



# 5<sup>th</sup> Annual MAV Student Challenge Final Rules January 2017



AHS International  
73<sup>rd</sup> Annual Forum and Technology Display  
May 8, 2017, Fort Worth, Texas USA

[www.vtol.org/mav](http://www.vtol.org/mav)

## Overview

The American Helicopter Society (AHS) International — *The Vertical Flight Technical Society* — invites student teams to participate in the 5<sup>th</sup> Annual Micro Air Vehicle (MAV) Student Challenge. This electric-powered vertical take-off and landing (VTOL) MAV competition seeks to encourage interest in autonomous/unmanned aircraft technology as well as small air vehicle design and fabrication. Similar to previous years, teams may choose to design either a remotely-controlled system or a fully-autonomous system. However, this year, every team must have a safety pilot and the ability to remotely control the aircraft in the event of unexpected/unacceptable aircraft behavior.

## Theme: Package Delivery in the Wild West

### The Story

This year's event features a "package delivery" aircraft challenge — with a Western theme: An old bandit suddenly came out of retirement to steal four very valuable antique "Texas Redback" bills during a museum transfer. The Texas Rangers police force has tracked the location of the bills to a secluded ranch outside the city, and they suspect that the old man is already regretting his latest heist. However, no one dares to enter the property due to fear of booby traps and gunfire from inside. To avoid the inevitable Wild-West-style shootout, the courts have allowed the police to use a delivery MAV to drop off a letter at his door. This letter includes the arrest warrant as well as an opportunity for redemption: if the bandit returns the Redbacks with the MAV, the Rangers will forgive the entire event. The bandit has already heard of their plan and decided he should probably go back to retirement! He has prepared an envelope of his own, with all four of the Redbacks inside, and he dropped it just outside his back door to show the Rangers that he already knew their plan. To ensure that the UAV sees the package and can carry it away, he wrapped a red ribbon around it and tied a small bow on top.

### The Challenge

Teams must fly an electric, VTOL-capable MAV that can carry the Ranger's envelope to the first target location, pick up the bandit's envelope from a second location, and fly back to the home base with the Redbacks intact. Both "No.10" envelopes weigh less than 25 grams (~1 oz) and hold standard, US letter-sized paper. Also, between the home base and the targets is a building-like obstacle that the MAV must avoid. Further design limitations and requirements are described throughout the rest of this document. Points will be awarded primarily for successful completion of mission stages; other elements such as flying characteristics, vehicle innovation, and time for mission completion serve as tie-breaking metrics.

**Point of Contact:** Please address any questions to Jacquelyn Banas at [jdbanas@gmail.com](mailto:jdbanas@gmail.com)

**Required Competition Elements:** All teams must participate in the following final competition elements in order to be eligible for awards.

1. **Task A: Design Presentation & Poster: 5-10 minutes**  
Each finalist team must prepare a poster and verbal presentation, including a short flight demo. Presentations should include the following information:
  - a. Air vehicle design process,
  - b. Autonomy elements (hardware and software),
  - c. Package delivery elements,
  - d. Ground control system capabilities
  - e. Safety systems.

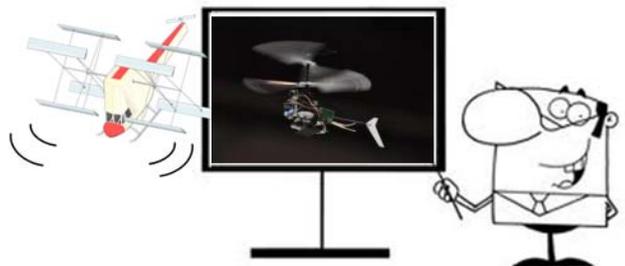


Figure 1. Poster Presentation and Free Flight Demo

Flight demonstrations are short, free-form style: teams are encouraged to showcase the capabilities of the aircraft for the audience. The total presentation and flight demo time should be kept under 10 minutes per team.

## 2. Task B: Indoor Package Delivery Mission: 10 min

As shown in Figure 2, the flight demo includes the following elements: steady-state hover, obstacle avoidance, visual recognition of the dropoff point, delivery of the first package, recognition of the pickup point, acquisition of the second package, and return to base (with the second package) in an efficient, well-controlled manner. Each team will have ten (10) minutes to attempt the mission.

Teams may conduct either a fully-autonomous mission or a remotely-piloted mission (manual flight) using an onboard vision system. For manual flight, teams will switch to camera-based flight after crossing a line-of-sight (LOS) boundary. All aircraft must remain within the Mission Boundary during flight, and each team must have a safety pilot ready to override the autonomous systems in case of unacceptable aircraft behavior.

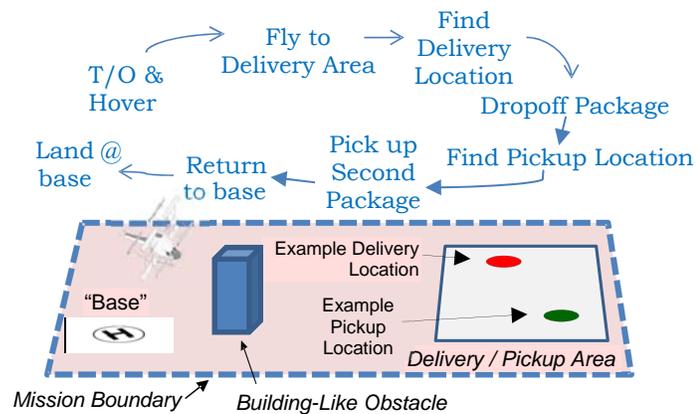


Figure 2. Task B - Target Search Mission

**Awards** – The team with the highest score in each of the following groups will receive a cash award, as determined by the panel of judges. Entrants in all categories must be able to fly the mission without violating any of the competition rules.

- **Best Autonomous Target Search**
- **Best Remotely-Controlled Target Search**
- **Most Innovative Vehicle Design**

Several participant awards may also be awarded. As in past years, the total prize money this year will be based on the contributions received from various event sponsors, but will be not less than \$5,000 USD.

## Who Can Apply

### Team Restrictions

Competition is restricted to teams of full-time university and/or high-school students. At least one member of the team must be a current AHS Student Member at the time of entry. High-school teams are encouraged to find a university or industry mentor to help guide progress through various competition milestones. Teams must have at least one member registered for the AHS Forum. Teams may request discounts or waivers for AHS Forum registration fees to allow student participants in the competition. If there are more than two teams per university, the competition coordinators reserve the right to disallow participation to limit the number of teams.

### Vehicle restrictions

The competition is restricted to aircraft with the following properties:

Configuration (each is a requirement):

- Vertical takeoff and landing (VTOL) as well as hover capability
- Any number of rotors/propellers
- Onboard flight-stabilization
- Onboard camera(s) needed for mission – Multiple cameras are allowed.
- Standard communication (preferred 2.4 GHz)

Space, Weight, and Power (SWAP):

- Electric-powered vehicles only (no gas-powered vehicles)
- Weight < 500g (17.6 oz) including batteries (not including the delivery packages)
- Size <45 cm (17.7 inches) in any dimension

Safety:

- “Kill Switch”: Dedicated hardware RC kill switch or remote-operation button command. Vehicle equipped to instantly cut power upon receiving “kill” command.
- All aircraft must include the capability to be flown remotely by a qualified safety pilot. This remotely-piloted mode must be able to override all autonomous

## Payload Description

1. The “Delivery Package” (from the Texas Rangers) is a sealed, standard US letter-sized No. 10 envelope, similar to Item #394057 at Staples.com. It will contain some sheets of paper so that the total weight is between 20 and 25 grams. Slight modifications of the Delivery Package are allowed in order to carry it, and these methods are left to the discretion of the teams. Punctures, cuts, and other means that expose the inside of the envelope are not allowed.
2. The “Pickup Package” (from the bandit) is also a sealed envelope of the same kind, containing the Redback bank notes. Its total weight will also be between 20 and 25 grams. This envelope has a red ribbon tied around it twice, similar to the diagram in Figure 3. Teams may not modify this envelope before picking it up. The pickup location will include small plastic “guide posts” to help keep the package in place while causing minimal interference to aerial pick-up mechanisms. Assume that these guideposts, as illustrated in Figure 4, are relatively small (about 1-2” high, about 0.25” wide) and the same color as the pickup location area where they are located. They will be located near the midpoint of each side of the envelope, affixed to the pickup target diagram itself. Each team may adjust the guide post locations prior to the start of each MAV flight attempt.



Figure 3. Pickup Package Diagram.

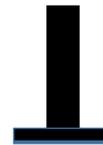


Figure 4. Small Guide Posts.

## Obstacle Description

The obstacle in this year’s course is a 3-D structure, consisting of foam board sides and colored to resemble a skyscraper in Fort Worth. Dimensions are approximately 8-10 ft tall, 3-5ft wide, and 3-5ft deep. The location of the building is at a point starting on the Line of Sight (LOS) boundary, and it may be placed on an angle with respect to this LOS boundary. Exact positioning will be determined the day of the competition.

## Selection and Competition Schedule

The team applications will undergo a gated review process involving several steps. These stages are outlined here and described in further detail below the schedule diagram.

1. Gate 1: Paper submission, including a Team Information Form as well as an abstract about the intended design.
2. Gate 2: A video submission of aircraft capabilities and safety measures.
3. Gate 3: A demonstration of safety features and vehicle capabilities prior to the Final Demo.
4. Final competition at the AHS Forum.

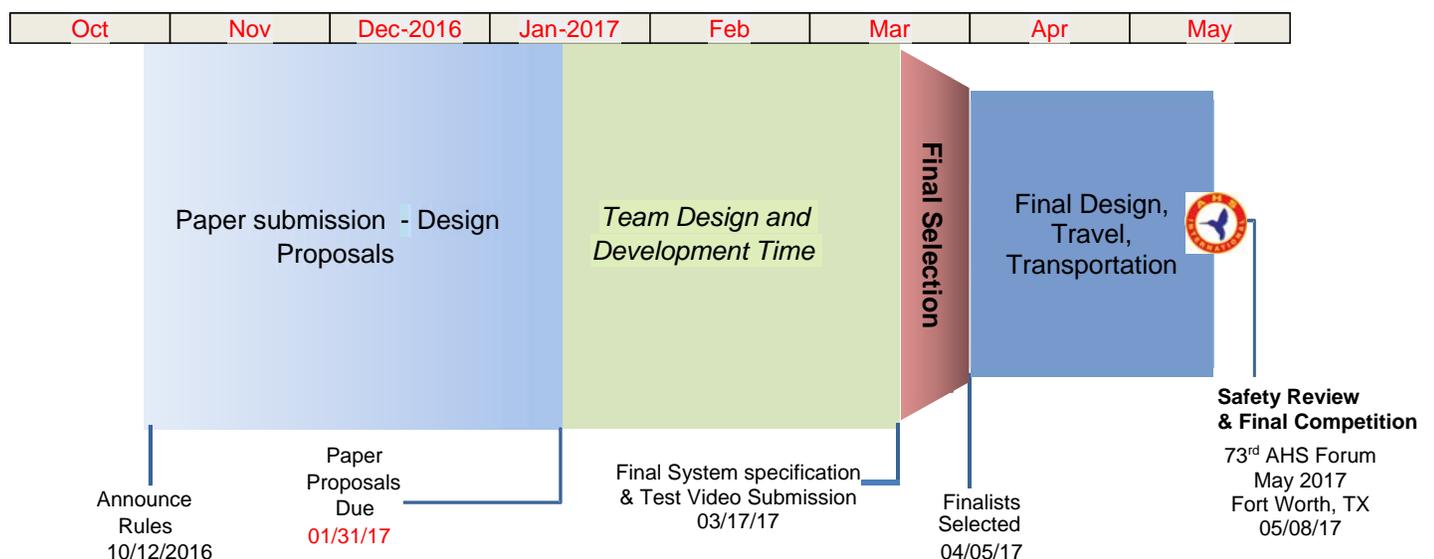


Figure 5. Schedule of Events and Selection Timeline

## ***Gate 1: Paper Submission (Due by January 31, 2017)***

Each participant team shall submit a completed **team information form** and an abstract with the following information:

- Team description, with key student and faculty members (1 page). Please include the major and year of each student team member. (For example: John Smith: Aerospace Engineering, 1<sup>st</sup> Year Masters Student).
- Vehicle specification and capabilities (1 page),
- Onboard-System & Remote-Operation development proposal (2 pages),
- Preliminary project schedule and plan to final demo (1 page).

This information will be used to judge relative progress of the teams and develop a preliminary ranking of teams. Preliminary ranking results will not be disclosed but will be incorporated into final selection. Please send a completed team form along with your paper proposal to Jacquelyn Banas ([jdbanas@gmail.com](mailto:jdbanas@gmail.com)) by 5 p.m. (GMT-5) January 31, 2017, with subject "2017 AHS MAV competition."

## ***Gate 2: Video Evidence of Competition Readiness (Due by March 17, 2017)***

- I. Each team shall submit a short system design document with the following information:
  - Final vehicle & system configuration description (2 pages),
  - Vehicle Autonomy and Remote operation capabilities, including target tracking results (2 pages),
  - Package Delivery and Pickup System description,
  - Gaps to address before final demo (1 page).
- II. Additionally, teams will **submit a video** showing the current flight capabilities of the aircraft. The following items must be included in the video for all teams:
  - Measurement of the vehicle dimensions and weight,
  - Stable hover capability
  - Ability of the vehicle to fly a simple course
  - Target recognition capability using the on-board camera system
  - Obstacle avoidance using only onboard systems
  - Preliminary proof of a package dropoff & pickup capability

Teams entering the remotely-operated category:

- Clearly show the vehicle operating through the transition to a remote operator, as it crosses the LOS boundary.
- Show that the aircraft can be flown using only onboard cameras as visual cues, for a stable hover as well as for the obstacle avoidance and delivery/pickup portions of the flight.

Teams entering the autonomous category:

- Ensure that the video is recorded while the autonomous mode is active, where possible. Verbally indicate when the vehicle is being flown remotely.
- Clearly show the real-time ground-station or recorded target-feedback information relevant to the delivery/pickup site recognition and obstacle avoidance.
- Demonstrate a takeover of the safety pilot, showing the transition from autonomous to remotely-controlled flight.

These results should be included in the paper submission as well for Gate 2.

## ***Finalists Teams Selection (Announced by Friday, April 5, 2017)***

Finalist teams will be selected using the Gate 1 and Gate 2 submissions in conjunction with the following criteria:

- Prior experience,
- Aircraft design diversity,
- Proof of vehicle readiness,
- Vehicle weight/size and constraints, and
- Plan realism.

The panel will select (approximately) **six finalist teams** on April 5<sup>th</sup> for participation in the AHS Forum competition.

## **Final Competition**

The final competition will take place in conjunction with the 73<sup>rd</sup> AHS International Annual Forum & Technology Display in Fort Worth, Texas. The Task A presentations and Task B flight demonstrations will be held on Monday, May 8, 2017 starting at 4 pm local time at the Fort Worth Convention Center. Prior to this final flight demonstration, teams are

required to arrive early to conduct safety checks of their vehicles. Please see the Ratings Structures section below for further details.

During the final competition, the teams will conduct Task A and Task B discussed earlier, in two separate categories: fully-autonomous aircraft will be scored against each other, separate from the manually-controlled vehicles. Teams will be rated according to the following metrics by an independent panel of judges from industry and academia.

Note: Additional personal or industry aircraft may fly the course after the competition for demonstration purposes, but these will not be eligible for an award. All aircraft must be registered with the competition coordinator and cleared through a safety review prior to flight on the course.

## Ratings Structures

### ***Safety Review – Quick Safety Checks Prior to the Competition***

Finalist teams are required to arrive in advance of the 4pm event time (no earlier than 3pm) for an informal safety check with the judges. The purpose of this check is to ensure that all “kill” switch systems are properly designed and transfers from autonomous to manual operation are possible, in the event of unexpected aircraft behavior. Teams may be asked to demonstrate short flights as part of this demonstration. Judges will contact finalist teams prior to the competition date to schedule each team’s safety check.

### ***Task A – Design Presentation and Flight Demo***

For Task A (Poster Presentation and Free-flight Demo) the metrics are provided in table below. The rating IDs A1-A5 will be combined in a specific weighted formula (to be disclosed in the Final Rules) in order to construct an overall score. Teams without functioning aircraft may be allowed to present their intended designs during the presentation portion of the competition, if time allows. Please contact the competition coordinator to request this.

<b>Task A</b>	<b>Design and Innovation Metrics</b>	<b>Rating ID (0-5)</b>
Originality	Not off-the-shelf, involves innovative engineering, solved challenging integration issues, unique capabilities	A1
Flight Performance	physical design, stabilization approach, aerodynamics and flight-stability, agility	A2
System Engineering	sensor-integration, remote pilot & GCS capabilities; antenna/wiring/sensor installation, craftsmanship.	A3
Maturity	Ruggedness, Field readiness, completeness of design, autonomy-readiness, potential for sensors.	A4
Teamwork	Inter-disciplinary teams, team “intangibles,” leadership shown.	A5

### ***Task B – Wild West Package Delivery Mission***

As discussed earlier, Task B is essentially a package delivery mission, with a single, building-like obstacle to avoid between the home base and the dropoff/pickup area. Aircraft must use only local information (onboard sensors and programming) to navigate the course and recognize areas of interest. The aircraft may offload some of the processing to the ground station if necessary, but teams are encouraged to include as much processing as possible in the onboard system. All vehicles must navigate through the air to find and pick up/drop off packages. Landings during the mission are allowed only for the purposes of dropping off and picking up packages as well as departing from/returning to the home base.

Points will be awarded for successful completion of each stage of the mission, as outlined below. These points represent maximum award points, and reduced numbers may be awarded based on partial completion—at the discretion of the judges. An additional qualitative assessment similar to the one used in previous years will be conducted for each mission phase, but this will only be used for tie-breaking purposes.

Teams will have a maximum of 10 minutes for flight attempts. More than one attempt at completing the mission is possible within that time, and the team’s intent to start a second attempt should be clearly announced. Each attempt must start from the home base and include all the mission elements, in order. Each flight will be separately scored by the judges.

Each team will be handed a standard “Delivery package” envelope at the competition, with a weight between 15 g and 25 g. Before starting the aircraft (and before starting the 10 minutes time), a team member will attach the envelope to the aircraft.

With the delivery package attached, each MAV is expected to conduct the following mission, in this order:

1. Liftoff and hover above the home base, at a height of 2 m (6.6 ft) above ground level (AGL). **(1 point)**
2. Takeoff and fly towards the delivery area, avoiding the obstacle. **(1 point)**
3. Recognize the “Delivery” location, and hover above it at 1-2 meters (3.3-6.6 ft) for 5 seconds. **(2 point)**  
Teams should verbally announce when the aircraft has recognized the delivery location, and judges will confirm that the ground station shows this result.
4. Drop the package on the “Delivery” location. The envelope must land within 1.5 meters (5 ft) of the center of the “Delivery” area. Aircraft may land to drop off the package. **(2 points)**  
Note: No points will be awarded for this part if the aircraft takes off with the package after landing.
5. Recognize the “Pickup” location, and hover above it at 1-2 meters (3.3-6.6 ft) for 5 seconds. **(2 point)**  
Teams should again verbally announce when the aircraft has recognized the “Pickup” location, and judges will confirm that the ground station shows this result.
6. Pick up the envelope at the “Pickup” location. Aircraft may land to pick up the package. **(3 points)**  
Note: The aircraft must still have the package when it flies away to keep all points.
7. Return to base, avoiding any obstacles. **(1 point)**
8. Perform a stable hover over the home base at 2 m (6.6 ft) AGL for at least 5 seconds. **(1 point)**
9. Perform a controlled landing on the home base with the package. **(2 points if the package is returned, 1 point if not.)**

Figure 6 shows the details of the competition area. The “Line of Sight” (LOS) boundary is the threshold beyond which an operator located near the base switches to onboard-camera-based control, as the vehicle moves into the right. The home base and mission boundary markings will remain the same as the 2015 designs, and the “Delivery” area will use the previous “target” design. An additional design is added for the “Pickup” location. Note that the Pickup Package will be located near the center of the Pickup Area and may obscure the image.

Details for each are depicted in Figure 7, Figure 8, Figure 9, and Figure 10, respectively. For autonomous operation, these “images” can be used by video-processing algorithms for target and home-base search and hover-hold operations. Although the delivery/pickups location area is roughly known, the exact location of each area of interest is unknown and may change from team to team.

Under no circumstance shall a vehicle overshoot the mission boundary by more than 1 m (3 ft). Vehicle altitude is **strictly limited** to 4.5 m (15 ft) AGL. Note that the overall dimensions in the diagram below are approximate and are subject to change based on space availability at the Forum location.

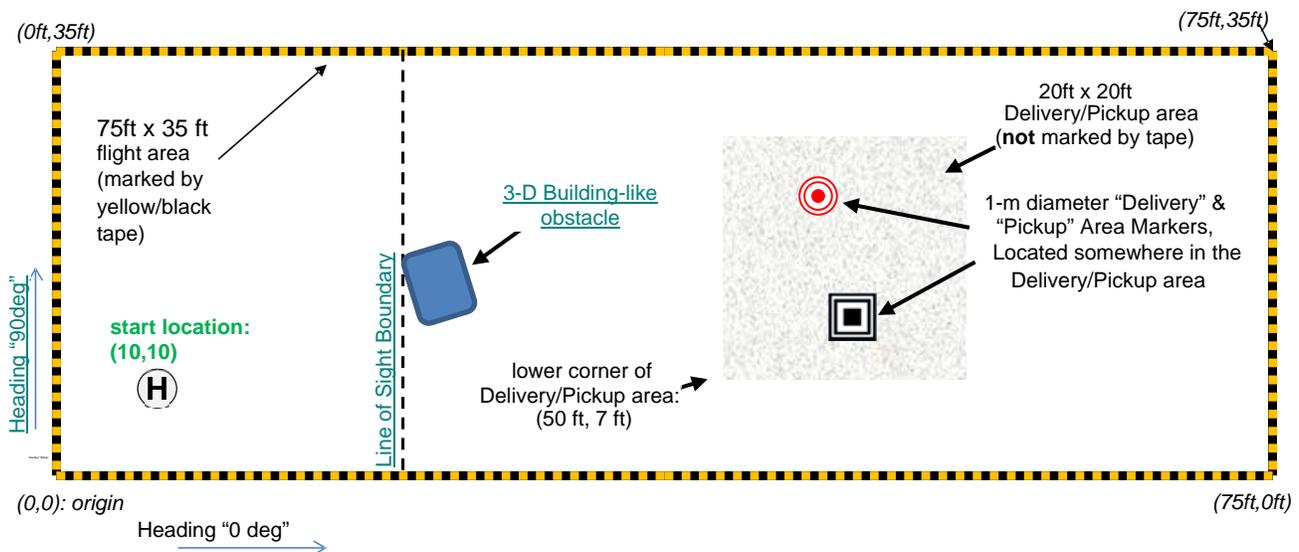


Figure 6: Approximate Layout of the Competition and Areas of Interest.



Figure 7: Floor-Attached Home Base (1m diameter)

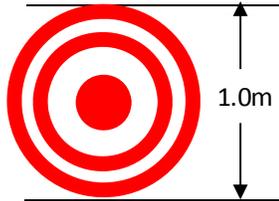


Figure 8: "Delivery" Area Marker (1m diameter)



Figure 9: "Pickup" Area Marker (1m length square)



Figure 10. Mission Boundary Marking Tape

For Task B, an additional qualitative assessment of the vehicle will be recorded for tie-breaking purposes. The panel of judges will use the following criteria (rating ID Q1-Q7) during each of the mission phases to rate the vehicle. All teams are encouraged to use the following criteria to guide their design.

Task B/ Mission Phase	Qualitative Criteria	Rating ID (0-5)
Take off & Hover	2 m (6 ft) hover height above base. Metrics: Time to stable hover & Hover stability.	Q1
En Route to Delivery/Pickup Area	Transition to this phase with clearly-announced user signal. Metrics: Qualitative smoothness of transitions and Time to reach delivery area.	Q2
Obstacle Avoidance	Avoid obstacles between the home base and the target search area. Metrics: Successful avoidance, Smoothness of flight around obstacles.	Q3
Target Search	Remote operator or Autonomous system will <u>use only onboard camera</u> to find each target. Metrics: Time to find target, Operator involvement	Q4
Target Acquisition	Establish a stable hover for at least 5 seconds over each delivery/pickup location target. Smoothly transition between searching, hover, and dropoff/pickup. Metrics: Lateral target tracking error, Stable roll/pitch performance	Q5
En Route Return to Base	Transition to this phase with user signal. Remote operator can use LOS. "Base" can use homing beacons for autonomous RTB. Metrics: Qualitative smoothness of transitions, Time to acquire stable hover over base	Q6
Hover and Landing	Acquire stable hover 2 m (6 ft) above base before landing. Metrics: Hover and landing performance, distance from center.	Q7

The disqualification rating will be given in case the vehicle violates the vehicle and demonstration limits. The following criteria will disqualify a team during final competition and nullify all mission points for the team.

Disqualification Criteria	DQ Number
Vehicle weight or size outside of stipulated limits.	DQ1
Flight above 4.5 m (15 ft) AGL	DQ2
Damage of either package.	DQ3
Overshooting the mission boundary by >1 m (3 ft).	DQ4
Failure for the Remote Operator to: <ul style="list-style-type: none"> <li>- Use only the onboard camera to stay within bounds.</li> <li>- Switch to onboard camera beyond the LOS boundary.</li> </ul>	DQ5

The ratings A1-A5 and points from the mission will be combined in a specific weighted formula to decide the three prize winners for the AHS competition. Ties will be determined using criteria Q1-Q7. Runners-up will receive participation awards. All prize awards are subject to availability of competition sponsors and award funds.

## ***Expenses and Support***

AHS will not provide any travel or accommodation support for finalist teams, or pay or reimburse any other expenses. Teams are responsible to raise funds for travel, accommodation, equipment transportation, and storage, if necessary. It is recommended that three team members attend the final demonstration in order to provide necessary support and safety operations. AHS may be able to consider a waiver or discount for AHS Forum registration fees for student participants. Please ask your advisers about signing up as a volunteer for the Forum, and contact the event organizer if additional support is needed.

AHS will provide onsite storage, power supplies and desk space for equipment checks and repair. Teams wishing to use projectors/digital media or require other equipment for the Task A presentation should contact the organizers prior to the event. Projectors and presentation screens may not be available for the competition.

## ***Disclaimers***

AHS assumes no responsibility for any actions caused by any participants of the MAV Student Challenge. These rules are subject to changes. Final rules and updates will be published at [www.vtol.org/mav](http://www.vtol.org/mav) and will be provided to all registered entrants.

Participation in the completion explicitly gives permission to AHS International to use photographic, video, documentation or other records of the competition for educational and promotional purposes.



The Vertical Flight  
Technical Society

## 5<sup>th</sup> Annual MAV Student Challenge Team Information Form

Team Name: \_\_\_\_\_

School/Department Name: \_\_\_\_\_

(Limit of 2 teams per university. If more, AHS *may* decide to accept only first two entrants.)

Point of Contact (Faculty, Email, Phone No.): \_\_\_\_\_

Forum Tech Session Presentation? (if any): \_\_\_\_\_

### Electric MAV Details

Type (Quadrotor, Helicopter, etc.): \_\_\_\_\_

Weight (without batteries): \_\_\_\_\_

Weight (with batteries): \_\_\_\_\_

Dimensions (all inclusive): \_\_\_\_\_

GCS Interface (data-link, RC, etc.): \_\_\_\_\_

Sensor Payload: \_\_\_\_\_

Max Speed (if known): \_\_\_\_\_

Describe implementation of remote-control operated power-kill switch:

Current Autonomous/Control Capabilities:

**Submission:** Please send a completed team form along no later than (NLT) January 31, 2017 to Jackie Banas (jdbanas@gmail.com), with subject "2017 AHS MAV Competition". Teams will have to submit a follow-up Gate-2 "paper & video" proposal NLT March 17, 2017. Large files should be transmitted via Google Drive (a location can be given if requested). Teams will be notified of final acceptance NLT April 5, 2017.