RULES FOR THE IMAV 2022 PACKAGE DELIVERY CHALLENGE

Changelog:

Version	Changes
0.1	First version
1.0	Added: package dimensions, picture of packages, rules for package attachment/detachment, picture of the truck, coordinates of mission elements. Changed: ArUco tag instead of QR code.
1.1	Update of the mission map.
1.2	Refined package rules, weight limitation excludes package weight, valid package delivery refinement for missions 4 and 6.
1.3	Aids allowed for the truck mission for reduced autonomy factor.
1.4	Flight log required for mission 6, delivery far and fast.
1.5	White border around ArUco marker 5 cm

INTRODUCTION

The outdoor mission of IMAV 2022 is centered around the theme of **package delivery**. The rules stimulate technical developments that solve key challenges, as will become clear from the scoring section.

THE LOCATION

The outdoor competition will be held at Unmanned Valley, on the former airbase Valkenburg (https://g.page/unmanned-valley?share).

Latitude: 52.171490°

Longitude: 4.417461°

MISSION

The mission consists of the following elements:

1. Delivery of a package at an ArUco tag with known GPS location.
2. Delivery of a package at an ArUco tag, the GPS location of which may be off by up to 100 m.
3. Delivery of a package at an ArUco tag at an unknown location in the field. Multiple ArUco tags are distributed in the field, and the package needs to be delivered at an ArUco tag specified to the team.
4. Silent delivery: delivery of a package at an ArUco tag with known location. More points are awarded, the more silent the delivery is.
5. Delivery of a package to a moving pickup truck.
6. Delivery far and fast: deliver a package to a known GPS location, after first flying a number of laps around two fixed points spaced 500 m apart. The more laps flown prior to delivery, the more points are awarded.

For each mission element n, a base score S_n is awarded as detailed per mission element below. The base score of a mission element cannot be negative.

A map of the missions is shown in Figure 1 precise locations are shown in the table below. MAVs have to take-off and land from the orange area.

FIGURE 1: MISSION ELEMENTS AND APPROXIMATE LOCATIONS

Mission element	**Latitude**	**Longitude**
Known drop location	52.171387°	4.420618°
uncertain drop location	52.169916°	4.415763°
Silent delivery	52.170707°	4.418157°
Pylon 1	52.169221°	4.415347°
Pylon 2	52.171357°	4.421790°
Unknown GPS delivery area		
D1	52.168043°	4.412970°
D2	52.167008°	4.413522°
D3	52.166332°	4.415778°
D4	52.170171°	4.423786°
D5	52.171484°	4.423171°
Truck delivery area		
T1	52.171974°	4.417091°

T2	52.171345°	4.417542°
T3	52.171776°	4.419102°
T4	52.172411°	4.418629°

ARUCO TAGS

Aruco tags are used in order to have easily recognizable markers, that can even help with pose estimation. The markers will be 5x5 bits codes measuring 20x20 cm, with a white border of 5cm around them. The dictionary used can be found here:
https://raw.githubusercontent.com/opencv/opencv_contrib/master/modules/aruco/src/predefined_dictionaries.hpp

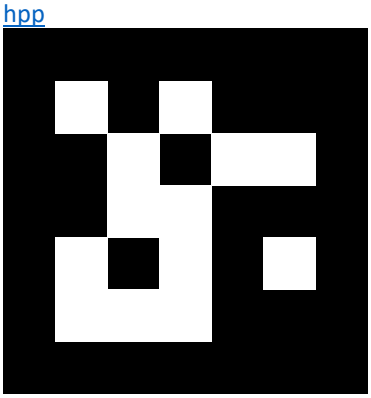

FIGURE 2: EXAMPLE OF AN ARUCO TAG

1. DELIVERY AT KNOWN LOCATION

For this mission element, deliver a package at a known GNSS location. The delivery location is additionally marked with an ArUco tag. Given a delivery at a distance d in meters to the centre of the ArUco tag, the base score for this mission element is:

$$S_1 = 2 - 0.2d$$

2. DELIVERY AT UNCERTAIN LOCATION

This mission element is similar to the above mission element, with the difference that the GNSS location of the ArUco tag is inaccurate, it may be up to 100 meters off, but is guaranteed to be inside the general mission area. The package should be delivered at the ArUco tag, and not at the provided (inaccurate) coordinates. Given a delivery at a distance d in meters to the ArUco tag, the base score is:

$$S_2 = 4 - 0.3d$$

3. DELIVERY AT AN UNKNOWN LOCATION, BASED ON AN ARUCO TAG

For this mission element, the delivery coordinates are unknown. The team will be given an ArUco tag, at which a package needs to be delivered. Multiple ArUco tags will be spread over the flight area, but the points are only awarded points if the package is delivered at the correct ArUco tag. Given a delivery at a distance d in meters to the ArUco tag, points are awarded according to:

$$S_3 = 8 - 0.4d$$

4. Silent delivery

For the silent delivery mission element, the goal is to deliver a package at an ArUco tag with known coordinates. To reduce nuisance for any residents in the area, the package should be delivered as silently as possible. The drop-off zone will be equipped with microphones at a distance to the ArUco tag of 5 meters, measuring the sound pressure level. Given a measured sound pressure level of P_m in Decibels (A-weighting), the element scoring is as follows:

$$S_4 = \frac{10}{\left(\frac{P_m}{50dB}\right)^3}$$

To count as a successful delivery, the package needs to be delivered within a distance of 5 meters, but hitting a microphone will result in zero points for this mission.

5. Delivery on a moving pickup truck

For this mission element, a package must be delivered to a moving pickup truck. The pickup truck is driving laps in the area marked purple in Figure 1, at a speed of 5 km/hour. The truck is driven manually, and no information is provided about the exact track of the truck. The truck will not make abrupt turns and will drive independent of drone maneuvers.

FIGURE 3: THE TRUCK THAT WILL BE USED FOR MISSION 5.

The bed of the truck is a flat surface, as the walls surrounding the bed are folded away as in Figure 3. The bed is also equipped with an ArUco tag. Points are awarded if the package is stable on the bed for five seconds.

$$S_5 = 10$$

If desired, a team can mount a beacon (e.g. GNSS station) on the truck. This will result in a penalty in the autonomy factor for this mission as is described in the scoring.

6. Delivery far and fast

Two coordinates, P_1 and P_2, are provided which are 500 meters apart. A package can be delivered to a known coordinate, also equipped with an ArUco tag, after having been flown X number of laps around the two coordinates. A lap constitutes of flying past the line orthogonal to P_1P_2, passing through P_1, and subsequently flying past the line

orthogonal to P_1P_2, passing through P_2. The drone has to carry a package. If the package is delivered at the end of the laps to the GPS coordinates of mission 1 ($D = 1$), this will result in double the score (otherwise $D = 0$). Points are awarded according to:

$$S_6 = X(D + 1)$$

The delivery is considered successful if the package is delivered within 10 meters of the ArUco code of mission 1, otherwise points will still be awarded with $D = 0$.

To check whether de drone actually flew past the points P_1 and P_2, it is required to produce a log of this drone's flight. The log should be a CSV file with the following format:

```
Time in seconds, latitude, longitude, altitude
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The log should have enough data points to reconstruct the flight in a reliable fashion, and should be provided to the jury at most half an hour after the timeslot.

SCORE

Weight is of primary concern for the safety of unmanned air vehicle operations. The scoring formula awards more points to lightweight drones that can perform missions fully autonomously.

The score is calculated with the following formula:

$$S = \sum_{n=1}^{N} 0.1 \frac{S_n A_n P_n}{\left(\frac{W_n}{W_{max}}\right)}$$

Where

- S is the total score
- n is each mission element
- A_n is the autonomy factor
- S_n is the points obtained per mission element
- P_n is the package factor
- W_n is the weight of the heaviest (single) drone that performed the mission
- W_{max} is the maximum allowed weight of an individual drone (without package): 5kg

The autonomy factor is specified in the table below. Note that it is possible to use 'aids' (e.g. beacon) for mission 5: delivery on a moving pickup truck. This will influence the autonomy factor according to the table below. For other missions, such aids are not allowed.

Autonomy level	A_n	A_n with aids
Remote piloted through video link, no line of sight flying allowed	1	0.5
Autonomous flight control: Flight is controlled autonomously but the operator is still controlling mission aspects, e.g., commanding transitions between control modes, control of payload, processing perception, and decision making.	2	1.5
Autonomous mission control:	5	3.5

All aspects of the flight and mission are automated, including detection and decision making. Typically, the operator does not touch the controls: hands-off control.		

If multiple drones are used to carry a package, the drones need to be able to fly independently to qualify as separate drones.

Mission Time

Each team will be assigned a time slot of 30 minutes to set up their equipment, prepare flight, fly the competition, land and retrieve the MAVs, clear the flight team area, flight zones and allocated radio channels. After the 30-minute time slot, all MAVs and equipment must be switched off. Failure to comply can lead to a penalty or disqualification. Any MAVS that have been lost during the mission should be retrieved as soon as possible in cooperation with the flight safety officer.

Safety

Every team needs to implement a geo-fence for each MAV that will be used. The exact coordinates of the geo-fence are provided prior to the competition. The preliminary coordinates are:

Waypoint	**Latitude**	**Longitude**
C1	52.171809°	4.416234°
C2	52.171331°	4.416569°
C3	52.169403°	4.410566°
C4	52.166762°	4.412007°
C5	52.165493°	4.415941°
C6	52.169922°	4.425183°
C7	52.173795°	4.423437°

Upon leaving the geo-fenced area, the drone should immediately abort flight, by stopping the motor(s) and/or deflecting control surfaces the maximal amount in opposite directions. This has to be demonstrated to the jury for each MAV (unless multiple identical drones are used). The demonstration means walking with the drone with armed motors (and dismounted propellers) over the geofence and showing that the drone aborts the flight.

Additionally, all teams have to comply with the safety rules document.

Mission Execution

During mission time, the following rules apply:

- The main ground station screen has to be shared via a VGA output (to a beamer or flatscreen delivered by the organization).
- If team members must enter the field, for instance in order to retrieve a drone, observations about mission elements cannot be used in subsequent missions and cannot be shared with other team members.
- Communication between team members should be in English.

The packages

Packages are provided with different weights and shapes:

Package	Weight [g]	Dimensions lxbxh [mm]	P (points factor)

1	100	100x60x40	1
2	200	100x80x60	2
3	500	150x100x70	3
4	1000	145x130x110	4

The packages are shown in Figure 4. Note that they do not contain handles or dedicated mounting points. They can be mounted to the drone/carrying system manually without a reduction of the autonomy score or picked up autonomously. However, delivery of the package should happen by the MAV system itself, the operator cannot detach the package from the MAV system manually. It is allowed to attach structural components to the package, but the packages are only provided to the team during the competition timeslot.

Each package can be used for each mission element. Packages need to be delivered intact. Dropping a package from an altitude higher than 2 meters results in zero points for this package.

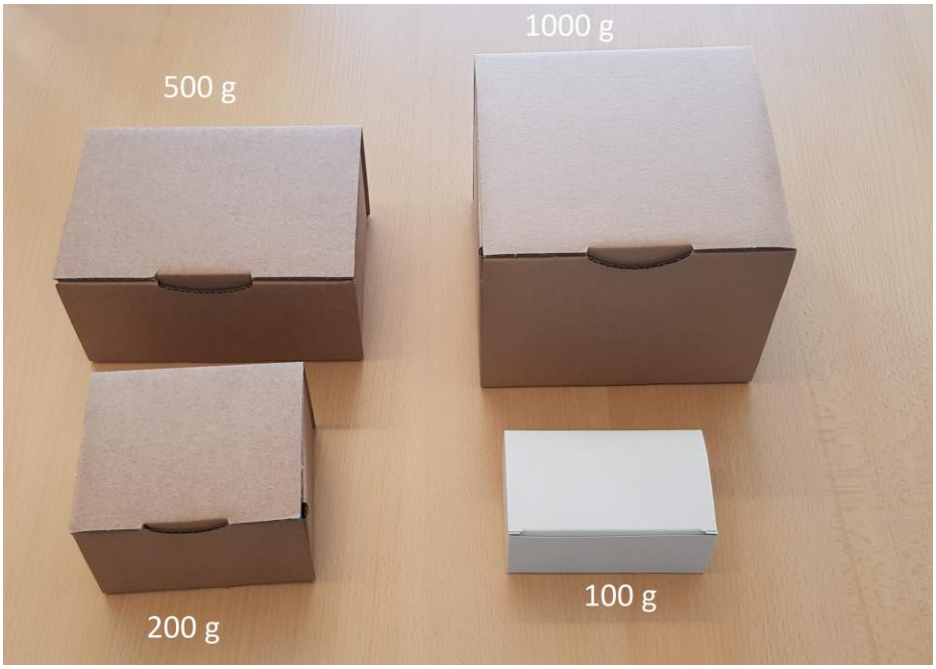

FIGURE 4: THE PACKAGES.