Vertical Flight Society
Montréal, Québec, Canada
May 18, 2020, 1:00 pm-5:00 pm
www.vtol.org/mav

Email Questions to: vfsmav2020@gmail.com

8th Annual VFS Micro Air Vehicle (MAV) Student Challenge Rules

Final 1.4: Jan 28, 2020

1 Overview

The Vertical Flight Society (VFS) invites student teams to participate in the 8th Annual VFS Micro Air Vehicle (MAV) Student Challenge. The Challenge will take place in Montréal, Québec, on May 18, 2020. 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. Teams may choose to design either a remotely-controlled system or a fully-autonomous system; however, every team must have a safety pilot and the ability to remotely control the aircraft in the event of unexpected or unacceptable aircraft behavior.

Team Restrictions: The competition is restricted to teams of full-time university and/or high-school students. High-school teams are encouraged to find a university or industry mentor to help guide progress through the various competition milestones. If there are more than two teams per school, VFS reserves the right to disallow participation to limit the number of teams.

- At least one member of the team must be a current VFS Student Member ($25/year) at the time of entry (see Section 12).
- Teams must have at least one member registered for the VFS Annual Forum.
- VFS has a student volunteer program, where VFS student members can sign up to work as a volunteer at the annual Forum and receive complimentary registration for the entire week in exchange for volunteering. The program is limited to certain number of volunteer slots and is on a first come, first served basis – see Forum Student Volunteers.
- Student registration rates are also available at a significant discount – see Forum 76 registration.

2 Theme: Sandbag Delivery for Flooding Relief on the Rivière Rouge

Quebec has a vast hydroelectric network that generates a large clean-energy supply from the boreal forest in the Canadian Shield, North of Montréal. The yearly snowpack melt and the abundant rain, cool temperatures, and natural terrain and bedrock create favorable conditions for this resource.

April 2019: The snowmelt and rains in 2019 were far above average and the Rivière Rouge in the Montagnes Laurentides region experienced a flooding event that threatened the integrity of a dam and

the safety of a nearby town. As a result, you have been commissioned to design a micro-air vehicle (MAV) to mitigate possible future flooding events by providing disaster relief. The MAV can either be manually piloted, or autonomous (with a lower risk for crew, this option is more valuable). Either way, the mission is the same.

May 18, 2020: Another record snowmelt and rain event. Roads have been washed out and time is critical, so an air delivery of assistance is required. Your design for an MAV is put to the test; aid is required in the form of sandbag delivery along the banks of the river before a storm arrives that will make it difficult — and then impossible — for flight in the area. Your MAV will take off from nearby helipads in Mirabel to pick up sandbags from the parking lot and transport them to the riverbank of the Rivière Rouge so that ground teams can place them to assure the loads on the dam don't exceed its design capacity.

3 The Course

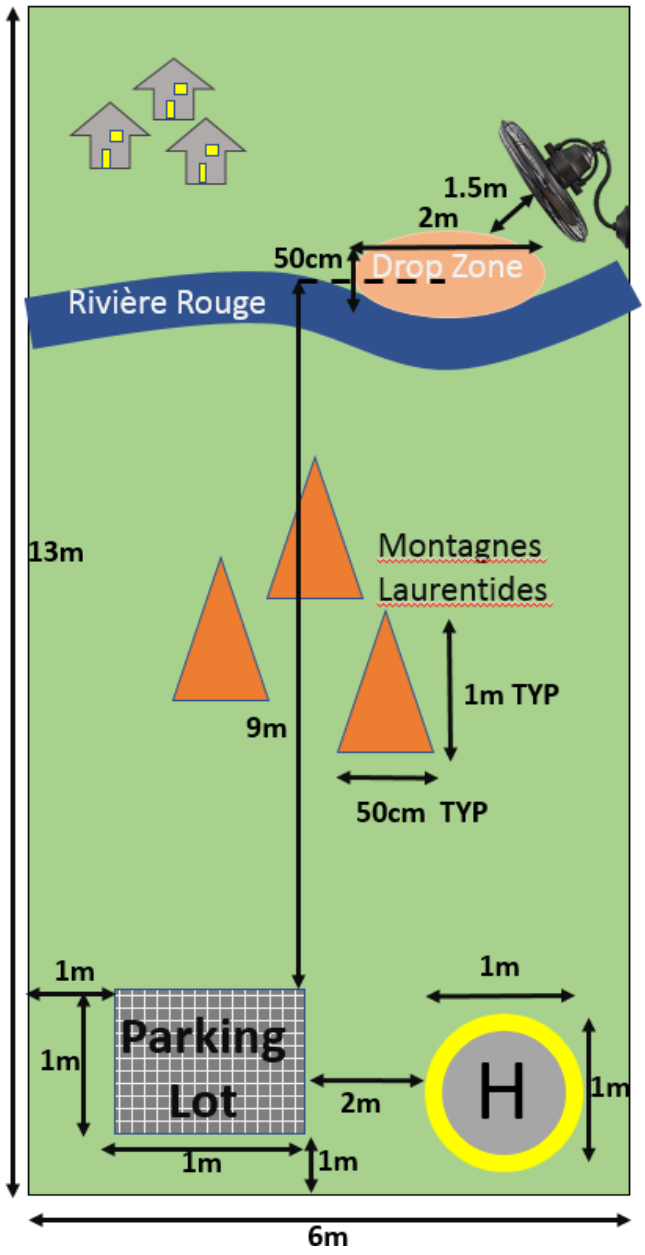

Figure 1: Schematic of the competition field

Figure 2: Competition field, McGill Tomlinson Fieldhouse

4 The Mission

4.1 Manually Piloted Category

Teams have 2 minutes to manually set up their sandbags in the "parking lot" which is a 1 meter by 1 meter gray square, and set up their MAV centered on the helipad, a yellow-bordered 1 meter diameter circle, which is 2 meters away from the parking lot edge (the MAV doesn't have to fit entirely within the helipad area). The team must place all the sandbags expected to be used during the competition — it won't be possible to manually place sandbags once the 10 minutes countdown starts. The team indicates when they are ready to start the mission.

When the team indicates they are ready to start, or when the 2 minutes is up, whichever occurs first, the timer starts (T=0) with a 10-minute countdown. Teams have this 10 minutes to finish any manual set-up that was not finished in the previous 2 minute period, clear all people from the course, take off from the helipad, fly to the parking lot, land in the parking lot, attach or load one sandbag remotely (without a direct human intervention) and transport it in the air to the drop zone for dropoff. The MAV can fly back to the parking lot to take another sandbag and bring it to the drop zone. The team repeats this as many times as they can. Once the sandbag delivery is completed or when the teams decide to stop the sandbags delivery, the MAV must land at the helipad (before the 10 minutes is up) with no direct manual intervention. The MAV can't land at the helipad with a sandbag on board — any onboard sandbags must be deposited at the parking lot before landing at the helipad.

The drop zone is a 2-meter long and 1 meter deep brown ellipsoid or rectangle along the length of the river. It is 9 meters away from the "parking lot", on the other side of the blue river. The sandbags must be sand encased in a fabric material, of a shape, weight and size determined by the team. The fabric material may have structure or fittings attached onto it (see "Payload Description" section).

At T=5 minutes, an industrial fan is turned on, with a constant power setting aimed towards the drop zone, for a wind velocity of 3 to 5 knots with the normal amount of turbulence produced by fans. The direction of the wind is 45 degrees to the length of the river as seen in Figure 1. The fan is located at 2.5 meters from the center of the drop zone.

A mountain range sits midway between the "parking lot" and the drop zone. This range consists of three cones of 50-centimeter base and 1-meter height (Mont Tremblant, Mont Saint-Sauveur, and Mont Habitant). MAVs can either fly around or over the mountains to and from the drop zone.

The course is covered by a green tarp. Its overall dimensions are 6 meters by 13 meters, which will be marked with red tape. The course is surrounded by safety nets. The pilot can't walk to follow the MAV for the completion of the tasks. The pilot stays in a defined area next to the helipad. 3 team members can stay next to the pilot to check telemetry parameters on screens, to check camera video/picture, to be ready to perform minor or large modifications, to physically move the MAV or sandbags if required or any others task.

The altitude of the competition is between 30 meters to 80 meters above sea level, and the temperature will be between 18°C to 26°C (indoors).

4.1.1 Mission Scoring

4.1.1.1 Sandbag

Once the round is finished, the sandbags and fabric material are put onto a scale to be weighed. One sandbag randomly chosen will be opened and emptied to verify that the sandbag abides by the rules. The fabric material and sand do count towards score, but any attachments to the fabric material do not count towards the score (they are removed before weighing). The MAV can carry only one sandbag at the time. All sandbags must have the same weight (± 10%).

4.1.1.2 Location of the sandbags in the drop zone

Sandbags must be either entirely inside the drop zone, or some part of the fabric encasing the sand must touch the perimeter of the drop zone. Any sandbag with any portion (attachment or fabric) touching the river does not count towards score, regardless of whether it is in the drop zone. Sandbags must be released either while the MAV itself is on the ground, or when the sandbag is on the ground and is attached/tethered to a flying MAV. Sandbags that are dropped from the air and first come into contact with the ground while not in contact with the MAV (or tethering device) are discounted.

4.1.1.3 Penalties

Touching the river: During the mission, if the MAV or any part of the cargo carrying system or the payload itself while it is attached to the MAV comes into contact with the river, the team has a penalty of 1 minute. During the penalty, the timer doesn't stop. The electric power of the MAV must be cut to allow the team to manually move the MAV to the helipad. Any currently onboard sandbags must be manually moved to the parking lot. If the sandbag was properly dropped within the drop zone before the MAV or any parts of the cargo carrying system came into contact with the river, the sandbag can stay in the drop zone. The team needs to wait until the end of the 1-minute penalty even if the team is able to complete the tasks in

less than 1 minute. The team is allowed to perform minor or large modifications to the MAV during the 1-minute penalty.

Leaving the allowed course (or coming into contact with the safety nets): If the MAV leaves the allowed course or comes into contact with the safety nets, the same 1-minute penalty is applied as in the case of touching the river.

Minor modification: During the competition, the team is allowed to perform minor modifications to the MAV. A minor modification is defined as a modification that affects less than 50% of the MAV structure. The team cannot change the battery. The minor modifications can only be performed at the helipad. The MAV can either fly or be manually transported to the helipad. The timer doesn't stop while the team is applying minor modifications to the MAV.

Large modification: During the competition, the team is allowed to perform large modifications to the MAV. A large modification is defined as a modification that affects more than 50% of the MAV (or swapping the MAV for an identical undamaged one). The large modifications can only be introduced at the helipad. The team can change the battery. The MAV can either fly or be manually transported to the helipad. The timer doesn't stop while the team is applying large modifications to the MAV. The team loses all the score of the already delivered sandbags from previous flights. The team can move the sandbags already in the drop zone to the parking lot.

Time restriction: If the MAV has not landed at the helipad before T=10 minutes, one half the mission score is forfeited.

4.1.1.4 Bonus

Each team needs to predict the total weight they will deliver at the drop zone for the design proposal. A team can have bonus points based on the following equation. A team can not have negative bonus point. This mean that no penalties will be given to a team who could not deliver the weight of sandbags predicted with an accuracy of 20%.

$$Bonus = \frac{total\ weight\ delivered}{number\ of\ delivery} - \left(\frac{relative\ error}{0.2}\right) * \frac{total\ weight\ delivered}{number\ of\ delivery}$$

Where the relative error is:

$$relative\ error = \frac{|weight\ of\ all\ delivered\ sandbags - predicted\ weight\ of\ all\ sandbags\ to\ deliver|}{predicted\ weight\ of\ all\ sandbags\ to\ deliver}$$

4.1.1.5 Calculation of the score

One point is given for each gram of sand delivered to the drop zone. 5% is added to the second delivery and 10% for the third and all subsequent deliveries. The mission score is calculated as follow:

$$mission\ score = 1 * sandbag\#1 + 1.05 * sandbag\#2 + 1.10 * sandbag\#3 + 1.10 * sandbag\#n$$

4.2 Autonomously Piloted Category

Teams that choose to design and build an autonomous MAV perform the same mission as above, and compete with all other MAV's equally, with the following revisions to the above rules:

The total mission score is multiplied by 4 for autonomous MAVs. This is because of the additional challenge, the anticipated reduction in speed, and the additional weight in hardware that these MAVs must carry (and contextually because the lower risk to human life increases value of the MAV).

For autonomous vehicles, if the vehicle touches the river, fails to continue to fly, or comes into contact with the safety nets or leaves the course, the mission attempt is paused and the timer is stopped for 1 minute. During this time, the team must manually bring the MAV to the helipad. If the MAV was carrying a sandbag, the MAV can keep it. The team can perform minor or large modifications with the same consequence as in the manually piloted category. If the vehicle touches the river more than twice, the timer will no longer be paused, but the team will still needs to bring the MAV to the helipad.

5 Final Competition Elements and Schedule

5.1 Safety checks (the first 30 minutes)

Each team will go through a safety check with the judges before the competition starts to make sure the MAV conforms to the mission required safety features. A maximum of 30 minutes will be allowed to perform the safety and registration check of ALL the teams. If a MAV doesn't reach all the safety requirements, the team could apply modifications and ask for another inspection before the end of the presentation period. If a team still does not reach the safety requirements, the team will only be allowed to perform the presentation, not the flight mission. The safety requirements are listed below. An official inspection check-list will be send to the selected teams.

- Proper operation of the remote kill switch on the controller
- Proper operation of the shunt plug and verification of the correct location
- Battery type verification
- Weighing of the MAV and sandbags
- Measurement of the MAV overall dimension
- Checking for the integrity and rigidity of the MAV
- All team members on-course must have safety-glasses

5.2 Presentations (1:30pm to 2:30pm)

The team should bring their presentation on a flash drive. The time allowed for the presentation is 5 minutes. There is a 3-minute question period from the judges after the presentation.

The presentation should be in English and should include, but not limited to:

a. Team member introductions
b. Air vehicle conceptual designs considered
c. Trade studies and analysis leading to the selection of the conceptual design used

d. Analysis process to optimize the mission performance of the MAV (graphs, figures of merit, quantitative methods, materials selection)
e. Preliminary tests
f. Detailed design
g. Performance verification and testing

The presentations are graded according to the rubric below.

PowerPoint presentation grading rubric (100 points)		
Category	Design and Innovation Metrics	Rating
Originality	Major subassemblies not off-the-shelf (other than powertrain and drive systems), involves innovative engineering to solve specific problems in an optimal way, solved challenging innovation problems, unique capabilities	15 points
Presentation	Clear, easy to follow and understand, good flow guiding the audience, good graphics, good speaking presence, get points across	15 points
Engineering	Judgement, analysis, design process, validation and testing process, good drawings and renders	30 points
Publicity	Good renders showing mission utility, clear performance metrics making the MAV the clear choice	15 points
Teamwork	Inter-disciplinary teams optimizing across boundaries, leadership	15 points
Public relations	Good answers to judge questions	10 points

5.3 Flight Mission (2:45pm-4:30pm)

Teams will have one attempt at the mission type they have selected (manual mission or autonomous mission). After the presentations are all complete, there is a 10 minute break. The 2-minute timer will then begin for the first team to setup. There will be two stations with tables next to the helipad. The next team must be at the waiting table and be ready to start as soon as the competing team finish. If a team is not ready for an attempt, they may forfeit half their score to be placed at the end of the rotation of the round of attempts.

6 Vehicle Design Restrictions and Requirements

The MAV vehicles are restricted in battery capacity and overall dimensions. These restrictions are:

1. Battery: One commercial LIPO battery of three cells or less (3S or less); the team needs to select the proper capacity.
2. Maximum weight: 3 lb, including one sandbag.
3. Overall dimensions: The MAV must fit in a 400 in² (2,580 cm²) rectangle when viewed from above on the helipad. The propellers and the shunt plug count in the overall dimensions.
4. The MAV must take off vertically and land vertically. No rolling/running takeoff allowed on the ground.
5. Remote kill switch on controller.

6. A shunt plug must be wired between the battery and ESC for manual disarming and arming of the MAV powertrain. The shunt plug must be red. The shunt plug must be removable with only one hand and without any tool. The shunt plug must be located outside the dotted line as shown on the figure below. The shunt plug must be located at least 6 in. from the tip of the rotor blade in the horizontal exterior direction of the MAV at any vertical position or at least 6 in. above the rotor plane at any horizontal position.
7. Auxiliary systems batteries are not allowed, except if the MAV performs the competition in autonomous piloting mode.
8. The name and address of the team's school must be written on the MAV.

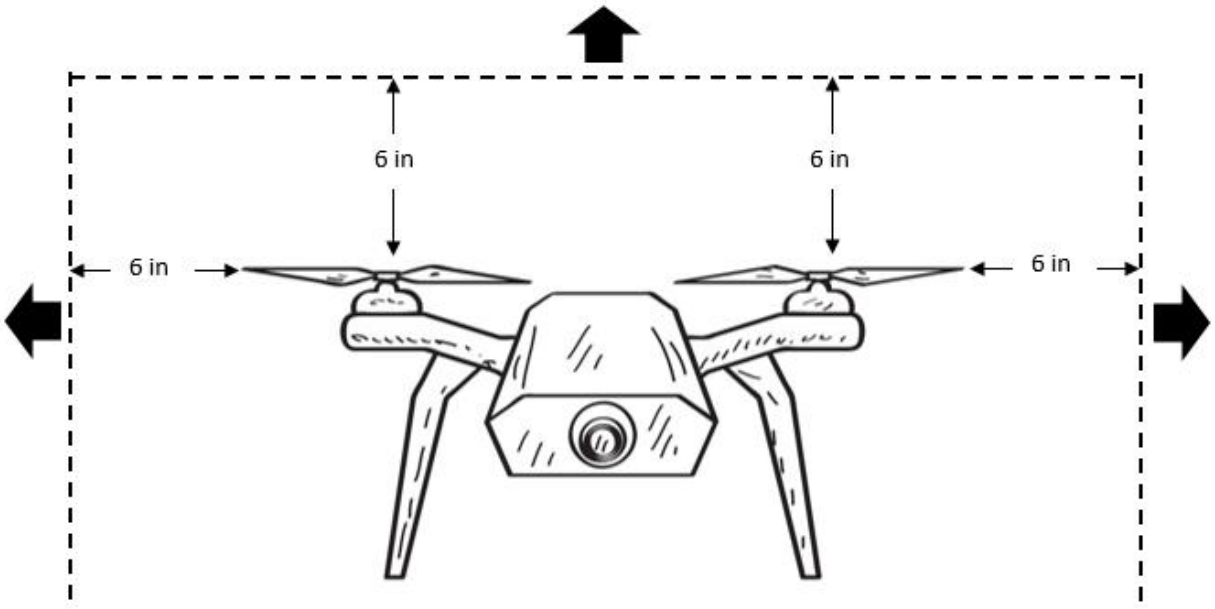

Figure 3: Boundaries for the position of the shunt plug.

7 Payload Description

Teams must fabricate their own payload, which consists of sand encased in a fabric material, and any other hardware (of any material) attached to the exterior side of the fabric. The fabric material itself cannot contain any means of reinforcement such as metallic material, epoxy/glue etc, although the attachment hardware can naturally be stiff. The fabric must contain the sand without leakage. The team is free to vary the payload size and shape, but keep in mind that the only weight that counts towards the score is the fabric and contained sand (any attachment hardware can remain on the sandbag after dropping, but is removed by the judges for weighing of the payload). The sand should be common naturally formed silicate sand – no heavy powders are allowed.

8 Selection and Competition Schedule

Gate 1: Design Proposal Submission – October 2019 to January 31, 2020

Teams submit a design proposal, maximum 10 written pages double spaced, not including a title page and one 11x17 assembly drawing of their MAV, as well as one page of a rendering of their MAV in action (13 total pages maximum including these). Topics should include: team information, budget, schedule, conceptual designs considered, preliminary analysis and trade studies/tests for selection of conceptual design, detailed design, planned tests, predicted weight and performance, powertrain and drives system selection, safety measures. The total weigh predicted in this design proposal is used for the calculation of the bonus point.

Submit papers to vfsmav2020@gmail.com **by January 31, 2020**. **Questions can be sent to the same email address. Based on the design proposal, 6-7 teams will be selected to go to gate 2.**

Gate 2: Video Evidence of Competition Readiness (March 16 2020)

Progress reports including:

- Final vehicle design pictures, 3-view drawing and system configuration description. Vehicle autonomy (time available to complete mission), max gross weight, empty (no payload) weight, payload pickup and dropping systems, gaps to address before final competition. 5 pages maximum, double spaced writing. A proof of liability insurance related with the operation of the MAV must be send with the progress report, see the insurance section for more details.

Video submission of aircraft capabilities and safety measures. Videos include at least:

- Measurement of MAV dimensions and weight. Stable hover demonstration. Demonstration of sandbag pickup. Agility with sandbag onboard. Sandbag drop-off performance. Any autonomous navigation abilities (not required for final competition, autonomy class gives advantages in scoring). Demonstration of safety remote kill switch.

Submit progress reports and videos to vfsmav2020@gmail.com by March 16, 2020. Videos can be sent via online link, e.g. in Google Drive.

Final Team Selection: Announced April 8, 2020

Finalists will be confirmed by a committee consisting of the members of the VFS Montreal-Ottawa Chapter, the VFS Unmanned VTOL Committee and past VFS MAV competition organizers, using the following criteria:

- Consistent progress and realistic achievability of the project
- Aircraft design maturity and performance

- Engineering judgement and analysis process used to arrive at design
- Team management, initial schedule vs. reality tracking, leadership and teamwork demonstration
- Proof of vehicle readiness
- Vehicle within constraints

9 Final Competition

The final competition is held in conjunction with the Vertical Flight Society's 76th Annual Forum & Technology Display in Montreal, Qc. Teams should show up at McGill Tomlinson Fieldhouse (475 Pine Avenue West, Montreal, Qc, H2W 1S4) by 1:00 pm latest (12:30 pm earliest) on May 18, 2020 to conduct safety checks of their vehicles and prepare for the itinerary:

- Safety checks and registration (1:00pm to 1:30pm)
- Presentations (1:30pm to 2:30pm)
- Presentation grading and mission preparation (2:30pm to 2:45pm)
- Mission (2:45pm to 4:30pm)
- Score calculation and winners announced (4:30pm to 4:45pm)
- Teams working area cleaning and departure (4:45pm to 5:15pm)

Please note that details are subject to change.

10 Ratings Structures

The final score is a combination of the presentation (100 points), the mission score and the bonus as shown below:

$$Final\ score = \frac{(Mission\ score + bonus)}{5} + presentation$$

11 Prizes

A total prize pool of $5,000 US is up for grabs.

- 1st place team wins $2,000.
- 2nd place = $1,500.
- 3rd place = $750.
- 4th place = $400.
- 5th place = $200.
- 6th place = $100.

12 Expenses and Support

VFS will not provide any travel or accommodation support for finalist teams, or pay or reimburse any other expenses. Teams may search for company sponsors for travel, accommodation, equipment, etc., and are free to display their sponsor's logos on their team shirts and MAV.

- At least one member of the team must be a current VFS Student Member ($25/year) at the time of entry.
- Teams must have at least one member registered for the VFS Annual Forum.
- VFS has a student volunteer program, where VFS student members can sign up to work as a volunteer at the annual Forum and receive complimentary registration for the entire week in exchange for volunteering. The program is limited to certain number of volunteer slots and is on a first come, first served basis – see Forum Student Volunteers.
- Student registration rates are also available at a significant discount – see Forum 76 registration.

13 Insurance

Teams will need to show a proof of liability insurance prior to the competition or a MAAC (Model Aeronautics Association of Canada) membership proof. American teams can show an AMA (Academy of Model Aeronautics) membership proof instead of MAAC. Only the pilot needs to show a MAAC or AMA membership proof.

14 Disclaimers

VFS assumes no responsibility for any actions caused by any participants of the MAV Student Challenge. These rules are subject to change. Final rules and updates will be published at www.vtol.org/mav. All competitors will be notified of any rules clarifications/necessary adjustments.

Participation in the competition explicitly gives permission to VFS International to use photographic, video, documentation or other records of the competition and all competitors for educational and promotional purposes only. The competition event, participant schools and team names may be the subject of a VFS *Vertiflite* article, web page postings, or other publicity.