International Micro Vehicle Conference and Competition

IMAV 2021 Competition Rules for Indoor and Outdoor Competitions, and Special Challenges

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Editor: Jose Martinez-Carranza

About

This is the official rule book for the IMAV 2021 competitions and special challenges.

This rulebook was elaborated in collaboration with members of the international committee and the local organizing committee.

Jose Martinez-Carranza, General Chair of the IMAV 2020-2021, served as Editor of this rule book and its future editions due to amendments.

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Control of Changes

Section	Changes

Index

Foreword

Welcome to the 12th Edition of the International Micro Air Vehicle conference and competition (IMAV) 2021. The IMAV is an annual international event bringing together scientists, technologists and enthusiasts on the research and technological development of micro-air vehicles.

For the first time ever, the IMAV will be organized in Latin America. The 12th IMAV 2021 will be held in Mexico, in the City of San Andres Cholula, in the State of Puebla, Mexico, in November of 2021.

The organization will be run by three Mexican academic institutions: The Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE); the Universidad de Las Americas Puebla, and the Benemerita Universidad Autonoma de Puebla.

Competitions of the IMAV are split up into two categories: indoor and outdoor competitions plus two special challenges. Both categories present challenges seeking to push the boundaries of the micro air vehicles' technology currently available to date. Competitors are expected to present novel hardware and software designs, including aerodynamic designs, novel set of sensors, and exemplar capabilities such as: flight endurance; agile flight; autonomous flight; intelligent behavior; and swarming coordination.

This year, the competition theme is **"search and rescue."** This is motivated by the fact that Mexico sits at the boundary of three tectonic plates causing frequent seismic activity. In September of 1985 and in September of 2017, strong earthquakes caused severe damage to the capital, Mexico City, and some neighboring cities. In the aftermath, buildings collapsed trapping people and creating disaster zones whose access became difficult to bring aid.

Inspired by the scenario described above, the IMAV 2021 places a set of challenges where micro air vehicles could be essential in the search for victims, to get rapid access and a fast overview of the disaster zone, as much as to bring aid by air to the disaster zone.

In addition, two special challenges are introduced: the Indoor Noise-Free challenge, and the Outdoor Surveillance Challenges. For the former, teams are expected to present MAV designs producing the least amount of noise as possible. This is motivated by the fact that noisy MAVs may induce stress for people trapped in a disaster zone. On the other hand, for the surveillance challenge, teams are expected to present MAVs with flight endurance capabilities, this is, MAVs capable of flying as long as possible, which could be used to monitor disaster zones for long periods of time.

Therefore, teams are expected to present novel ideas, prototypes and solutions aiming at paving the way for the next generation of micro air vehicles that can be deployed in real disaster scenarios such as the ones mentioned before.

Jose Martinez-Carranza
General Chair
IMAV 2021

Introduction

Mexico is a beautiful country that has natural landscapes as well as big cities that give a home to millions of people. In 1985, Mexico lived one of its biggest tragedies so far, an earthquake that destroyed many cities around the country. People armed with hope and brotherhood were able to overcome the tragic moment and move on.

Earthquake, Sep 19 1985. Taken from
https://www.bbc.com

However, even when measures are taken, natural disasters are prone to happen and therefore, people need to be prepared in the case of a contingency.

Motivated by the above, the 12th International Micro Air Vehicle competition will focus on the use of Micro Air Vehicles (MAVs) to provide aid and assistance in a disaster zone scenario.

Furthermore, by addressing the missions described in this year's competition in both indoor and outdoor categories, teams are encouraged to propose and present:

- Aircraft efficiency and innovative designs
- Light and small MAVs
- Autonomy and image processing
- Stability in turbulence
- Multi-MAV cooperation

General

The following frequency bands are allowed in Mexico:

Frequency Band	Power Limit	Notes
902 – 928 MHz	3 milli Watts (0.003 W) EIRP	RFD900 Radio Modems are highly recommended.
2.4 GHz – 2.4835 GHz	10 milli Watts (0.01 W) EIRP	
5.725 GHz – 5.850 GHz	25 milli Watts (0.025 W) EIRP	
3.4 – 3.5 GHz 10.15 – 10.65 GHz	* See detailed requirements in related UIT-R decisions (UIT-R F.1568)	

NOTE: 698 – 806 and 1755 – 1850 MHz is not permitted to be used in Mexico.

Operation of FPV equipment in the 410 – 430 and 806 – 869 MHz is strictly prohibited. This band is utilized by Aeronautical Radio Navigation Services, public security and government which includes aircraft collision avoidance radar systems, security federal and state.

Failure to abide by the boundaries and frequencies will lead to a severe penalty and disqualification.

Safety

To comply with Mexican MAV regulations:

- The maximum take-off weight of any MAVs must not exceed 10 kg.
- A kill switch for each MAV is mandatory and the remote for it should be handed over to the IMAV judges when the teams are performing the outdoor mission.
- For the outdoor competition, the maximum flight altitude is 400 ft (approx. 120m) above Ground Level (AGL), however, the ceiling has been reduced to comply with competition rules. This is 100 m.
- All MAVs should stay inside the designated flight areas and below 100 m. If a MAV strays outside the designated flight area, it should either land or turn back immediately inside the flight area.
- Please ensure safe working practice while working with MAVs.

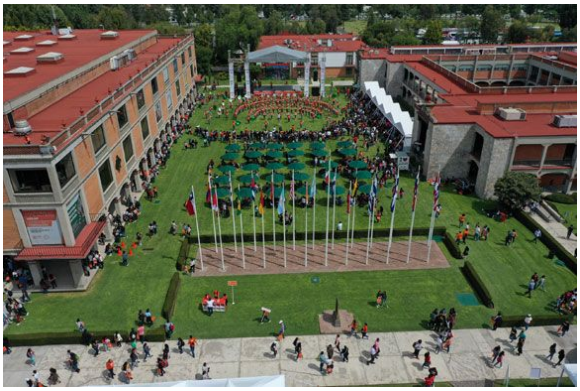
Location

Indoor Event

The indoor event will be held at the Morris “Moe” Williams sports complex belonging to Universidad de las Américas Puebla (https://udlap.mx/web/en/), located in San Andrés Cholula, approximately 20 minutes from Puebla downtown and 30 minutes from the Hermanos Serdán international airport.

Address:
Universidad de las Américas Puebla
Ex-Hacienda Santa Catarina Mártir S/N
72810 San Andrés Cholula, Puebla, Mexico.

Map: https://goo.gl/maps/2iAh2UQoGJAD3gJU6



Outdoor Event

The location will be disclosed soon.

Presentation Factor

The team is rewarded when a team member presents the tasks and actions currently performed. The goal is to make the demonstration of each team more **lively and accessible to the public**. A video feedback of the ground station is also possible and is strongly recommended (standard VGA cable or HDMI).
The presentation factor will be determined according to the description of:

- The MAV system and its design
- The initial plan to perform the mission elements
- The tasks actually performed
- The level of autonomy of each task / MAV

Presentation factor is an additional 10% of the final score (P from 1 to 1.1)

NOTICE: Team will be required to bring a poster to be presented in a poster session during the two-day conference of the IMAV. This is mandatory as it improves the exchange of knowledge and experiences between all the teams and the conference visitors.

- Note that a ***Best Competition Poster Award*** will be granted.

Indoor Competition

Thirty-two years later in 2017, on the same date, another earthquake occurred in Mexico. The contingency plans for disasters were activated immediately as well as the recognition of disaster zones. Many buildings were destroyed, making it difficult to identify people injured or trapped in the rubble. Due to the danger of unstable structures, small remote control vehicles were employed in addition to rescue dogs to support the search for people to aid.

Earthquake, Sep 19 2017. Taken from https://www.milenio.com

Earthquake, Sep 19 2017, “binomio canino”. Taken from http://gruporivas.com.mx

We know we can be better prepared for future natural disasters with intelligent technology such as autonomous vehicles that aid in rescue tasks in dangerous zones. It is for this reason that the objectives of the indoor competition are the search and rescue in an emulated disaster zone.

Therefore, it is requested to develop one or more autonomous MAV that takes off in any of the initial positions allowed. Then, the MAV must avoid dynamic poles in an environment with smoke (as if it were a collapse with dust). At the end of this section, the vehicle is required to search for dummies in a scenario consisting of an enclosed structure and a free area; a notification must be sent when a dummy is found. In the final stage, it is necessary that the MAV finds the landing zone and surpasses a wind current (generated with a fan) while performing the landing.

The challenge posed above requires teams to implement algorithms to push the capabilities currently available in MAVs as they are required to fly among dynamic objects, in an environment with smoke and into the darkness in confined spaces. MAVs competing in this category must carry sensors to detect heat emitted by dummies simulating people on the ground that has to be found in order to be rescued. Finally, when performing landing, competing MAVs may face disturbance induced by wind, hence robust control is required.

We encourage participants to present novel designs seeking to reduce the size of the MAV, its weight and its capability to perform full autonomous navigation, robust to dynamic obstacles and collision avoidance. In this sense, a best design prize will be granted as well.

Indoor Competition Rules

- All participants are required to be familiar with the contents of the document and comply with it.
- For this competition, if needed, only manual take-off will be allowed.
- If the MAV has to land outside the landing platform, manual landing will be allowed, however, to continue with the mission or another mission, take-off has to be performed from the take-off zone.
- ***Teams will be allocated 30 minutes to attempt the indoor missions.*** However teams can use a “Wild Card” to pause their participation.
- The “Wild Card” may only be used to pause the competition time slot only once.
- The MAV’s diameter must be less than 0.7 m.
- More than one MAV will be allowed to fly at the same time. A MAV is considered to be used effectively if the MAV performs successfully a mission or a subtask in the mission. For instance, avoiding the poles, performing landing, or finding a dummy.
- 1 pilot per MAV is required, so that he/she can land and shut down any MAV of the team at any time.
- All flying MAVs need to stay within the designated flight area.
- All MAVs will be checked before flight and must be airworthy.
- All MAVs have to be in sight of at least one team member.
- Only the competing team may fly their MAV during their competition slot.
- All batteries must have a means of monitoring the voltage to prevent cells from dropping too low and becoming a hazard. They must also have appropriate storage when not in use, or charging (eg. LiPo safe bags).
- The team is always responsible for the safety of its MAV and is liable for any accidents caused by their aircraft.
- A human pilot must be able to take over manual control of the MAV at all times in case of an emergency.
- Instructions given by IMAV staff shall be followed without argument.
- Decisions made by the IMAV judging panel are final.
- You must always communicate your intentions with the organizers before flying any MAV and comply at all times with the safety instructions given by them.
- If a MAV crashes, hits a pole, structure or any other element within the arena, the judge may ask the teams to land the MAV. The judge will enter the arena to pick the MAV and bring it to the take-off zone. Only then the team members will be able to touch the MAV.
- Failure to follow these rules may result in penalty or disqualification.

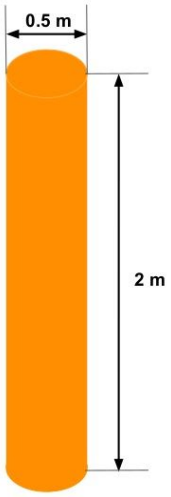
Description of Missions

The IMAV 2021 indoor mission is targeted towards the application of MAVs for search and rescue. The indoor event consists of 4 mission elements. Teams must attempt to complete as many of these mission elements as possible to achieve the maximum number of points.

A take-off zone will be indicated before the competition begins and it will be the same for all the teams. Taking off from the ground is mandatory and can be performed automatically or manually. *This year, taking off will not grant any points.* ***No other zone will be used for taking-off.***

Mission 1: Fly through a dynamic obstacle area with smoke

In this mission, the MAV must traverse the obstacle zone without colliding. The zone will be covered with smoke, and the obstacles will be in continuous lateral movement. The obstacles are four orange posts of 0.5 m in diameter and 2 m in height, as shown in the figure.

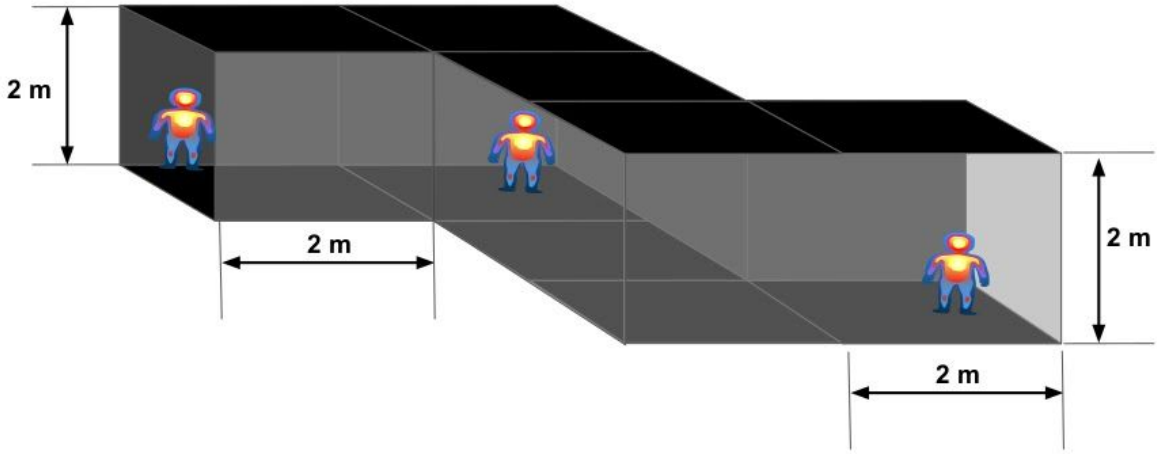


The speed at which the poles will move is 2 m/s.

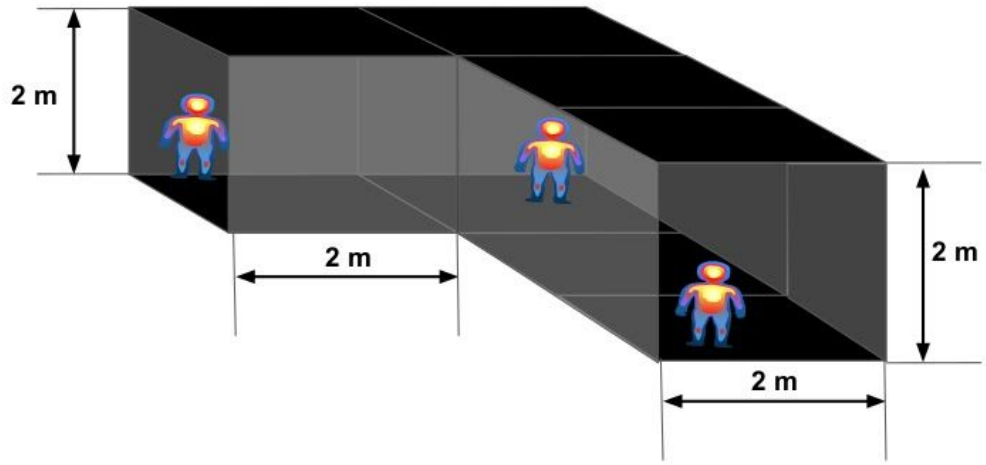
The teams have the option to fly through the obstacle area with the poles not moving. If this is the case, the obstacles will be placed randomly in a fixed position.

Mission 2: Exploration inside a structure with poor illumination

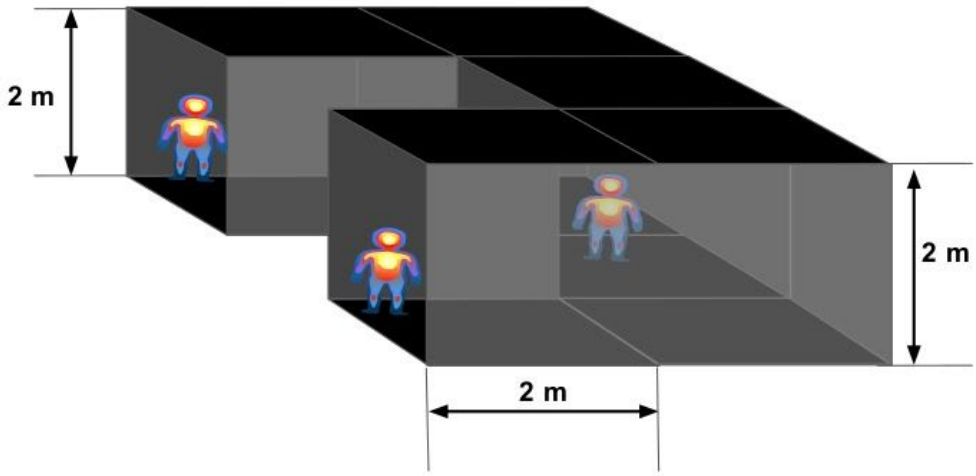
The objective of this mission is to search for heat-emitting dummies inside a structure. The structure will be randomly selected and will not have lighting inside. The possible figures of the structure are shown below.



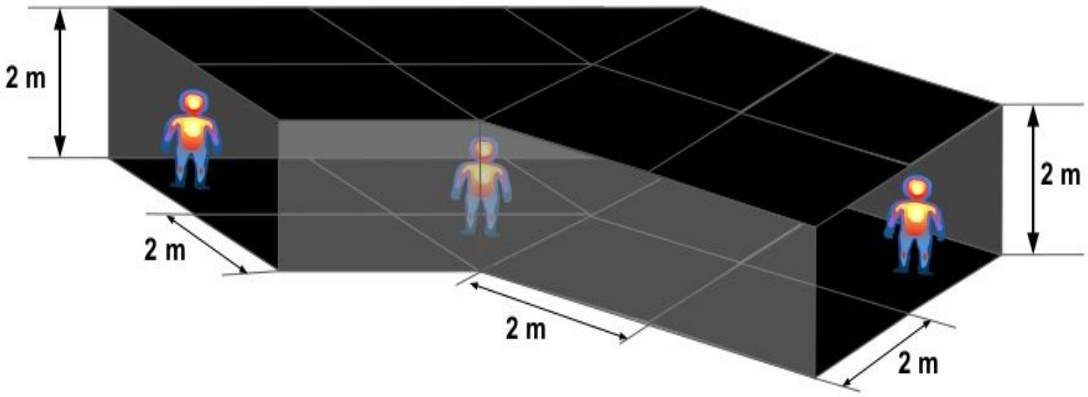
Structure 1



Structure 2



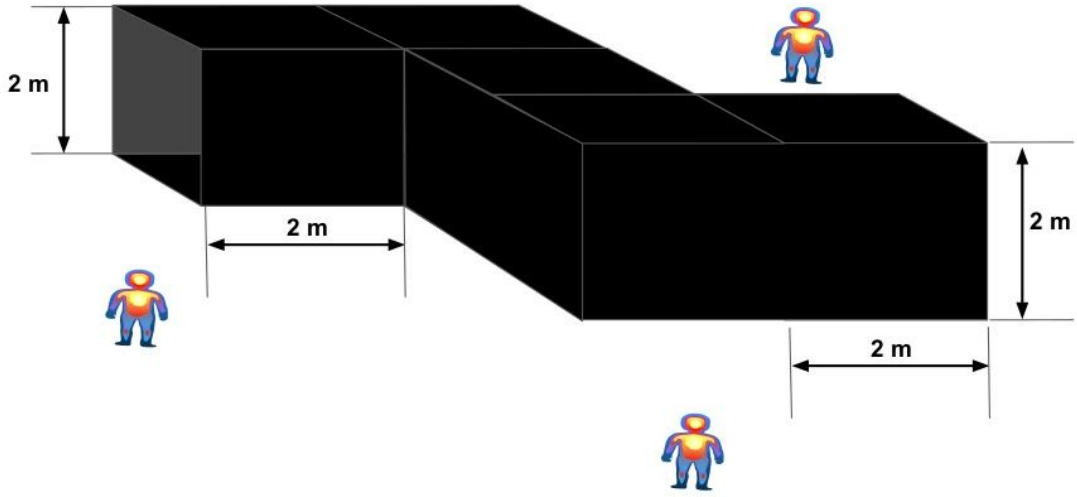
Structure 3



Structure 4

Mission 3: Exploration outside the structure

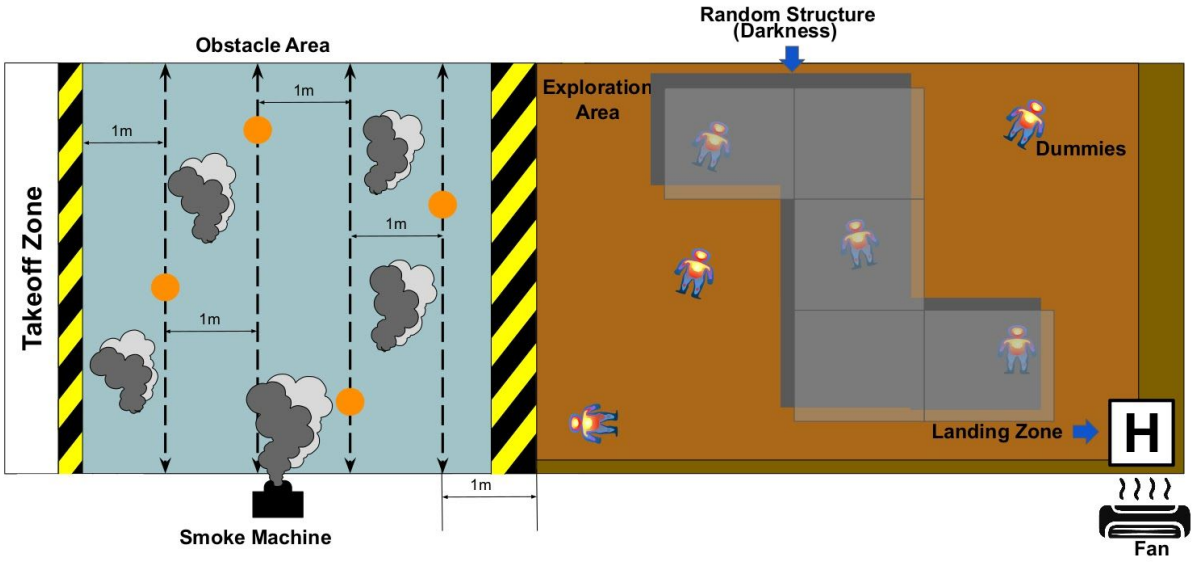
As with mission 2, the MAV must look for dummies, but now outside the structure. The dummies will emit heat and will be found around the structure.



NOTICE: Each dummy will be marked with a distinctive number visible in RGB or thermal images. When detecting the dummy, an ***alert*** has to be generated by the MAV, for instance: a sound, a sign or image displayed on the GCS. It is expected that for the detection, the MAV has to hover over the dummy while generating the alert.

Mission 4: Precision landing with disturbance

The last mission requires the MAV to land precisely in the landing zone, this zone will be disturbed by a fan to prevent the MAV from landing on the platform. Teams may request that the fan be turned off.



Arena Description

Indoor Competition Scoring

Factor Definitions		
Variable	**Description**	**Value**
P	Presentation Factor	P = (up to 1.1)
MaxTime	Maximum allocated time to solve the indoor missions [min].	
UsedTime	Time used to find all the possible dummies either within the structure with poor illumination or in the outside area in the arena [min].	
w	Weight of the MAV [kg].	
di	Number of dummies found within the structure with poor illumination.	
do	Number of dummies found outside the structure.	
Ft	Time factor [min].	Ft = MaxTime / (2*UsedTime)
Fp	Processing factor when carried out off board.	Fp = 1
	Processing factor when carried out on board.	Fp = 1.5
Fw	Weight factor when the MAV weighs less than 0.5 kg.	Fw = 1.5
	Otherwise.	Fw = 3 / (2*(w + 1))
Fs	Swarm factor for when only 1 MAV is used in the whole competition.	Fs = 1
	Swarm factor increased by 0.5 for each MAV used effectively in the competition.	Fs = Fs + 0.5
AFp	Average value of the processing factors of each MAV effectively used in the competition.	
AFw	Average value of the weight factor of each MAV effectively used in the competition.	

Score Values per Mission		
Mission 1	Navigating through static poles	**M1 = 1**
	Navigating through dynamic poles	**M1 = 1.5**
Mission 2	Finding dummies inside structure with poor illumination	**M2 = di * Ft**
Mission 3	Finding dummies outside structure.	**M3 = do* Ft**
Mission 4	Landing with a fan off.	**M4 = 1**
	Landing with a fan on.	**M4 = 1.5**

TOTAL INDOOR COMPETITION SCORE
TotalScore = (M1 + M2 + M3 + M4) * AFp * AFw * Fs * P

Scoring Examples

MAV	**Weight**
Drone Parrot Bebop 2	0.5 kg
DJI Drone Tello	0.08 kg
DJI Drone Matrice 100	2.431 kg
Built Drones	0.7 kg

	Team 1	Team 2	Team 3	Team 4	Team 5
Used MAV's	2 (Bebops)	1 (Bebop) and 2 (Tellos)	1 (Matrice 100), 1 (Built Drone) and 1 (Tello)	1 (Matrice 100)	4 (Tellos)
P	1	0.8	1.1	1	1.1
MaxTime [min]	30	30	30	30	30
Used Time [min]	23	17	8	30	12
W [kg]	W1 = 0.5 W2 = 0.5	W1 = 0.5 W2 = 0.08 W3 = 0.08	W1 = 2.431 W2 = 0.7 W3 = 0.08	W1 = 2.431	W1, W2, W3, W4 = 0.08
di	0	1	3	1	2
do	3	1	3	3	2
Ft	0.6521739	0.8823529412	1.875	0.5	1.25
Fp	Fp1 = 1.5 Fp2 = 1	Fp1 = 1 Fp2 = 1 Fp3 = 1	Fp1 = 1.5 Fp2 = 1.5 Fp3 = 1	Fp1 = 1.5	Fp1, Fp2, Fp3, Fp4 = 1
Fw	Fw1 = 1 Fw2 = 1	Fw1 = 1 Fw2 = 1.5 Fw3 = 1.5	Fw1 = 0.4371 Fw2 = 0.8823 Fw3 =1.5	Fw1 = 0.4371	Fw1, Fw2, Fw3, Fw4 =1.5
Fs	1.5	2	2	1	2.5
Afp	1.25	1	1.333333333	1.5	1
Afw	1	1.3333333333	0.939847754	0.4371903235	1.5
M1	1	1.5	1.5	1.5	1
M2	0	0.8823529412	5.625	0.5	2.5
M3	1.9565217	0.8823529412	5.625	1.5	2.5
M4	1.5	1	1.5	1.5	1
TotalScore	**8.3559782**	**9.0980392157**	**39.28563615**	**3.2789274263**	**28.875**

Indoor Noise-Free Challenge

MAVs have become significantly useful in civilian applications and for the monitoring of livestock or fauna in natural habitats. However, during flight operation, several MAVs still produce high levels of noise with a negative impact on humans and animals.

In a disaster scenario, the arrival of one or two MAVs could increase stress or provoke anxiety/fear on those people trying to deal with the situation.

Motivated by the latter, this challenge encourages teams to present novel MAV designs with the goal of achieving noise-free flight operation.

For this challenge, the MAV has to take off from a designated area, loaded with a 500g package, the MAV has to fly over a microphone placed on the ground in the middle of the arena.

Once the MAV is over the microphone, the MAV has to remain in hovering for 1 minute. Meanwhile, the audio signal of the flight will be recorded with the microphone. The height range in which the MAV must be kept close to the microphone will be between 1 m and 2 m.

Teams have two options for carrying the load: 1) a package slung underneath the MAV, in which case the MAV and the package will have a separation distance of 0.5 m; 2) placing the package on the top of the MAV.

The winner will be the MAV with the minimum noise level.

MAV restriction:

- Only multi-rotor MAVs will be allowed in this challenge.
- 500gr ≤ MAV weight
- 0.7 m ≥ MAV diameter

Size of package:

0.30 x 0.30 x 0.15 m (length x width x height)

For this challenge, the scoring is based on two elements:

- Distance: The distance between the MAV and the microphone will be measured in pixels. A camera fixed on the arena, looking at the microphone and the MAV, will be used to measure the distance between the MAV and an imaginary vertical line define by the microphone's position on the camera image.

- Noise: The amount of noise produced by the MAV will be measured with the Sound Pressure Level (in dB).

The challenge will be carried out the same day of the indoor competition in the same arena, but after the indoor competition concludes.

Teams participating in the indoor or outdoor categories are welcome to participate in this challenge as well.

Total Scoring for the Noise-Free Challenge:

Total Score = $\frac{1}{\sum(Cx_{MAV} - Cx_{cam})} + 10\ log(\frac{P}{P_0})^2$

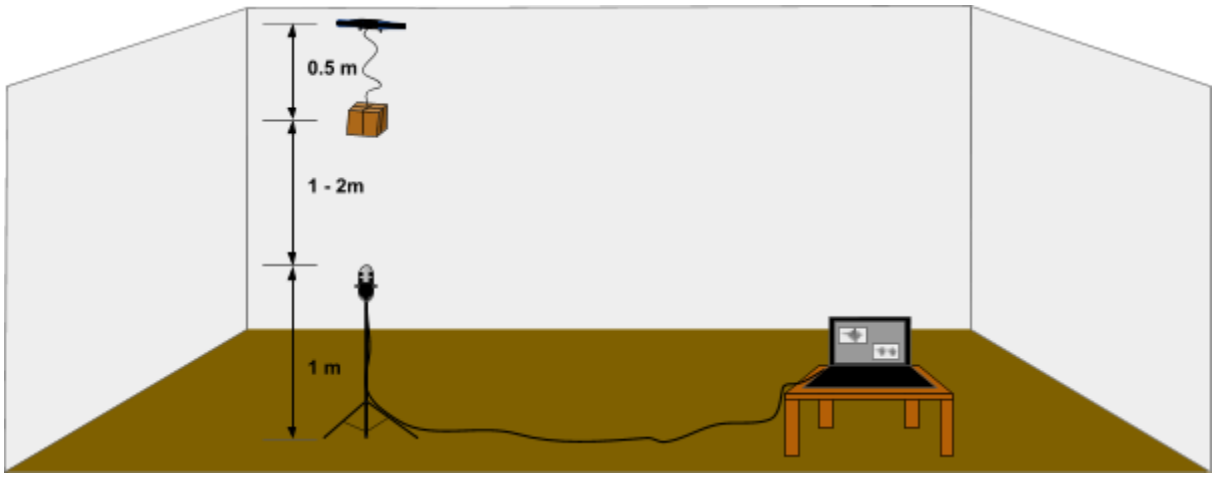
Where:

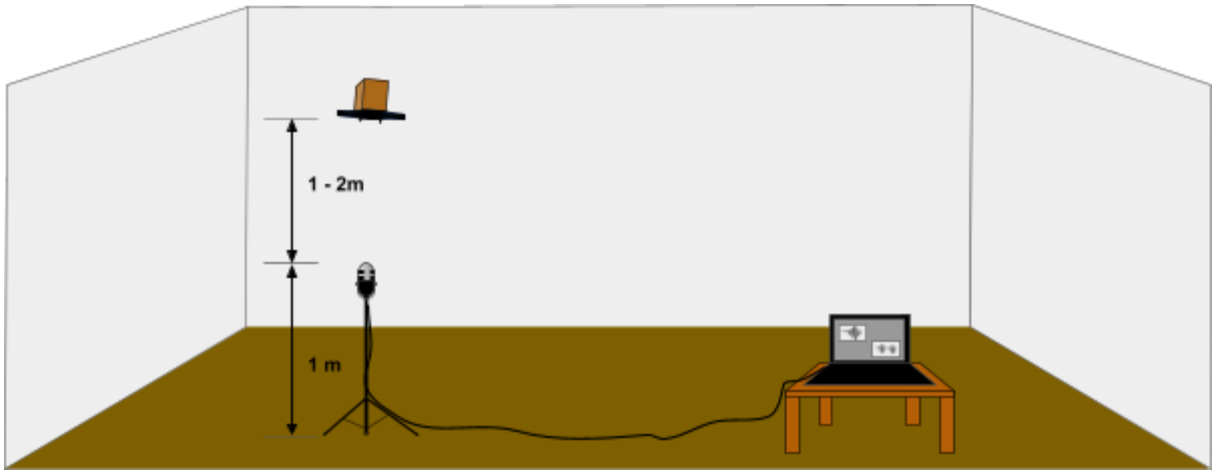
Cx_{cam} : $\frac{Camera\ width}{2}$

Cx_{cam} : $MAV's\ position\ in\ x\ image\ coordinate$

P : $Sound\ pressure$

P_0 : $Standard\ reference\ pressure$





Outdoor Competition

For this competition we continue with the disaster zone scenario where buildings have collapsed, motorways and main roads are either damaged or clogged as people are trying to flee. However, not everybody may have managed to flee, some people may be injured and unable to move away from the disaster zone, hence requiring urgent medical attention, water and food.

Under the scenario described above, MAVs may prove useful to get access to the disaster zone remotely in a rapid manner and without compromising more human lives. In addition, equipped with sensors, MAVs may be used to generate a map representing the affected area, useful to assess the zone. Furthermore, as aid may be needed with urgency, one or more MAVs could be utilized to carry and deliver supplies to specific drop zones, previously given. However, due to the damages, some of these drop zones may be covered in rubble, thus the MAVs will need to fly over the drop zones and sense which one of them is free of obstacles in order to deliver the aid.

Earthquake, Sep 19 2017, aerial photo. Taken from https://www.univision.com/

Outdoor Competition Rules

- All participants are required to be familiar with the contents of the document and comply with it.
- ***Teams are allocated 30 minutes to attempt the outdoor missions.*** However teams can use a “Wild Card” to pause their participation.
- The “Wild Card” may only be used to pause the competition time slot only once.
- There is no limit to the number of MAVs to be used in this competition.
- If several MAVs are used in a mission that will earn extra points.
- 1 pilot per MAV is required, so that he/she can land and shut down any MAV of the team at any time.
- All flying MAVs need to stay within the designated flight area.
- All MAVs will be checked before flight and must be airworthy.
- All MAVs have to be in sight of at least one team member.
- Only the competing team may fly their MAV during their competition slot.
- All batteries must have a means of monitoring the voltage to prevent cells from dropping too low and becoming a hazard. They must also have appropriate storage when not in use, or charging (eg. LiPo safe bags).
- The team is always responsible for the safety of its MAV and is liable for any accidents caused by their aircraft.
- A human pilot must be able to take over manual control of the MAV at all times in case of an emergency.
- Instructions given by IMAV staff shall be followed without argument.
- Decisions made by the IMAV judging panel are final.
- You must always communicate your intentions with the organizers before flying any MAV and comply at all times with the safety instructions given by them.
- Failure to follow these rules may result in penalty or disqualification.
- **This year, take-off and landing will not grant any points.**

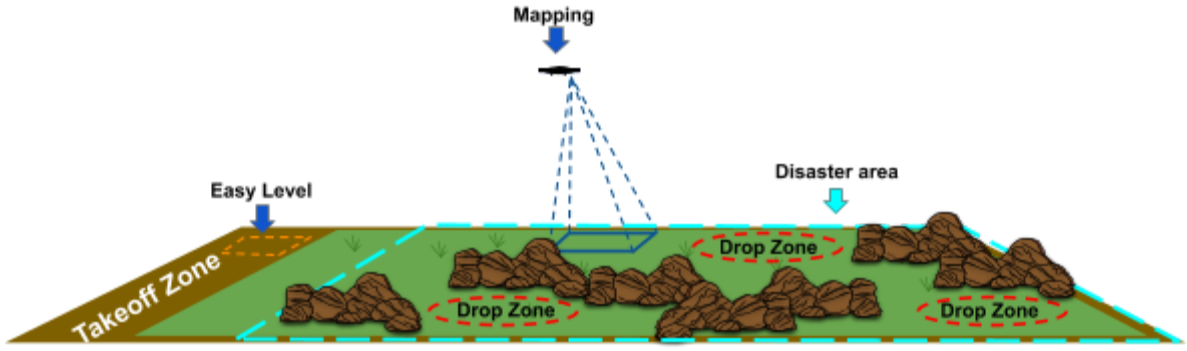
Description of Missions

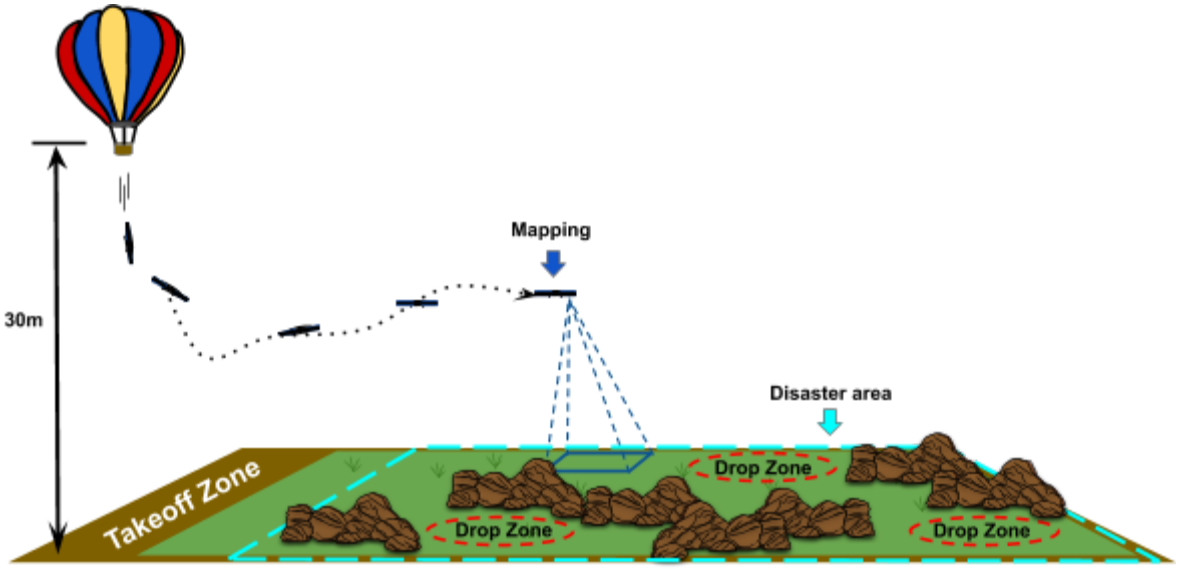
This competition will be carried out in a wide open area where 4 missions will be faced by the teams. For the missions, teams are allowed to use any type of MAV, this is, multi-rotors, hybrids, VTOLs or fixed wings.

A take-off zone will be indicated before the competition begins and it will be the same for all the teams. If MAVs take off from the ground, this area will be used for that purpose. Take off from the ground can be performed automatically or manually. *This year, taking off will not grant any points.* ***No other zone will be used for taking-off.***

Mission 1: Mapping.

- Only one MAV is allowed for this mission.
- A 3D model or a 2D panoramic image (mosaic or orthophotography) of the disaster area has to be generated.
- The area will be defined by a rectangle with each vertice associated with a GPS coordinate. These coordinates will be given to the team in advance.
- There are two levels of performance for this mission:
    - **Easy:** the MAV takes off from the take-off zone and flies over the disaster area, recording images or video to generate the map.
    - **Difficult:** the MAV will be lifted with an external aircraft (balloon or large hexacopter, capable of lifting up to 15 kg). In this case, the MAV has to be on, however, the motors should be off. At a height of 30 m, the MAV will be released from the external aircraft. The MAV will have to turn on its motors in order to recover from the free fall and then fly towards the disaster zone to carry out the mapping.
- Extra points will be awarded if the mapping is carried out in real time and transmitted to the ground control station for the public to watch it.
- Extra points will be awarded if the map is a textured 3D model.
- If the map is generated off-line, up to 20 minutes will be given to the team to generate the map.
- Time will be measured from take-off/release until the team decides that it has recorded sufficient data (in the case of off-line processing) or when the map is indicated to be complete (in the case of real time mapping). When the time is stopped, the MAV may land on the take-off zone or within the disaster area.

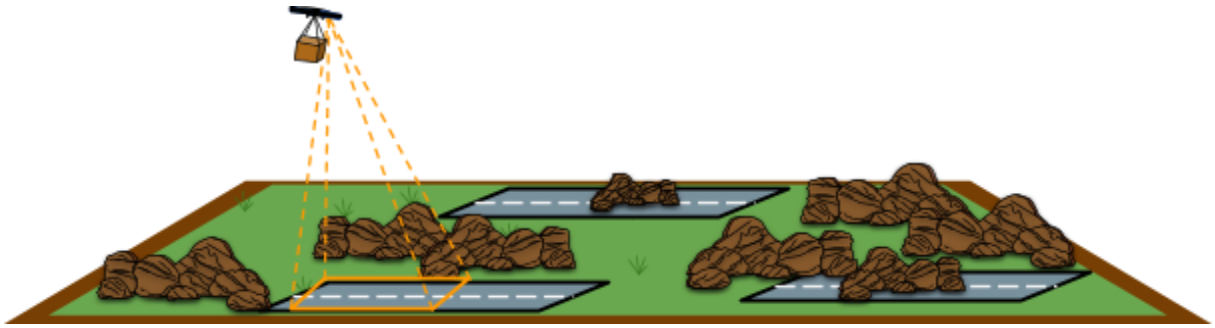




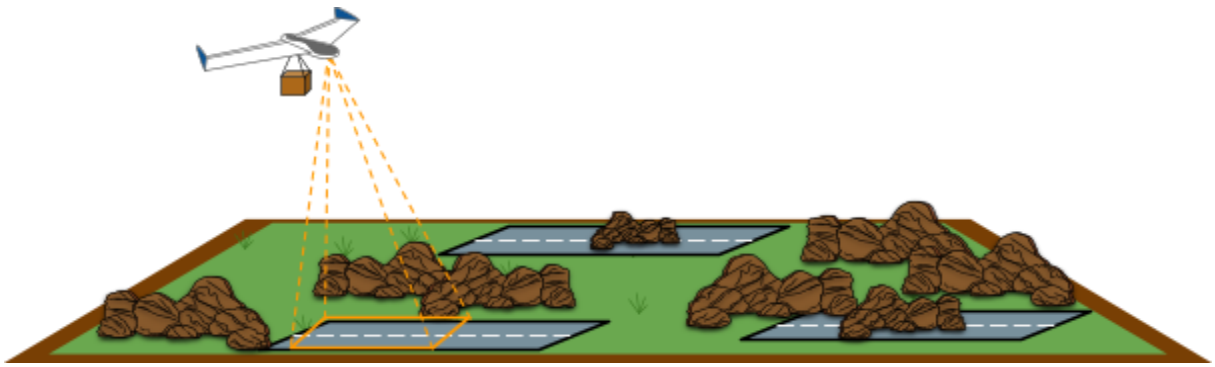
Mission 2 and 3: Available Drop Zone Detection and Package Delivery

- One or more MAVs will take off from the ground, from the take-off zone.
- Each MAV will carry a package previously attached to it. The package can be attached manually and it has to be done before take off.
- A total of 10 packages have to be carried and delivered on a drop zone.
- 3 drop zones will be available for delivery. Their location will be given as a GPS coordinate in advance. However, two out of three drop zones will be covered with obstacles, hence the MAV will not be able to deliver the packages on such drop zones. A third drop zone will be free of any obstacles and available for delivery. Hence, the MAV will have to fly over each one of the drop zones to discover the one free from obstacles.
- The GPS location of the drop zones will be given before the competition starts. However, when a MAV is ready to take off, at that moment two of the three drop zones will be chosen randomly and covered with obstacles.
- Each drop zone will have a diameter of 5 m. A package is delivered successfully if it is placed within this diameter.
- It will not be allowed to enter any information through the GCS once the drop zones have been covered with obstacles.
- Once the available drop zone is detected, this information has to be shared automatically with other MAVs, in the case that more than one MAV is used in this mission.
- Only the execution of take-off and landing command will be allowed via the remote controller or the GCS. If needed, the MAV can be thrown by hand for taking off.
- For delivery, the MAV has to descend towards the drop zone and release the package once the MAVs height is less than 1 m from the ground.

- Once the MAV releases the package, it has to return to the take-off zone to be loaded with another package.
- The time for this will be measured from the time the first MAV takes off until the last package is delivered. The total number of points will be given by the number of packages successfully delivered inside of the drop zone times a time factor.
- Once the last package is delivered (or the team decides to stop delivering packages) the MAV will be allowed to land on the drop zone or somewhere nearby. This will not grant any points.
- Weight of each package: **100 g.**



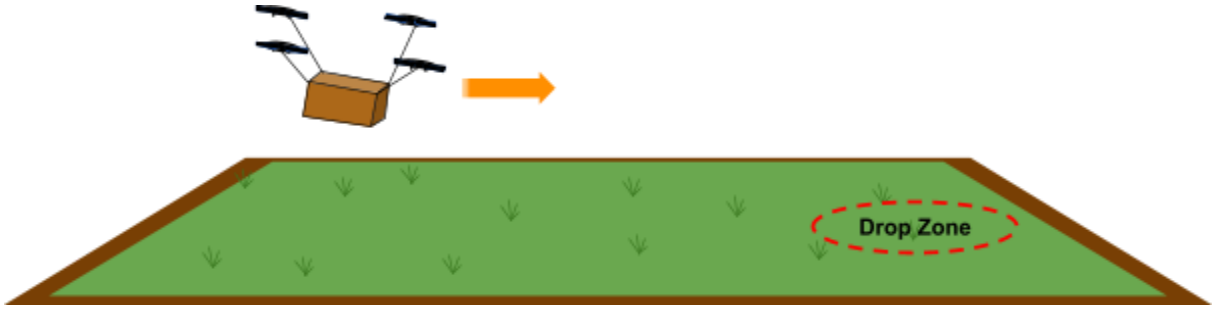
NOTICE: If a team uses a multi-copters, VTOLs or hybrids with vertical landing, then the packages have to be delivered by descending towards the ground as indicated before. However, if a team uses a fixed-wing then the landing zones will be defined by three lanes with length of 10 m and a width of 5 m. In this case, the fixed-wing MAV can descend closer to the ground to release the package. If the package hits the ground within the drop zone it will be counted as valid even if afterwards it bounces and falls outside the drop zone. Note that two out of three lanes/drop zones will also contain obstacles.



Mission 4: Cooperative carrying.

This mission is motivated by the fact that a heavy load has to be brought to a drop zone. Therefore a team of two or more MAVs have to lift and carry a package to the drop zone.

- MAVs to be used in this mission can not be larger than 40 cm in diameter.
- Weight of package: **1 kg**.
- Size of package: **50 x 50 x 20 cm.**
- Each MAV has to use a flexible cord or leash that will be attached from one end to the MAV and from the other end to the package. The package will have the corresponding holes to tie the cord/leash to it.
- A drop zone will be given before the mission starts and it will be free of obstacles.
- The MAVs will take off from the take-off zone.
- Time will be measured from the time of take off until the package is dropped within the drop zone.
- To deliver the package, the team of MAVs have to descend to the ground and release the package until it touches the ground. Afterwards the MAVs can land within the landing zone or nearby.
- The drop zone will have a diameter of 5 m.
- The delivery will be considered successful if the package is dropped within the drop zone and remains within the zone after release.



Outdoor Competition Scoring

Factor Definitions		
Variable	**Description**	**Value**
P	Presentation Factor	P = (up to 1.1)
MaxTime	Maximum allocated time to solve the outdoor missions [min].	
UsedTime_i	Time used to solve mission i [min].	
w	Weight of the MAV [kg].	
Pd	Number of packages successfully delivered in the drop zone.	
Ft_1	Time factor for mission 1 [min].	Ft_1 = 10 / (2*UsedTime_1)
Ft_3	Time factor for mission 3 [min].	Ft_3 = MaxTime / (2*UsedTime_3)
Ft_4	Time factor for mission 4 [min].	Ft_4 = 5 / (2*UsedTime_4)
Fz	Launching factor when MAV takes off from take-off zone	Fz = 1
	Launching factor when MAV is released from balloon	Fz = 2.0
Fm	Mapping factor for 2D Map built off line.	Fm = 1
	Mapping factor for 3D Map built off line.	Fm = 1.5
	Mapping factor for 2D Map built on line.	Fm = 2
	Mapping factor for 3D Map built on line.	Fm = 3
Fp	Processing factor when carried out off board.	Fp = 1
	Processing factor when carried out on board.	Fp = 1.5

	Processing factor will be increased by 0.5 if the MAV performs autonomous flight. Take-off and landing may be manual.	Fp = Fp + 0.5
Fw	Weight factor when the MAV weighs less than 0.5 kg.	Fw = 1.5
	Otherwise.	Fw = 3 / (2*(w + 0.5))
Fs_i	Swarm factor for when only 1 MAV is used in the whole competition.	Fs_i = 1
	Swarm factor increased by 0.5 for each MAV used effectively in the mission i.	Fs_i = Fs_i + 0.5
AFp_i	Average value of the processing factors of each MAV effectively used in the mission i.	
AFw_i	Average value of the weight factor of each MAV effectively used in the mission i.	

Score Values per Mission		
Mission 1	Mapping.	**M1 = Ft_1 * Fz * Fm * Fp * Fw**
Mission 2	Drop zone is given in advance	**M2 = 0**
	Detecting the available drop zone autonomously.	**M2 = 2 * Fs_2 * AFp_2 * AFw_2**
Mission 3	Package delivery.	**M3 = Pd * Ft_3 * Fs_3 * AFp_3 * AFw_3**
	Extra bonus of 1 point if all the 10 packages are delivered successfully.	**M3 = M3 + 1**
Mission 4	Carrying a heavy load.	**M4 = Ft_4 * Fs_4 * AFp_4 * AFw_4**

TOTAL OUTDOOR COMPETITION SCORE
TotalScore = (M1 + M2 + M3 + M4) * P

Scoring Examples

	Team 1	Team 2	Team 3	Team 4	Team 5
P	1.1	1	1.05	1.05	1.03
MaxTime [min]	30				
UsedTime_i [min]	(1) = 4, (3) = 12, (4) = 2	(1) = 5, (3) = 15, (4) = 2.5	(1) = 5, (3) = 13, (4) = 2.5	(1) = 6, (3) = 15, (4) = NA	(1) = NA, (3) = 15, (4) = NA
w [kg]	0.5	1	1	0.5	NA
Pd	10	9	9	5	10
Ft_i	(1), (3), (4) = 1.25	(1), (3), (4) = 1	(1), (4) = 1, (3) = 1.1538	(1) = 0.8333, (3) = 1, (4) = NA	(1) = NA, (3) = 1.1538, (4) = NA
Fz	2	1	1	1	NA
Fm	3	1	1	1.5	NA
Fp	1.5	1	1	1	NA
Fw	1.5	1	1	1.5	NA
Weights of used MAVs for M2 [kg]	w_1, w_2, w_3 = 0.5, w_4, w_5 = 0.4	w_1 = 1	w_1, w_2 = 1	w_1, w_2, w_3 = 0.3	NA
Weights of used MAVs for M3 [kg]	w_1, w_2, w_3 = 0.5, w_4, w_5 = 0.4	w_1 = 1	w_1, w_2 = 1	w_1, w_2 = 0.3	w_1, w_2, w_3 = 0.1, w_4, w_5 = 0.7
Weights of used MAVs for M4 [kg]	w_1, w_2, w_3 = 0.5, w_4, w_5 = 0.4	w_1 = 1	w_1, w_2 = 1	NA	NA
Fp_i for M2	(1), (2), (3), (4), (5) = 1.5	(1) = 1	(1), (2) = 1	(1), (2) = 1.5, (3) = 1	NA
Fp_i for M3	(1), (2), (3), (4), (5) = 1.5	(1) = 1	(1), (2) = 1	(1), (2) = 1.5	(1), (2), (3), (4), (5) = 1.5
Fp_i for M4	(1), (2), (3), (4), (5) = 1.5	(1) = 1	(1), (2) = 1	NA	NA
Fw_i for M2	(1), (2), (3),	(1) = 1	(1), (2) = 1	(1), (2), (3) =	NA

	(4), (5) = 1.5			1.5	
Fw_i for M3	(1), (2), (3), (4), (5) = 1.5	(1) = 1	(1), (2) = 1	(1), (2) = 1.5	(1), (2), (3), (4), (5) = 1.5
Fw_i for M4	(1), (2), (3), (4), (5) = 1.5	(1) = 1	(1), (2) = 1	NA	NA
Fs_i	(2), (3), (4) = 3	(2), (3), (4) = 1	(2), (3), (4) = 1.5	(2) = 2, (3) = 1.5, (4) = NA	(2) = NA, (3) = 3, (4) = NA
AFp_i	(2), (3), (4) = 1.5	(2), (3), (4) = 1	(2), (3), (4) = 1	(2) = 1.3333, (3) = 1.5, (4) = NA	(2) = NA, (3) = 1.5, (4) = NA
AFw_i	(2), (3), (4) = 1.5	(2), (3), (4) = 1	(2), (3), (4) = 1	(2) = 1.5, (3) = 1.5, (4) = NA	(2) = NA, (3) = 1.4, (4) = NA
M1	16.875	1	1	1.875	0
M2	13.5	2	3	8	0
M3	85.375	9	15.5769	16.875	73.6923
M4	8.4375	1	1.5	0	0
TotalScore	**136.60625**	**13**	**22.1307**	**28.0875**	**75.903**

Outdoor Surveillance Challenge

A special challenge is proposed to be run alongside the outdoor competition. It is inspired by the scenario where a disaster zone may need to be surveilled for long periods of time.

This challenge has been created to encourage teams to present novel MAV designs. The MAVs should be able to fly surveillance laps within a defined area ***for as long as possible.***

MAVs will be allowed to lap within a maximum radius of up to 500 m, with vertical variations of up to 25 m. The maximum height for this mission will be up to 100 m.

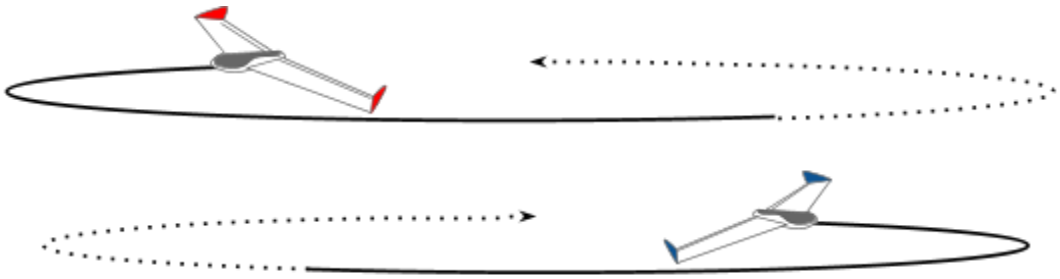
In principle, **teams are encouraged to present designs based on pure fixed-wing or any other hybrid configuration such as tailsitters, tiltwing or tiltrotor designs which can be operated from small spots**.

This challenge does not have a time limit. It will take place in the location of the outdoor competition, but in a different area to that where the outdoor missions will be carried out.

The challenge will run in parallel with the outdoor competition.

Depending on the number of teams, two or three MAVs may fly at the same time, although at different heights. The time to reach the assigned height will be considered part of the flight time. Time will be measured from the time the MAV takes off until it lands due to low battery or predefined battery status.

Teams participating in the indoor or outdoor categories are welcome to participate in this challenge as well.



For this challenge, the scoring is based on three elements:

- **Flight time**
  - FlightTime [min]
- **Weight of the MAV**
  - TotalMassFactor (A maximum weight of 2 kg will be allowed), according to the following rule:
    - Less than 100 gr: 1.5
    - Otherwise: 3.0 / (2*(TotalMass[Kg] + 0.5))
- **Handling**
  - **Capable to be operated from small spots:**
    - LaunchRecoveryBonusFactor=1.0 for horizontal take-off and landing
    - LaunchRecoveryBonusFactor=1.25 for vertical take-off and landing
    - LaunchRecoveryBonusFactor is increased by 0.25, if taking-off and landing is fully automated
    - LaunchRecoveryBonusFactor is increased by 0.25, if the flight is fully automated

Total Scoring for the Surveillance Challenge:

TotalScore = FlightTime * LaunchRecoveryBonusFactor * TotalMassFactor