teams shall provide (at a minimum) the following drawings:

- Three-view external geometry including vehicle dimensions for all vehicle configurations.
- Fuselage and wing internal layout including center of gravity location for all vehicle configurations.
- All modular add-on interfaces.

2.4.6 Additional Tasks for Graduate Teams

Graduate teams must complete the following tasks:

1) Develop control laws for one of the vehicle configurations. Demonstrate that the vehicle is stable and controllable in all flight segments. Show that the vehicle can perform a ship-board vertical takeoff and landing subject to the high-wind and gusty conditions described in #10 of Table 1.
2) Create an animation of one of the vehicle configurations rejecting an 8 m/s side gust during Segment 1.

3. Glossary

- AGL Above Ground Level
- cg Center of Gravity
- FAR Federal Aviation Regulations (US)
- FM Figure of Merit
- FOD Foreign Object Debris
- HIGE Hover In Ground Effect
- HOGE Hover Out of Ground Effect
- HSVTOL High-Speed Vertical Takeoff and Landing
- ISA International Standard Atmosphere
- KTAS Knots True Airspeed
- LOI Letter of Intent
- LZ Landing Zone
- NLT No Later Than
- MCP Maximum Continuous Power
- MEP Mission Equipment Package
- MMGW Mid-Mission Gross Weight
- MRP Maximum Rated Power
- MSL Mean Sea Level
- PDF Portable Document Format
- psf pounds per square foot
- RFI Request for Information
- RFP Request for Proposals
- ROA Radius of Action
- ROC Rate of Climb
- SAWE Society of Allied Weight Engineers
- SDC Student Design Competition
- SDGW Structural Design Gross Weight
- SI Système Internationale
- TBD To be Determined
- TOGW Takeoff Gross Weight
- US United States
- V Velocity/speed
- VFS Vertical Flight Society
- VTOL Vertical Takeoff and Landing
- XMSN Transmission