IMAV 2019 Competition Rules

Indoor & Outdoor Events

V1.1 - May 28 2019

* Note that rules are subject to some revisions and updates

Introduction

The indoor and outdoor competitions are set up to highlight the following points:

- 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 Spain:

Frequency Band	Power Limit	Notes
915 – 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 – 5.875 GHz	25 milli Watts (0.025 W) EIRP.	
3.1 - 4.8 Ghz 6 - 9 Ghz	* See detailed requirements in related ECC decisions (ECC/DEC/(06)12)	Generic UWB

433 MHz or 868MHz is not permitted for use in Spain.

Operation of FPV equipment in the 960 – 1215 MHz is strictly prohibited. This band is utilised by Aeronautical Radio Navigation Services, which includes aircraft collision avoidance radar systems.

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

Safety

To comply with Spanish Drone regulations:

- The maximum take-off weight of any MAVs must not exceed 10 kg
- 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 30 metres
- All MAVs should stay inside the designated flight areas and below 30m. 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 on MAVs.

Location

The event is held from September 29th to October 4th in Madrid, Spain. This will consist of 2 practise days, 2 competition days and 2 conference days.

Indoor Event

The indoor event will be held at the School of Industrial Engineering http://www.etsii.upm.es/ (belonging to Universidad Politécnica Madrid) in the middle of Madrid and approximately 3 km from Madrid old town.

Address:

Escuela Técnica Superior de Ingenieros Industriales
Universidad Politécnica de Madrid
Calle de José Gutiérrez Abascal, 2
Madrid, Spain

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

Outdoor Event

The outdoor event will be held at Aeródromo Valle de La Laguna, south east of Madrid and less than 50 minutes drive from the main venue. Buses will be provided to and from the Indoors and Conference venue.

Address:

Aeródromo Valle de La Laguna
Carretera M-316 (Valdelaguna-Chinchón)
Km 3,2, Valdelaguna, Madrid, España

Map: https://goo.gl/maps/N8HFQk4auty

Scoring

The final score will depend on the success of each mission element (E = mission element score), the level of autonomy for each mission element (A), the mass factor (M), the “in-a-row” factor (I), the Time factor (T), and a presentation made by the team during the mission (P). Note that only the best score of all attempts will be kept . Awards will be determined using the following formula:

$$Total\ Score\ =\ P \times \Sigma(MAV\ Score)$$

Where,

$$\text{Indoors}: MAV\ Score\ =\ E \times I \times A \times M$$

$$\text{Outdoors}: MAV\ Score\ =\ E \times T \times A \times M$$

Where,
P = Presentation (from 1 to 1.1)
E = Element score[1]
I = In-a-row Factor
A = Autonomy Level
M = Mass Factor
T = Time Factor

[1]Note that Element scoring is defined under the specific event information.

Presentation factor (P)

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 for 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)

In-a-Row Factor (I)

The in-a-row factor allows a multiplier for a single MAV that is able to complete multiple elements in succession (one after another). The multiplier starts counting after the first mission element is completed (take-off is not included). In-a-row can only be counted from the take off pad/zone.

Mission Elements Done In-a-Row	I Multiplier
1	1.00
2	1.33
3	1.66
4	2.00
5	2.33
6	2.66
7(max. available)	3.00

Time Factor (T)

The time factor allows a multiplier for finishing (more details given in the outdoors mission section) the outdoors mission early (maximum factor given to teams finishing 10 minutes earlier).

$$T = min(2{,}1 + \frac{25 - time\ ending}{10})$$

Level of Autonomy (A)

Level of Autonomy	**Factor**
Video based control: control of the MAV through an FPV system.	1
Autonomous target detection: the navigation is manual, however the detection and processing of targets is automatic	4
Autonomous flight control: the navigation is completely autonomous, however the operator is switching between mission elements and package handling	6
Fully autonomous control of both the navigation and target detection.	12
Fully autonomous control of both the navigation and target detection. Also, all the computations are made onboard.	15
Using external aids* , such as visual markers, or operating the drone outside the operating zone	-2 applied to factor

*Any external aid you wish to use should be consulted with the organizing committee first
NOTE: this factor cannot change in the same run.

Mass Factor (M)

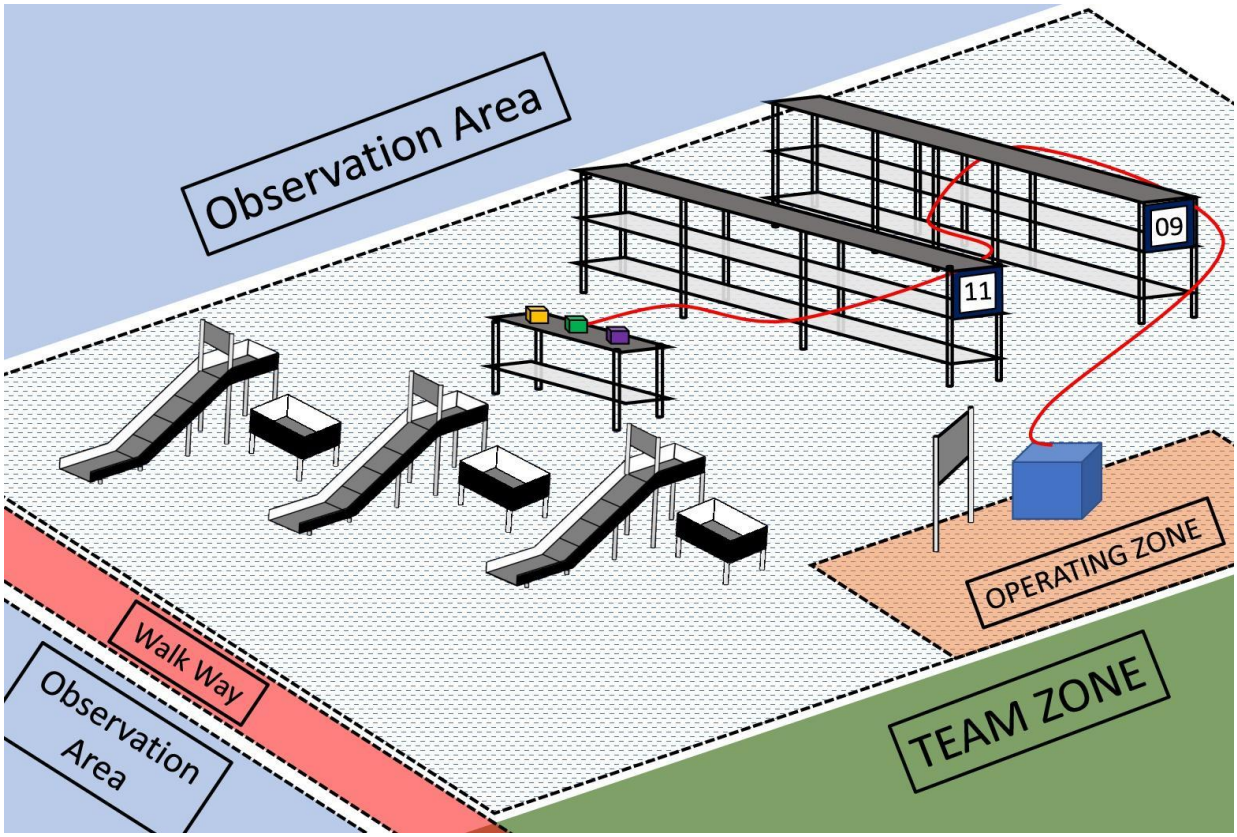
This year there will be a mass factor allocated to each MAV, rather than a size factor, defined as follows:

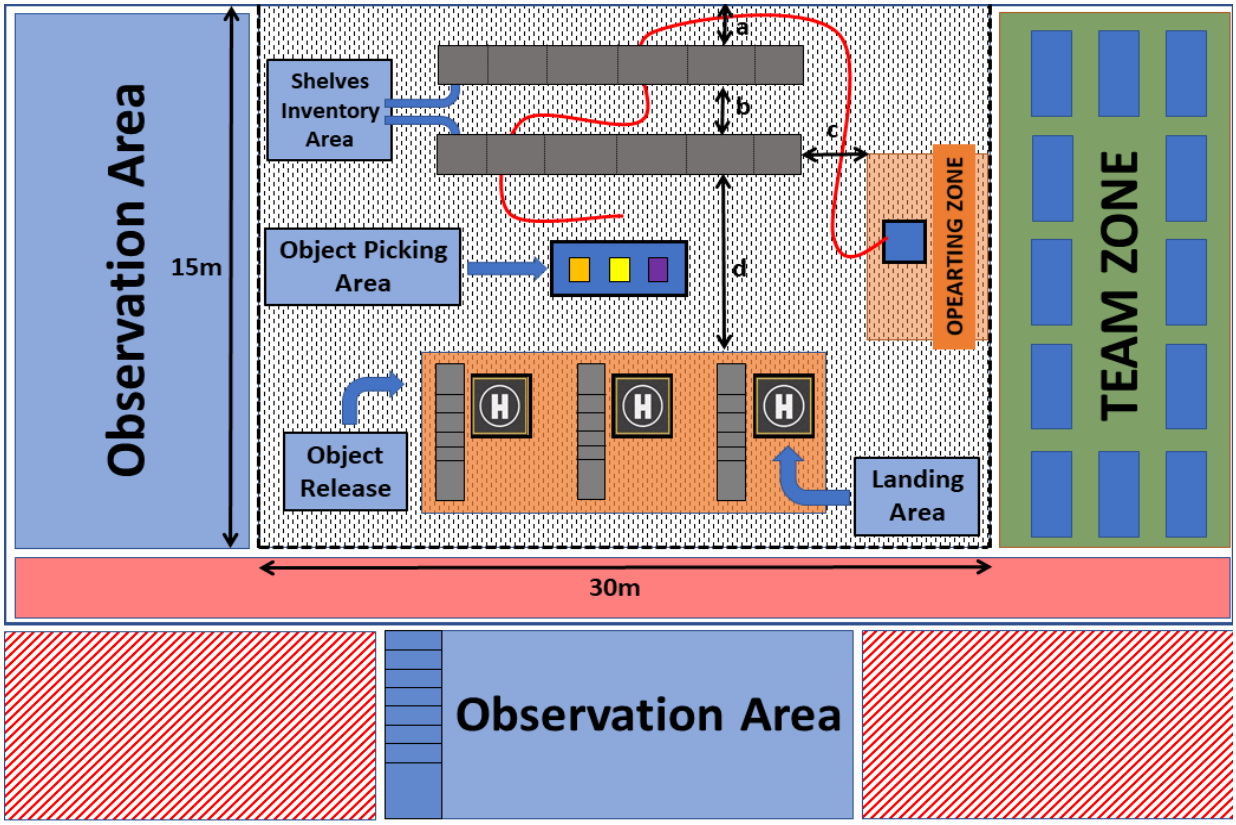
$$M = min(5, 0.5 + \frac{500}{MAV\ mass\ (grams)})$$

*Note: This is done to not unfairly penalize fixed wing, protections and alternative MAVs. lighter than air craft will, but limited to maximum points (multiplier of 5)

Indoor Course

*Note: diagram is not to scale, obstacles are representative only and may not be configured in these exact locations during the competition.





Indoor Competition Rules

- Up to two drones are allowed to fly at the same time, each scoring separately.
- If inventory is achieved by two drones flying simultaneously, the inventory zone for each drone is determined and said a priori.
- 1-pilot per drone is required, so that he/she can land and shut down any UAV 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 have their radio equipment on during the competition
- Only the competing team may fly their MAV during their competition slot
- All teams shall present each of their MAVs for scrutineering
- All batteries must have a means of monitoring the voltage to prevent cells 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.
- The main ground station screen has to be shared via a VGA or HDMI output (to a projector or screen delivered by the organisation)
- 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.

- The “Wild Card” may only be used to pause the competition time slot once. When all other teams have competed, remaining time from the first attempt may be used to complete the course (time permitting).

Failure to adhere to these rules may result in penalty or disqualification.

Indoor Mission Brief

The IMAV 2019 indoor mission is targeted towards the application of drones to warehouse inventory tracking. In principle, drones can effortlessly scan products in inventory in 3D and even manipulate or carry objects. It is currently a major effort to perform such tasks with safe, lightweight drones, especially if the environment is not to be changed.

Teams are allocated 25 minutes to attempt the course, with the option to “pause” their time once by using their “Wild Card”.
The indoor event consists of 8 mission elements. Teams must attempt to complete as many of these mission elements as possible to achieve the maximum number of points.
Points will be deducted if any part of the aircraft touches an obstacle that is not the takeoff and landing pad, including the ground.

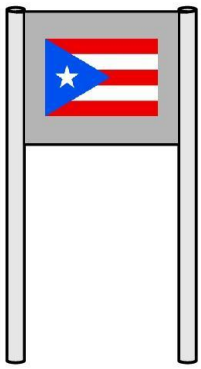
Description and Score of Mission Elements

1. **Mission element one: Takeoff**

Each MAV is required to take off from the operating zone. There will be two options:

a) From the ground. The MAV will take off from the ground of the operating zone.

b) From the charging station. In the operating zone, a structure simulating the charging station will be provided. This structure will be a cuboid of 1-1.5 m height where the MAV can be placed for performing the takeoff maneuver.



In front of the taking-off zone there will be a pole with a distinctive flag. This flag will indicate in which conveyor belt the MAV is required to release the package.

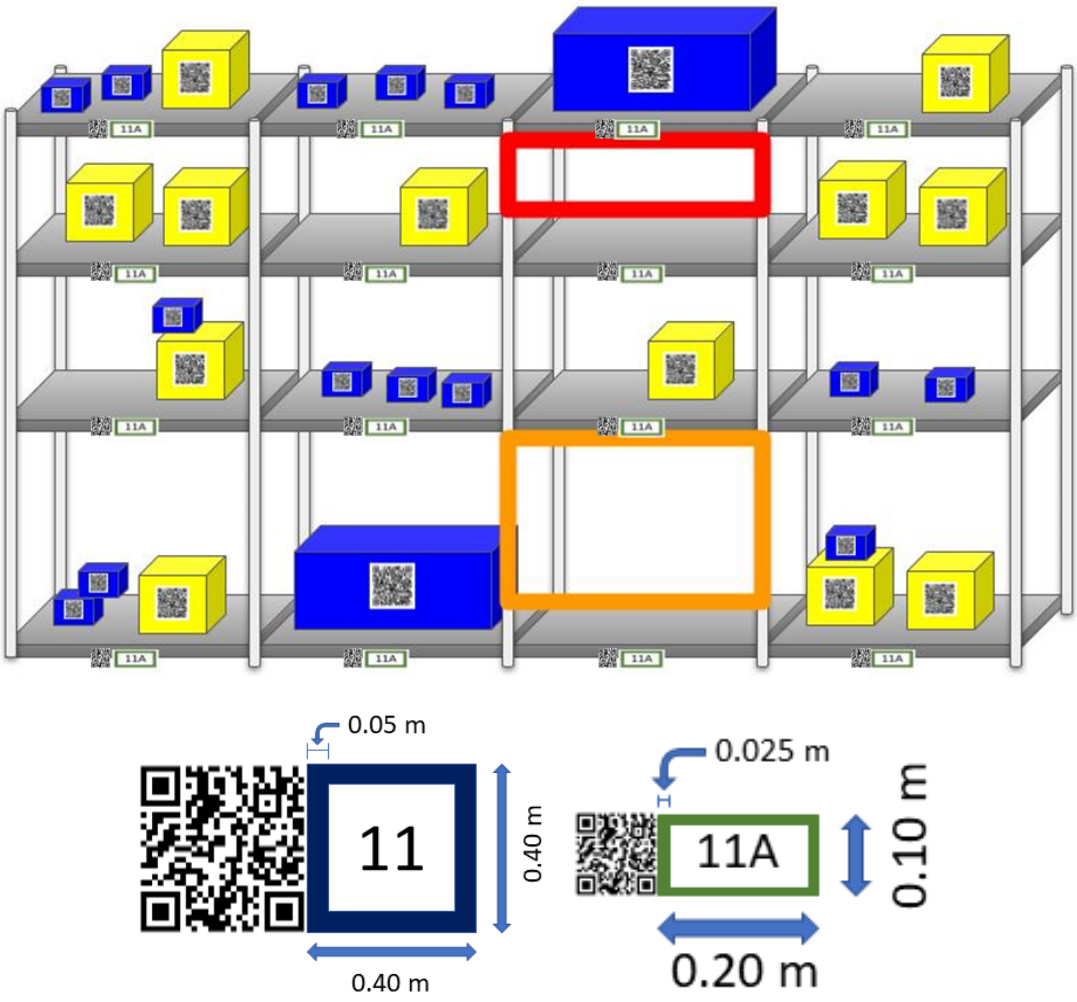
2. Mission element 2 and 4: Inventory of the shelves.

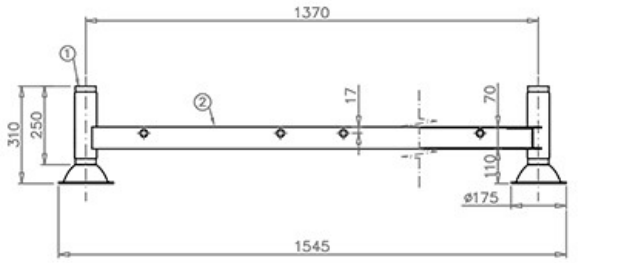
In this mission element, the MAV is required to perform the inventory of predefined packages given to the team before taking-off by providing the packages location in a 6 m x 4 m x 1 m shelves. A total of 8 QR codes representing 8 packages (4 packages per shelf) will be provided. Teams are required to perform the inventory of the provided packages in any order. For every package on a shelf the following data should be provided:

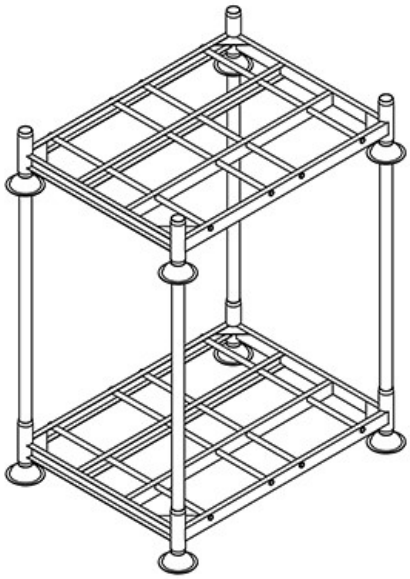
- QR code that identifies the package (size of the code xxxxx)
- Shelf identification code, situated at both ends of each shelf, that is made of a plate with a colored frame and an alphanumeric code inside (size 0.4 x 0.4 aprox.)
- Position along the shelf, that can be obtained using identification plates with a colored frame and an alphanumeric code (size 0.2 x 0.1 aprox.)

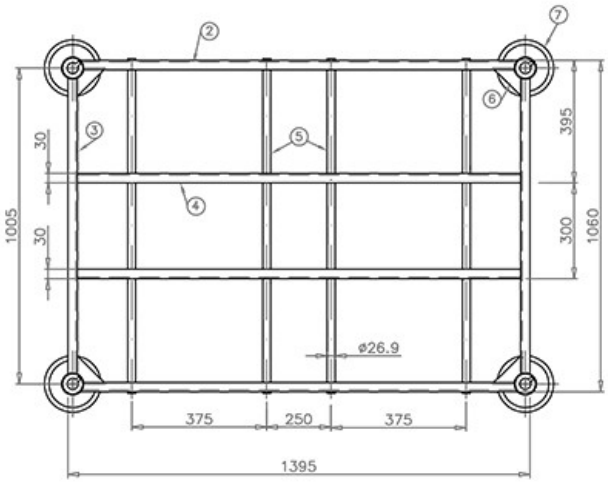
Alternatively, teams can have the option to perform the inventory using QR codes instead of the alphanumeric identification plates. Less points will be provided in this case according to the Indoor Competition Scoring table.

Each team should indicate at the beginning of the mission (i.e. before takeoff) which option they select to perform the inventory (identification plates with alphanumeric codes or QR codes).









3. Mission elements 3 and 5: Crossing the shelves

Each MAV is required to cross the shelves and continue the mission. To this aim, each shelf will contain two designated crossing zones.

a) Crossing the shelves through a colored frame. On the shelves, there will exist a colored frame. The specific dimensions of the frame will be provided.

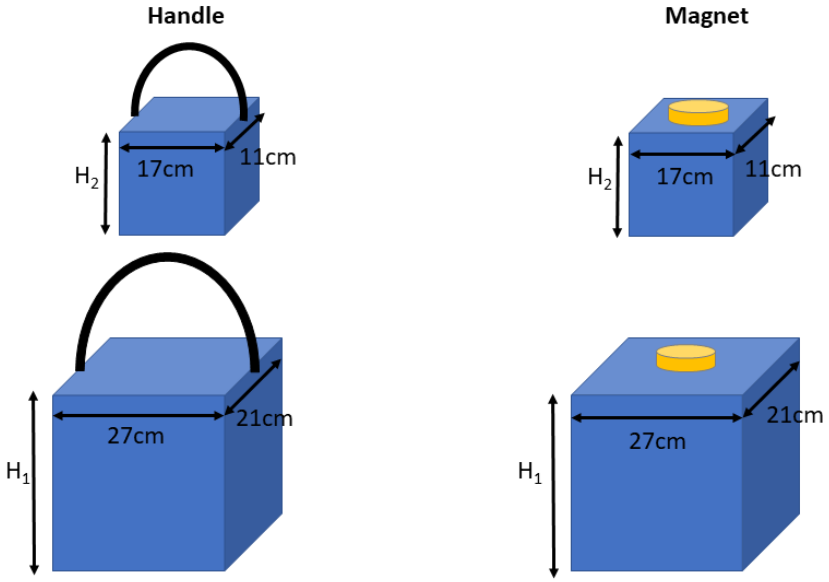
b) Crossing the shelves through a normal hole. The MAV will have the possibility of crossing the shelves without using the colored frame.

Teams are allowed to give up on mission elements 3 and 5 by crossing the shelves flying above or surrounding it. No mission score will be given to mission elements 3 and 5 in this case.

4. **Mission element 6: pickup a package**

In this mission element, the MAV is required to pick up a package. There will exist packages of two different sizes (e.g. 27cm x 21cm and 17cm x 11cm) and weight proportional to the MAV weight (preliminar ranges considered are: MAV weight < 500g => package weight =25g; MAV weight > 500g & < 1000g => package weight =50g; MAV weight > 1000g & <2000g => package weight =100g; MAV weight > 2000g => package weight =200g). In order to perform the picking task, each package can have different picking options: a handle, a magnet or no aid. Each team should select the picking option for the packages before starting the mission.

Teams are allowed to give up on mission element 6 by pre-loading the package onboard the MAV before takeoff. No mission score will be given to mission element 6 in this case.



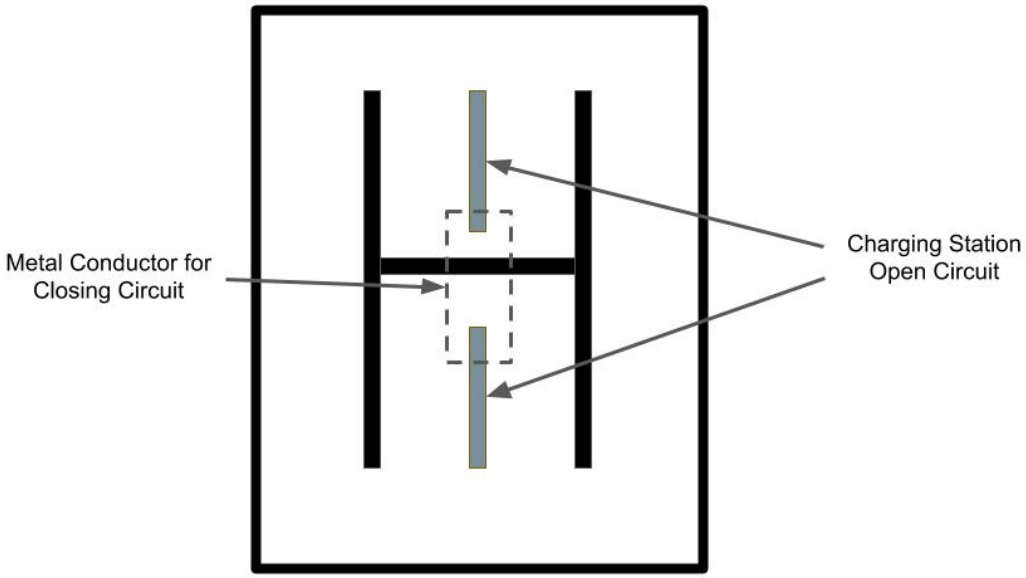
5. **Mission element 7: Release the package**

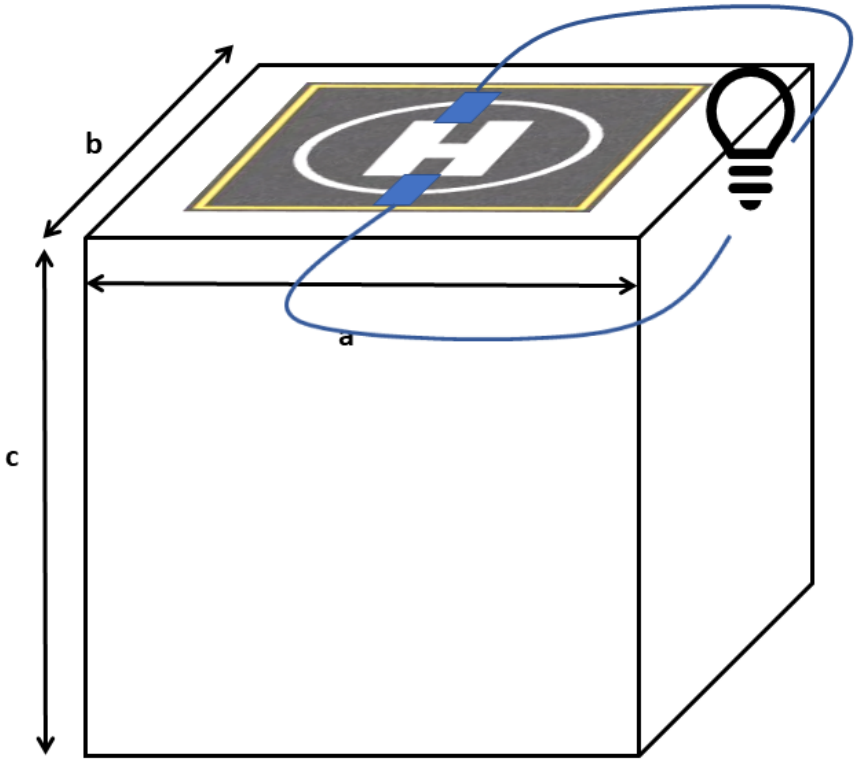
In this mission element, the MAV should recognize first the corresponding release zone. For this purpose, each of the three conveyor belts located at the release zone will have a flag representing one of the countries currently participating at IMAV 2019. The MAV should locate the correct flag (the flag that was shown in the operating zone). After recognizing the corresponding conveyor belt, the MAV should perform the release maneuver in the designated place.

6. **Mission element 8: Land in the charging station.**

Next to each conveyor belt, a charging station will be provided. This station will have a helipad printed on it, indicating the landing zone. Inside the helipad, two metal strips will be

provided. In order to correctly land the MAV in the charging position, the MAV should touch the metal strips for closing the circuit. The correct landing maneuver in the charging position will be indicated with a green light indicator, once the MAV closes the circuit.





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Indoor Competition Scoring

Mission Element	**Description**	**Points Available**
Take-off	Successful take-off from take-off platform Successful take-off from charging station (it only scores if an mission element is attempted after taking off)	+2 +5 (max. 7 points)
	Points deducted for each obstacle/ground hit	-2 (each) Cap at max -50 pts.
Inventory QR	Successful package location provided (QR) Successful package location provided (Visual code) Full inventory bonus	+5 (each) +15 (each) +10 (max. 130 points)
Shelf crossing	Successful shelf crossing Hole size bonus: -Very large (150 cm x 150 cm) -Large (150 cm x 90 cm) -Medium (150 cm x 60 cm) -Small (150 cm x 40 cm) Crossing through hole without frame	+5 +0 +5 +10 +15 +10 (max. 30 points per shelf, 60 points in total)
Package Picking	Successful package pick Pick big package Use handle aid Use no aid	+10 +5 +5 +12 (max. 25 points)
Package release	Successful release on conveyor belt Release on correct conveyor belt	+10 +10 (max. 20 pts)
Landing	Successful land Land on charging station Enabled charging	+2 +10 +10 (max. 22 points)

Scoring examples.

Team A:
UAV: Parrot Bebop. RGB-D camera and processing board. Weight : 750 g.

Task	Score
Take off from the charging station.	7
Correct location of 6 packages(QR)	30
Crossing shelf 1 through a medium hole with frame.	15
Crossing shelf 1 through a small hole with frame.	20
Package preloaded	0
Release the package on conveyor (not correct)	10
Land on the charging station without enabling charging.	12

- Total points: 94.
- In a row factor (5 tasks) : 2.33
- Mass factor: 1.167
- Autonomy Score (fully autonomous) : 12
- **Final Score** : 3067,156

Team B:
UAV: DJI Matrice 100. RGB-D camera ,processing board and lidar. Weight : 3400 g.

Task	Score
Take off from the charging station.	7
Correct location of 8 packages	130
Crossing shelf 1 through a small hole without frame.	30
Crossing shelf 2 through a small hole without frame.	30
Picking of big package without aid	25
Release the package on correct	20

conveyor	
Land on the charging station enabling charging.	22

- Total points: 264.
- In a row factor (6 tasks) : 2.66
- Mass factor: 0.647
- Autonomy Score (fully autonomous onboard) : 15
- **Final Score** : 6815.239

Outdoor Course

Outdoor Competition Rules

- 1 pilot per MAV is required.
- Teams can perform the outside missions with several MAVs with a maximum of 3 MAVs per team can be used.
- At least one team member must maintain visual line-of-sight contact with their MAV.
- All other team members (including those not competing) must remain in the pits or spectator “no-fly” zone.
- All MAVs will be checked before flight and must be airworthy and demonstrate required fail-safes (see Safety document).
- Only the competing team may have their radio equipment on during the competition.
- Only the competing team may fly their MAV during their competition slot.
- All batteries must have a means of monitoring the voltage. Teams must use appropriate lipos bags while storing or charging the batteries.
- The team is always responsible for the safety of its MAVs and is liable for any accidents caused by their aircraft.

- The main ground station screen has to be shared via a VGA or HDMI output (to a projector or screen delivered by the organisation)
- A human safety pilot must be able to take over the aircraft at all times in case of an emergency.
- Instructions given by the IMAV staff and field marshalls shall be obeyed without argument.
- Decisions made by the IMAV judges are final.
- Note: You must keep radio communications with all MAVs during operations to abide by Spanish regulations.

Failure to adhere to these rules may result in penalty or disqualification.

Outdoor Mission Brief

Note: The weights of the packages for outdoor competition have been updated. Please take a note them.

The outdoor mission aims to present the capabilities of the teams for fast and autonomous package delivery using MAVs. The outdoor area consists of a flight area of 30,000m2 where the MAVs will be required to perform the delivery of the given packages.

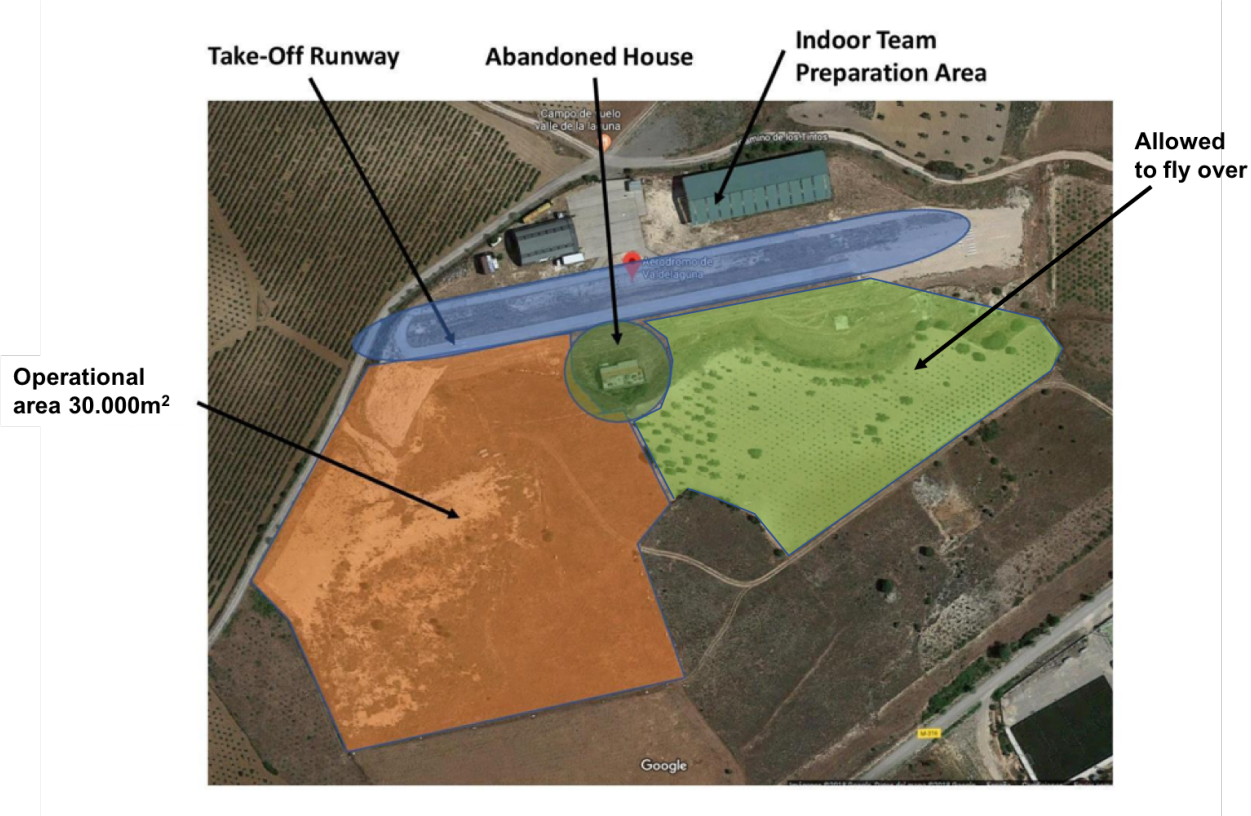

Fig 1: Layout of the outside competition

Teams are allocated a 25 minute time slot with the option to “pause” their time once by using their “Wild Card”. The outdoor competition consists of 5 mission elements. All the mission elements need to be performed from the take-off point.

Points will be deducted if the MAV hits the balloons which will be placed as obstacles at several locations near the take-off and landing zone. The mission elements for the outdoor event are as follows:

Take-off

- Autonomous take-off will be awarded points while manual take-off will not be awarded any points. Hand launching of fixed wing aerial vehicles allowed but will be considered manual take-off.
- At Least one mission element apart from landing or mapping needs to be performed in order for the take-off points to be considered for punctuation.

Delivery of the Packages

- Each team has to perform delivery of all given packages in their respective mailboxes.
- Three mailboxes of increasing sizes and six packages of different sizes will be provided; two packages have two be delivered to each mailbox. Up to two packages are allowed to be carry per drone.
- Location of the mailboxes will not be provided previously to the teams.
- The teams can attach the packages to their MAVs before take-off manually.
- Each package will have a mechanism for picking as shown in Fig. 2. Teams are also allowed to design their own attachment mechanism if they don't want to use the default one.
- Images of the mailboxes: TBD
- The mailbox and package configurations will be as follows:
    - Mailbox 1:
        - color: red
        - size: 0.75 x 0.65 x 0.30 m (length x width x height)
        - Number of packages to be delivered: 2
        - Color of packages to be delivered: red
        - Weight of the package: 100 grams
        - Size of package to be delivered: 0.10 x 0.10 x 0.10 m (length x width x height)
    - Mailbox 2:
        - color: blue
        - size: 1.2 x 1.2 x 0.30 m (length x width x height)
        - Number of packages to be delivered: 2
        - Color of packages to be delivered: blue
        - Weight of the package: 120 grams
        - Size of package to be delivered: 0.20 x 0.20 x 0.20 m (length x width x height)
    - Mailbox 3:
        - color: yellow
        - size: 1.5 x 1.5 x 0.30 m (length x width x height)
        - Number of packages to be delivered: 2

    - Color of packages to be delivered: yellow
    - Weight of the package: 140 grams
    - Size of package to be delivered: 0.30 x 0.30 x 0.30 m (length x width x height)

- Distribution of points for delivery of the packages in the mailboxes is as follows:
    - Points will be awarded for every package delivered within a range of 5m of a mailbox.
    - Additional points will be awarded for precision delivery i.e package delivered inside the mailbox but not in the correct mailbox.
    - Maximum points will be awarded for correct and precision delivery (package falls inside the correct mailbox).
    - Points are proportional to the size of the package i.e bigger package delivery higher the points.
    - If teams are not able to perform the autonomous detections, they can put Aruco like markers around the mailboxes with a penalty of -2 in the autonomy factor.

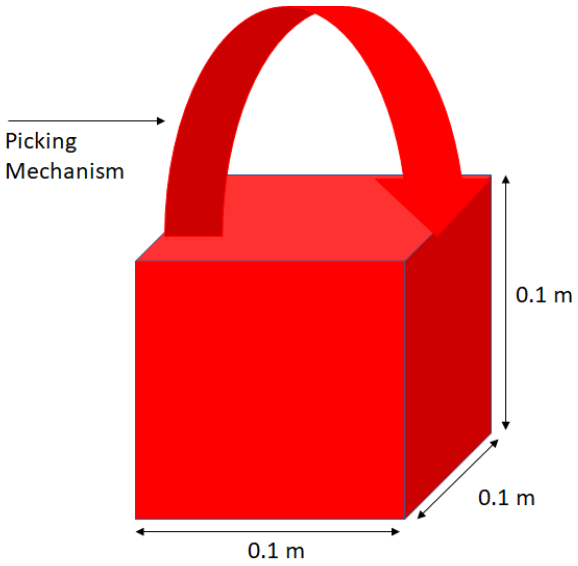

Fig 2. Image of the package to be delivered with its picking mechanism.

Delivery of a Fragile Package

- Apart from the 6 packages mentioned above, each team has to deliver a fragile package in a designated area near the entrance of the house.
- Bonus points will be awarded to those who are able to deliver the package inside the house.
- Bonus points will only be awarded to those who are able to deliver the package with all the contents inside intact.
- Weight of the fragile package: 100 grams.
- Fragile package will have a picking mechanism as shown in Fig. 2. Teams are also allowed to design their own attachment mechanism if they don't want to use the default one

- Size of package will be: 0.10 x 0.10 x 0.10 m (length x width x height)

Detection of Lost Packages:

- Some packages have fallen down during previous deliveries and need to be located.
- Each team is required to detect and provide the GPS location (GPS readings should be latitude-longitude) in real time of 3 different packages each of size 0.50x0.50x0.30 m (length x width x height).
- All packages will have the same color which will be orange.
- Teams can also provide the location of the lost packages in the offline 2D map instead of real time but will be given less points. Teams will be provided 20 mins after the completion of their time slot to provide the map.

Detection of Crashed Multirotor MAV:

- Due to bad weather conditions in a previous delivery, a multirotor MAV has crashed and needs to be located in order to be recovered.
- Each team will have to detect the crashed multirotor and provide its GPS coordinates in real time (GPS readings should be latitude-longitude).
- The multirotor will be in the size range of 0.65 x 0.65 x 0.4 m to 0.9 x 0.9 x 0.5 m (length x width x height).
- Teams can also provide the location of lost multirotor in the offline 2D map instead of real time but will be given less points. Teams will be provided 20 mins after the completion of their time slot to provide the map.

Landing

- Fixed wing aerial vehicles will be required to land in narrow runway of width 1.5 m, whereas multirotors will be required to perform precise landing in a square of size 1m x 1m.
- The square for the multirotors will contain a Helipad sign as shown in Fig. 4. And the runway for the fixed wing landing is shown in Fig. 5.
- In case of fixed wing aerial vehicle points will be deducted if the MAV lands outside the specified width and length of the runway.
- In case of multirotor MAVs points will be deducted if the MAV lands outside the specified square.
- Out of all the landings performed the best one will be considered.
- At least one mission needs to be performed apart from take-off or mapping in order for the landing mission to be considered for punctuation.

Fig 3. Images of the crashed MAV. One of them would be used to simulate the crashed MAV.

Mapping

- Teams will generate a 2D RGB map of the specified area.
- 2D maps will be judged based on the quality of the stitching of images (visually).
- Teams will be given 20 mins after their time slot in order to generate the 2D map.
- Additional points are awarded for:
    - Detecting a house in the 2D map with its GPS coordinates.
    - Detecting mail boxes in the 2D map with its their GPS coordinates.
- Example of the 2D RGB map can be seen in Fig. 6.

Time Factor:

- Bonus points will be awarded for teams able to deliver all packages before the allocated time slot. Note that delivering all packages means accounting at least the minimum score for each package.

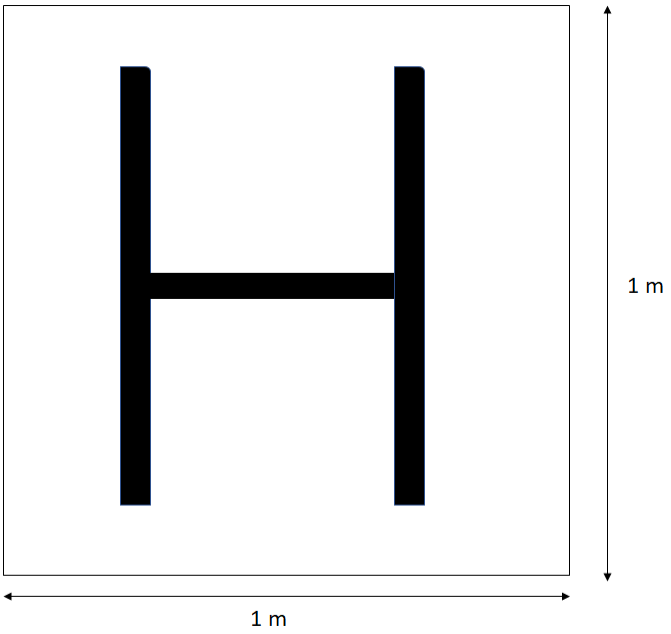

Fig 4. Image of the helipad for landing of multi-rotors.

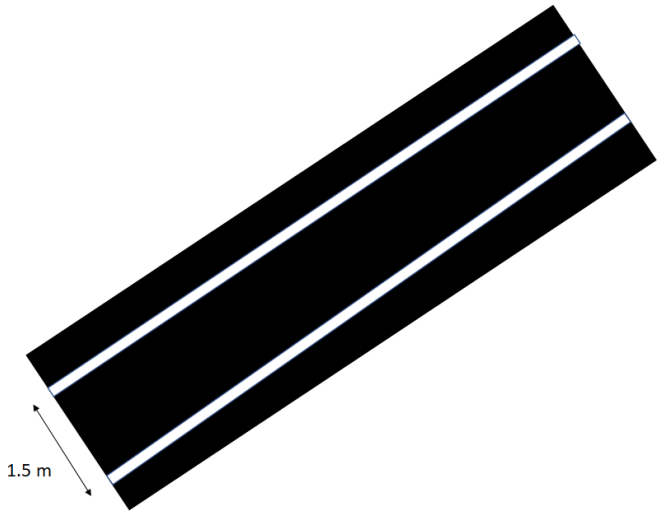

Fig 5: Runway for landing of fixed wing aerial vehicles

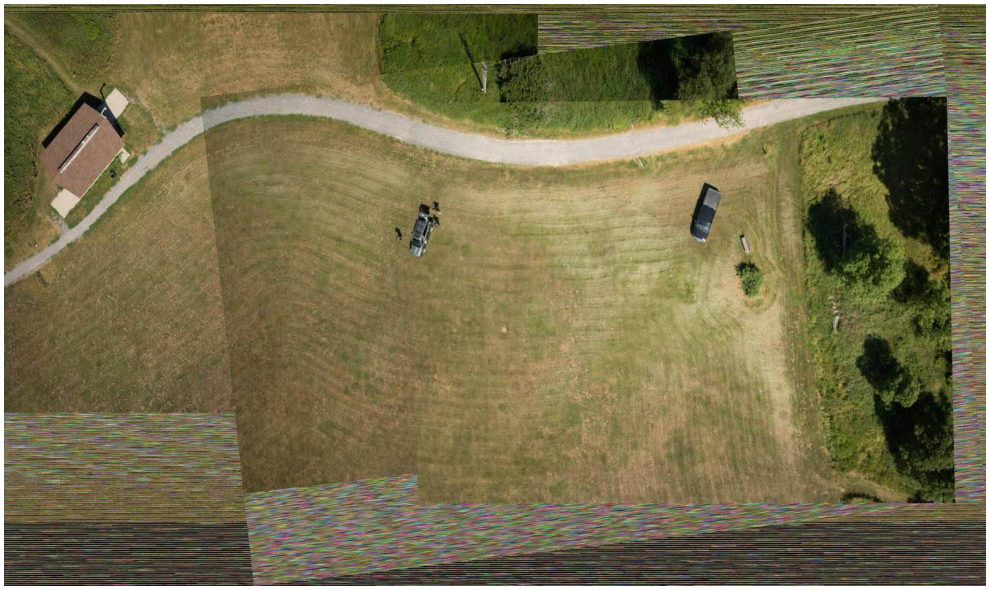

Fig 6: Example of the required 2D RGB map

Outdoor Competition Scoring

The scoring of each element is as follows:

Mission Element	Description	Points Available
Take-off	Successful autonomous take-off from the designated area	2
Mapping	Map created Detect house in map Detect mailboxes	+10 +5 +5 (max. 30 pts)
Object detection	Lost package detected (each) Crashed MAV detected Real time detection (each)	+5 +5 +5 (max. 40 points)
Package delivery	Successful package delivery (each) Precision delivery (inside mailbox) (each): -Small mailbox -Medium mailbox -Big mailbox Delivery on correct mailbox (each)	+5 +5 +10 +15 +5 (max. 120 points)
Fragile package delivery	Successful delivery in front of the house Precision delivery Delivery inside the house Fragile object not broken after delivery	+5 +5 +15 +20 (max. 45 points)
Landing	Controlled landing	+1

	Landing inside landing area Landing inside precision landing area	+5 +5 (max. 11 points)
Video Relay	Video from aircraft relayed to ground station for viewing by spectators	+10

Scoring examples.

Team A:
UAV: Matrice 100. Weight : 3400 g.

Task	Score
Take off	7
Map created (mailboxes and house detected)	60
Crashed MAV and 3 packages detected in real time.	40
All 6 packages delivered inside correct mailboxes.	120
Fragile package precision delivery (not broken)	30
Landing inside precision landing area	11
Video relay	10

- Total points: 278.
- Time factor (1 minute left) : 1.05
- Mass factor: 0.647
- Autonomy Score (fully autonomous onboard) : 15
- **Final Score** :2832,8895

Team B:
UAV: 3x Parrot disco. Weight : 740 g.

Task	Score
Take off	7
Map created (mailboxes and house detected)	60

Crashed MAV and 3 packages detected in map.	20
All 6 packages delivered around correct mailboxes.	60
Fragile package delivery (broken)	5
Landing inside precision landing area	11
Video relay	10

- Total points: 173.
- Time factor (5 minutes left) : 1.25
- Mass factor: 1.176
- Autonomy Score (fully autonomous offboard) : 12
- **Final Score** : 3051.72