IMAV2017

General Indoor and Outdoor

competition rules

v2.3

Changelog

December 2016 - v0.0
- Initial draft (limited access)

December 2016 - v0.1
- review
- virtual challenge

January 2017 - v1.0
- first public release

May 2017 - v2.0
- correct outdoor location
- maximum outdoor flight altitude at 30 meters
- pictures of elements and locations
- some size of elements
- minor corrections
- some details on special challenges

May 2017 - v2.1
- correction for outdoor mission: one storage is opened for inspection

June 2017 - v2.2
- outdoor time slot reduced from 25 to 15 minutes
- virtual environment files available online

September 2017 - v2.3
- cooperative carrying modification: 2 possible payloads with different scores
- extra pictures (indoor/outdoor targets and missing person, indoor drop objects)

Introduction

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

- Aircraft efficient and innovative designs
- Small and light MAVs
- Autonomy and image processing
- Multi-UAV cooperation

To promote autonomous and remote operations, RC-only control is no longer planned as part of the competitions. However, teams with an innovative RC-only platform can request a demo slot.

In addition to this, a drone **Virtual Challenge** will be held to encourage teams using simulation tools in their airframe and algorithm conception, and to emphasize their work.

Safety and security requirements

For security and safety details see the latest version of the IMAV2017 safety regulations documents published on the **www.imav2017.org** website.

- All participants are required to be familiar with the contents of the document and comply with it. Safety checks will be performed before each flight
- Due to regulation and safety, the maximum weight for all types of MAV is **2 kg** and the maximum flight altitude is **30 m** above ground level
- Safety areas are described in a Google Earth (kml/kmz) file available on imav website and the map in the outdoor competition section
    - All MAVs should stay inside the flight area (green line). When crossing this limit, a MAV should either land or turn back immediately inside the flight area.
    - The second border (red line) defines the border of the no-fly zone. Any MAV crossing this line should turn OFF its motors (fixed-wing aircraft may glide upon the control of the safety pilot and land as fast as possible).
- Allowed frequencies and maximum power:
    - 26 MHz, 41 MHz, 72 MHz: max power 100 mW
    - 2.400 GHz to 2.454 GHz and 868 MHz: max power 100 mW
    - 2.455 GHz to 2.483 GHz : max power 10 mW
    - 5.8 GHz: 25 mW
    - The use of the 900 MHz frequency is not allowed

Failure to abide by the boundaries and frequencies can lead to a penalty or disqualification.

Location

The outdoor flight competitions will take place on Sept. 20 at **Francazal airfield** (Google Maps).

Lat: 43.5434864°
Lon: 1.3598355°

The indoor flight competitions will take place on Sept. 21 at **ISAE-Supaero gymnasium** (Google Maps).

10 avenue Edouard Belin
31400 Toulouse
France

Competition slot: preparation time & flight time

Teams are not assigned a specific preparation time and a flight time but rather a competition slot. In this slot, they will set up their equipment, prepare the flights, fly the mission, and land all the MAVs. *Failure to land all vehicles within the slot can lead to a penalty or disqualification*.
The order of the teams' slots will be randomly decided on the morning of the day of the competition. At any time, before or during the mission, a team can decide once, and only once, to postpone the rest of its mission. In this case, the rest of flight slot of the team is shifted to the end. Therefore, all teams must be ready to fly at any time.
Time slots are **15 minutes** for the Indoor mission and **15 minutes** for the Outdoor mission.

Scoring

The final score will depend on the success of the mission elements (**M** = sum of the successful mission elements), the level of autonomy for each mission element (**A**), the size factor (**S**), the "in-a-row" factor (**I**), and a presentation made by the team during the mission (**P**).
Awards will be determined using the following formula:

- Total score = $\text{Sum}_{\text{each MAV}}(M \times A \times S \times I) \times P$

In order to ease the jury's task, the teams flying multiple MAVs shall clearly identify (color, number) each vehicle.

A task yields points only once. If several aerial vehicles perform the same task, the scoring will be applied to only one vehicle so as to maximize the overall scoring.

In addition, **special jury prizes** will be awarded (see at the end of this document).

Size factor (S)

The maximum size of the MAV is **1.5 meter,** which is determined by:

- the wing span of the aircraft
- or the maximum horizontal distance of a rotary wing (including blades).

The maximum takeoff weight is **2 kg** for all type of MAVs.

Size factor = 1/(size of the MAV in meter)

Level of autonomy (A)

The level of autonomy describes how a MAV is operated in order to fulfil the mission elements. The factor associated to each autonomy level is then used to compute the final score.

Level of autonomy	**factor**
Video based control: control of the MAV through FPV system	1
Autonomous flight control: the navigation is completely autonomous but the operator is controlling the mission and the payload	5
Autonomous target detection: the navigation is manual but the detection and processing of the targets is automatic	5
Fully autonomous mission control: the navigation and the decision making are autonomous, without assistance of the operator	10
Using external aids such as visual markers	-2 applied to factor

The video based control (factor 1) can only count for a single mission element (per MAV). If several mission elements are performed with this level of autonomy, only the best score will be kept (and other elements not taken into account).

Technical demonstrations are going to be a separate flight session with or without autonomy. The main issue there is to illustrate a novel technique/strategy which does not fit with the tasks proposed. While they will not compete for the mission scores, **they are eligible for the special jury prizes**.

In-a-row factor (I)

The “in-a-row” factor encourages participant to complete as many mission elements as possible without stopping. The more mission elements completed in a single trial, the higher is the factor.

Number of mission elements completed in a single trial	**factor**
1	1.0
2	1.1
3	1.2
4 (Max)	1.5

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 analog video).

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 = 0 to 10 % of the total score (P from 1 to 1.1)

Mission elements (M)

A mission consists of multiple elements that can be performed in any order by one or more MAV. For each mission element, a score is awarded to the MAV that accomplishes the assigned task (see scoring tables further):

- a MAV can attempt to complete the mission element as many times as needed in the allotted time but only the best score will be used for the final scoring
- if several MAVs are doing the same mission element (including take-off and landing), only the best score is kept, except for the cooperative mission (in which case, all MAVs involved in the best attempt are considered in the final scoring)

Outdoor mission

Important Note: Due to technical and legal constraints the location of the outdoor competition have been moved to a small area and the end of the Francazal airport runway. The hangar scanning is then no longer possible. Some mission elements have been rewritten accordingly, but as close as possible to the original rules.

1. Automatic take-off
    a. a take-off is considered automatic as long as the safety pilot does not transmit any commands (except mission start signal)
    b. the MAV can be hand-launched.
    c. points are awarded for every MAV that performs at least one other mission element during its flight, except precision landing (taking off and landing is not enough to count as a valid mission flight)
2. Flight performance
    a. fly as many laps as possible in the competition slot around 2 poles during a single flight (landing in the middle would reset the number of laps)
    b. begins when crossing the “start” line; only laps that have been completed count in the final score
    c. the MAV must land before the end of the allotted time to be valid
    d. flight altitude is only limited by the boundaries of the flight zone
3. Mapping
    a. produce the map of the blue area on the map below, which include a small house and several storage places
    b. the garage of the house and one storage are opened and can be inspected
4. Target detection and recognition
    a. search and identify targets (hazardous materials or missing people) outside and inside the house’s garage or the storage places (storages are numbered S1, S2 and S3 as shown on the map below, not all of them have targets in front, only one storage is opened)
    b. targets can be located on the map produced by the team (see previous mission element) or a rough map provided by the organizers

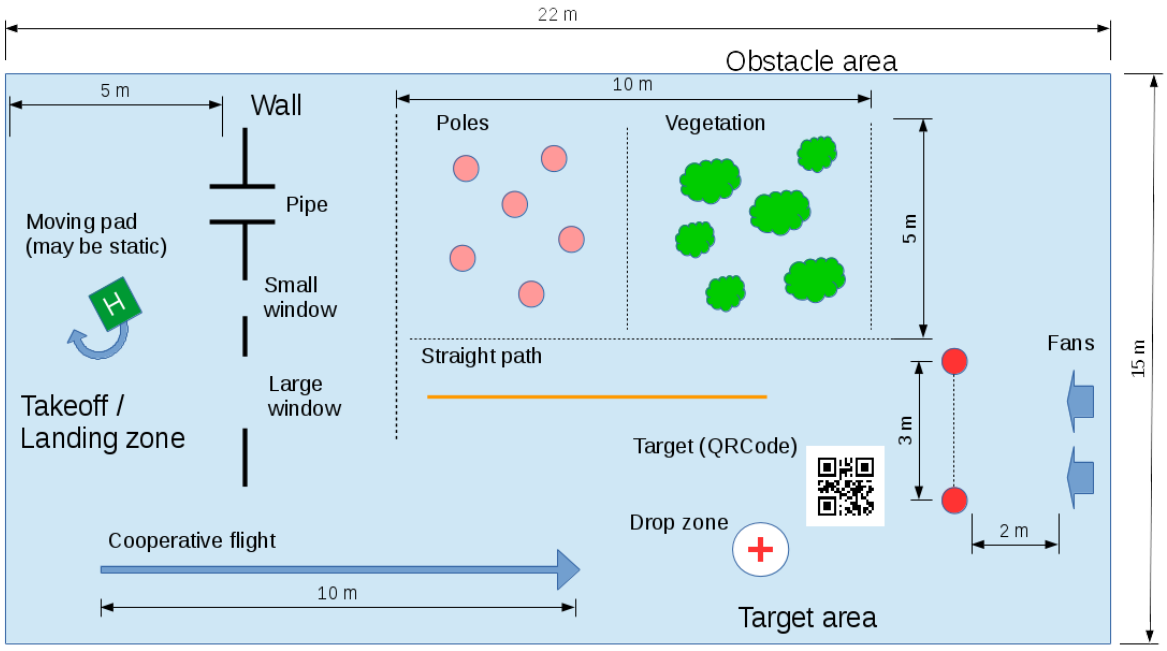
5. Cooperative carrying
    a. at least 2 drones should carry a weight over a distance of 50 meters
    b. attaching the MAVs to the weight can be done by team members, no autonomous grasping are required
    c. 2 objects of different weight can be chosen by the teams
6. Precision landing
    a. a landing will be classified as one of the following: a field landing, a normal landing, or a precision landing
    b. the size and place of each landing zone (normal/precision) depends of the type of MAV (fixed-wing, VTOL)
    c. in case of rough landing, the team will be asked to demonstrate the airworthiness of the vehicle
    d. extra points are awarded if the MAV is able to take-off again (fly higher than 5m) after staying still 10 seconds on the ground and without any operator intervention
    e. all MAVs must land within the time slot, otherwise all mission elements since last take-off will be discarded for this MAV

Mission elements	Mission score
Automatic take-off	1
Flight performance	number of laps / 8
Mapping	2 for automatic processing (2D or 3D map, can be done off-line but within mission time) +1 for images from inside the house's garage +2 for images from inside the opened storage
Target detection	1 for clear view of the target 1 for automatic detection and classification of the target 1 for correct location on the map
Cooperative carrying	1 per MAV involved if the minimum distance is reached x3 bonus when using the heavy payload +1 for precision landing of the carried weight
Landing (precision/normal/field)	2, 1, 0 extra points: +1 by taking off after 10 seconds staying still without any operator assistance

Indoor mission

1. Take-off
    a. take-off are performed from a pad that can be fixed or moving
    b. points are awarded for every MAV that performs at least one other mission element during its flight, except precision landing (taking off and landing is not enough to count as a valid mission flight)
2. Flying through the window
    a. the MAV must pass through one of windows or the pipe on a wall
3. Flying through the "obstacles" zone
    a. several obstacles must be crossed with different difficulties
        i. fixed poles (simple structured colored elements)
        ii. vegetation (unstructured elements)
        iii. fans (turbulent atmosphere)
    b. it is possible to use the straight line path without obstacle at any step
    c. each type of obstacle can be attempted separately or in a row (and in-a-raw factor will be applied except if straight line path is used)
    d. if a MAV flies above the obstacles, points will not be awarded
    e. for the fans, if a MAV is pushed away from the corridor materialized by two poles, points will not be awarded

4. Target detection and recognition
    a. a target is placed on the ground after the “obstacle” zone
    b. the task is to find the target and process the data on it (QRCode)
    c. the data found on this target is a reference of an object that should be dropped in the “drop” zone
5. Drop zone
    a. a “drop” zone is after the “obstacle” close to the target
    b. the object to drop depends on the data found on the target and can’t be carried a-priori on the MAV (as the possible choice is large, i.e. medicines)
    c. the two choices are
        i. go back to the beginning through the “obstacle” zone, pick the product, come back and drop
        ii. send the information to a second MAV that flies to the drop zone with the correct product
6. Cooperative carrying
    a. at least 2 drones should carry a weight over a distance of 10 meters
    b. attaching the MAVs to the weight can be done by team members, no autonomous grasping are required
    c. 2 objects of different weight can be chosen by the teams
7. Precision landing
    a. the MAV can perform a precision landing on either the fixed or moving platform
    b. in case of rough landing, the team will be asked to demonstrate the airworthiness of the vehicle
    c. extra points are awarded if the MAV is able to take-off again after staying still 10 seconds on the ground and without any operator intervention



Mission elements	**Mission score**
Take-off	0 from fixed pad 1 from moving pad
Fly through the wall	pipe: 2 small window: 1 large window: 0.5
Fly through obstacle zone	straight path: 0.5 per MAV fixed poles: 1 per MAV vegetation: 1.5 per MAV fans: 1.5 per MAV
Target detection	1 for a clear view of the target 1 for reading the data
Drop zone	1 for dropping the object inside the drop zone +1 if the drop is done in one row after flying through one of the window and the obstacle area
Cooperative carrying	1 per MAV involved if the minimum distance is reached x3 bonus when using the heavy payload +1 for precision landing of the carried weight
Landing (precision)	0.5 on the fixed pad 1 on the moving pad extra points: +0.5 if taking off after 10 seconds staying still without any operator assistance

Special jury prizes and challenges

Jury prizes

The IMAV jury members, will award two special prizes:

- **System prize**: this prize is awarding the team that presents the highest level of innovation of MAV system elements such as autopilot hardware or software design, Human-Machine Interface, payload control, computer vision, code analysis, simulation.
- **MAV Design prize**: this prize is awarding the highest level of innovation of aerodynamics or mechanical solutions

Virtual challenge

Design and implementation of complex systems usually require much preliminary work, including simulation. In order to encourage teams to follow this approach in as realistic as possible environment and to showcase this work, a virtual challenge is proposed alongside the traditional competition.
The key idea of this challenge is that a virtual environment modeling the indoor flight area will be provided to all the teams. Data from standard sensors (inertial measurement units, sonar, lidar, cameras) will allow you to develop and test algorithms and control for the real mission elements. During the IMAV event, teams willing to participate to the challenge will be able to connect their work to the same simulation tool hosted by the organizers. The evaluation of the teams will be done on:

- the number of tasks performed in the virtual world
- the time to perform the mission
- a short presentation of their work to the jury

The simulation framework will be based on Gazebo and can be addressed via several tools (ROS, MATLAB/Simulink, ...). The virtual environment is available on IMAV2017 website and Simulink examples are also provided.

Treasure hunt challenge

In this outdoor challenge, the goal is to find hand-made objects which are not visible using a video camera. More precisely, 4 disks will be placed horizontally on the grass within a 15x15-meter square area. Each disk is 40-cm diameter and 4-cm thick. It will be painted with camouflage-colour so as to be almost impossible to detect through a video camera. Three disks will be made of foam and one disk will be made of steel (40 kg). The objective is to locate the maximum number of disks by providing (X,Y) coordinates in meters with respect to the lower left corner of the square area. A maximum of 4 locations will be provided per team. Each correct location provides 1 point. “Correct location” means that the X,Y coordinates are provided with an uncertainty of less than 30 cm. Identification of the metallic disk provides 3 points.

The challenge will be evaluated according to the following criteria:

- flight autonomy
- autonomous calculation of locations
- duration of the hunt
- efficiency of the path planning

Drone team parade trophy

In this challenge, the goal is to have a patrol of UAVs (fixed-wing, rotorcraft or mixed) flying in a formation so as to demonstrate their coordination and flight accuracy skills.
This challenge will be evaluated according to the following criteria :

- accuracy of the formation shape and number of UAVs involved
- accuracy of the path followed by the UAVs
- aesthetic qualities of the formation
- elapsed time necessary to reach the formation configuration

Record breaking session

This indoor challenge consists of lifting up a 500-gram payload 50 cm above the ground during 1 minute. “50 cm above the ground” means 50 cm counted as the vertical distance between the lower part of the payload and the launch pad which will be placed on a table. The UAV can be attached to the payload before the flight. The winner of this challenge will be simply the team with the smallest electrically powered UAV capable of lifting that 500-gram payload under the above conditions. “Smallest” means the UAV which maximum dimension in flying configuration is the smallest among the competitors. Because of the flight regulations, the UAV takeoff weight should be less or equal to 1.5 kg (so that the flying vehicle will not exceed 2 kg including the payload). “Maximum dimension” is defined as in the Size factor section (above). RC-control mode will be allowed for this challenge.

Technological demonstration

The goal of this flight demonstration is to highlight novel disruptive MAVs architectures / technologies. RC-control mode may be accepted for the technological demo which may take place either during the indoor session or during the outdoor flight session.

Static exhibition

A static exhibition will be planned in order to show both prototypes and commercial MAVs to the participants.

Size and shapes

All dimensions presented here might be updated. GPS coordinates of some outdoor elements (poles, landing zones,...) will be provided to the team on the day of the competition.

Windows for indoor mission

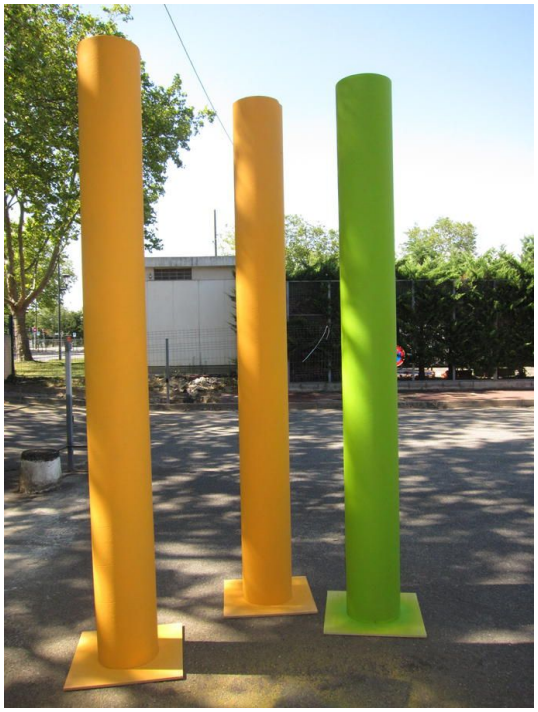
Large window: 1.5m x 1.0m
Small window: 0.8m x 0.8m
Pipe: 0.8 to 1.0 meter diameter, 1.0 to 1.2 meter long

Final dimensions will be provided in a later version of this document.

Indoor poles

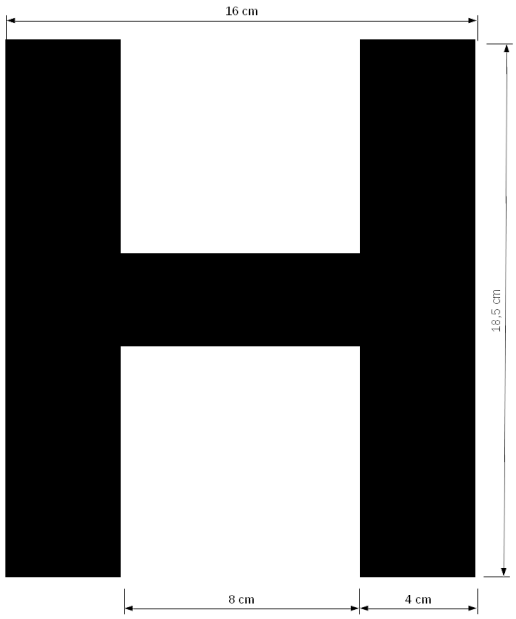
Dimensions for the indoor poles (obstacle zone):

- height: 3 m
- diameter: 30 to 40 cm
- colors may change
- poles are used in the obstacle area
- two of them materialize the beginning and the end of the “fan” obstacle



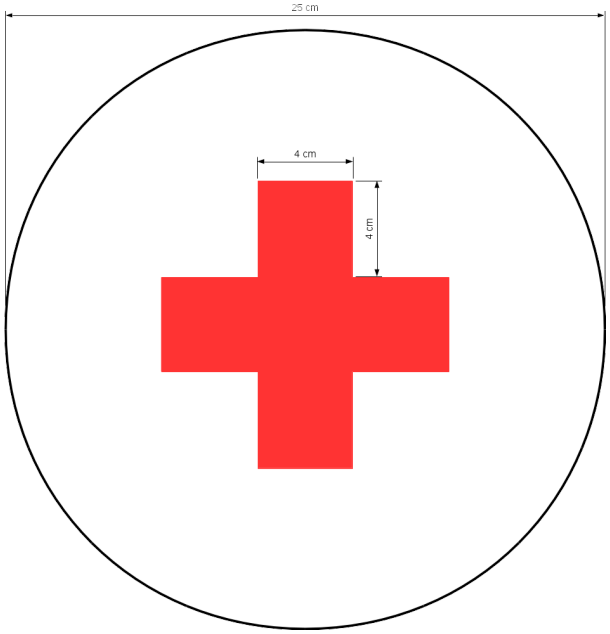
Indoor and outdoor takeoff and landing zone

The takeoff and landing zone is a 1 meter square platform with a black H letter on it. The platform is at least 50 cm above ground.



Indoor drop zones

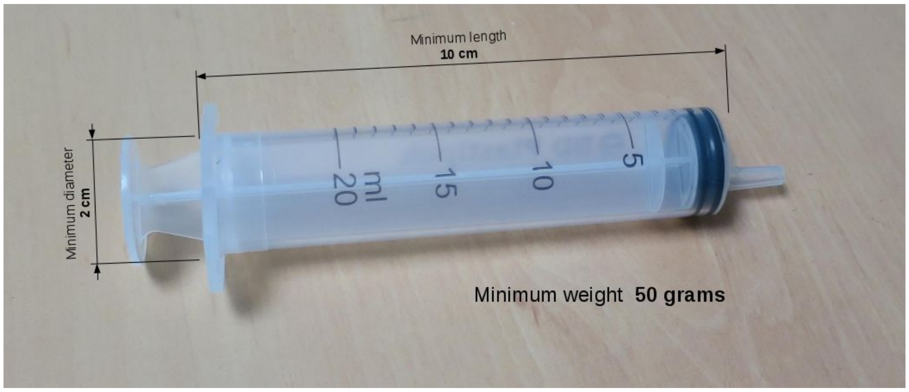
The center of the drop zone is marked by a cross. If the dropped object is at least touching the outer circle, it is counted as inside the drop zone.



Drop object

The object to drop represents a medicine in a cylinder shape (like a syringe) to be dropped close to an injured person. The required dimension and weight are:

- minimum length: 10 cm
- minimum diameter: 2 cm
- minimum weight: 50 grams



The final object provided by the organization is a copper tube with the following characteristics:

- length: 10 cm
- outer diameter : 2.2 cm (thickness 1 mm)
- weight: 54 grams

It is also possible to add tapes to help holding it as long as it is easy to remove afterwards. Teams who prefer to use their own object can do it as long as the minimum above requirements are respected.

Indoor target (QRCode)

QRCode are two-dimensional barcodes that can be decoded using various software libraries (for example ZBAR). It should be printed on a A4 paper with at most 25x25 pixels ("version 2").

Indoor vegetation

TBD

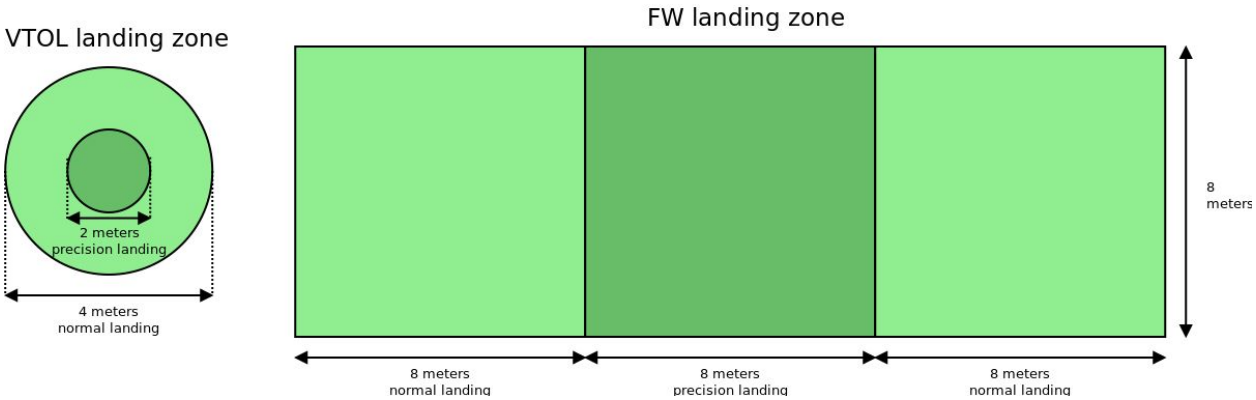
Indoor location pictures

Outdoor poles (performance)

Distance between the two poles: 250 m
Pole height: 6 m

Outdoor landing zone

The center of the VTOL landing area will have the same **H** pattern than the indoor landing zone.



Outdoor location pictures

The doors of the storage is about 3.5 x 3.5 meters. As an old military shelter, the walls are very thick and could make communication difficult while attempting to fly inside.

Cooperative carrying weight

Two objects of different weights are available with different scoring factors.

- light plastic frame: 400 to 500 gr
- heavy wood frame: 2.1 kg

Outdoor target and indoor/outdoor missing person

40 cm diameter red pot

Scoring examples

TBD