IMAV 2023 – Micro Aerial Vehicles Competition

Outdoor Competition Rules

Changelog:

Version	Changes
0.1	First draft version
0.2	Added aerial support mission, hikers information, location
1.0	Added AruComarkers and coordinates
1.1	Added coordinates, added antenna coordinates and limitations
1.2	Added minimum Timeslot usage time, specified the waypoint handling task 3, specified time format for CSV data

Changes compared to previous versions are highlighted

Content

1. Introduction

This document provides cumulative information about the IMAV 2023 outdoor competition. Besides general remarks and a schedule, it gives a detailed description of the competition areas, the mission elements, and the scoring rules.

The outdoor competition focuses on a search and rescue operation in an unknown environment. The main challenges for this competition are:

- Fast and reliable information-gathering
- Mission planning
- Autonomous operations

To encourage mission planning, four different tasks can be completed but only three MAVs are allowed to be airborne at any time. Due to the time penalty for longer missions during the competition slot, teams will encounter a higher need for mission planning to score maximum points.

2. Safety and Security Requirements

For safety and security details see the latest version of the *IMAV 2023 safety regulations document* which is published on the website (https://2023.imavs.org/). This document contains general flight safety rules and regulations, as well as flight safety zones and failsafe requirements. All participants are required to be familiar with the contents of the latest version of this document and comply with it. Before the first flight, each team has to demonstrate that all MAVs can sustain the security and airworthiness check. For the outdoor teams, this ideally takes place on the practice day.

3. Outdoor Competition

For safety and regulatory reasons, it is not allowed to start any motors outside the flight area on the practice day as well as on the competition day (except motors without propellers attached). Any tests or lift-offs have to take place within the green zone following the day's schedule in consultation with the flight manager.

3.1 Setting

A group of hikers embarked on a multi-day hiking trip through a sparsely populated region. While on the trail, they encounter bad weather, which caused them to lose their orientation and become stranded. When the hikers fail to return as scheduled, a search and rescue team is deployed to locate them. However, due to the large search area and limited visibility, the search team is unable to cover the area effectively without air support.

In this scenario, a group of MAVs equipped with a camera will be used to locate the lost hikers. At first, a sensor-equipped MAV has to fly to the remote search area and inspect the geographic characteristics. During the search and mapping of the area, all possible locations of the missed hikers are identified. Based on this information, a MAV will perform a detailed search by inspecting key areas of interest. As soon as the hikers are located, the MAV will investigate the number of missed hikers and their health status. This information is forwarded and a rescue team can be sent out. To improve traffic safety while driving to the rescue site, a MAV can accompany the rescue vehicle and provide a bird's eye view of the upcoming track condition.

3.2 Location - Outdoor

This year's outdoor competition will take place at the Aldenhoven Testing Center (ATC).

Website: https://www.aldenhoven-testing-center.de/en/

ATC - Aldenhoven Testing Center of RWTH Aachen University GmbH
Industriepark Emil Mayrisch
52457 Aldenhoven
Germany

<u>The ATC is a restricted testing facility with entrance restrictions. Access is only possible on Monday from 11.30 am till 05.30 pm. On Wednesday access is possible from 08.00 am to 06.00 pm.</u>

Besides the practice and competition day, no access can be granted.

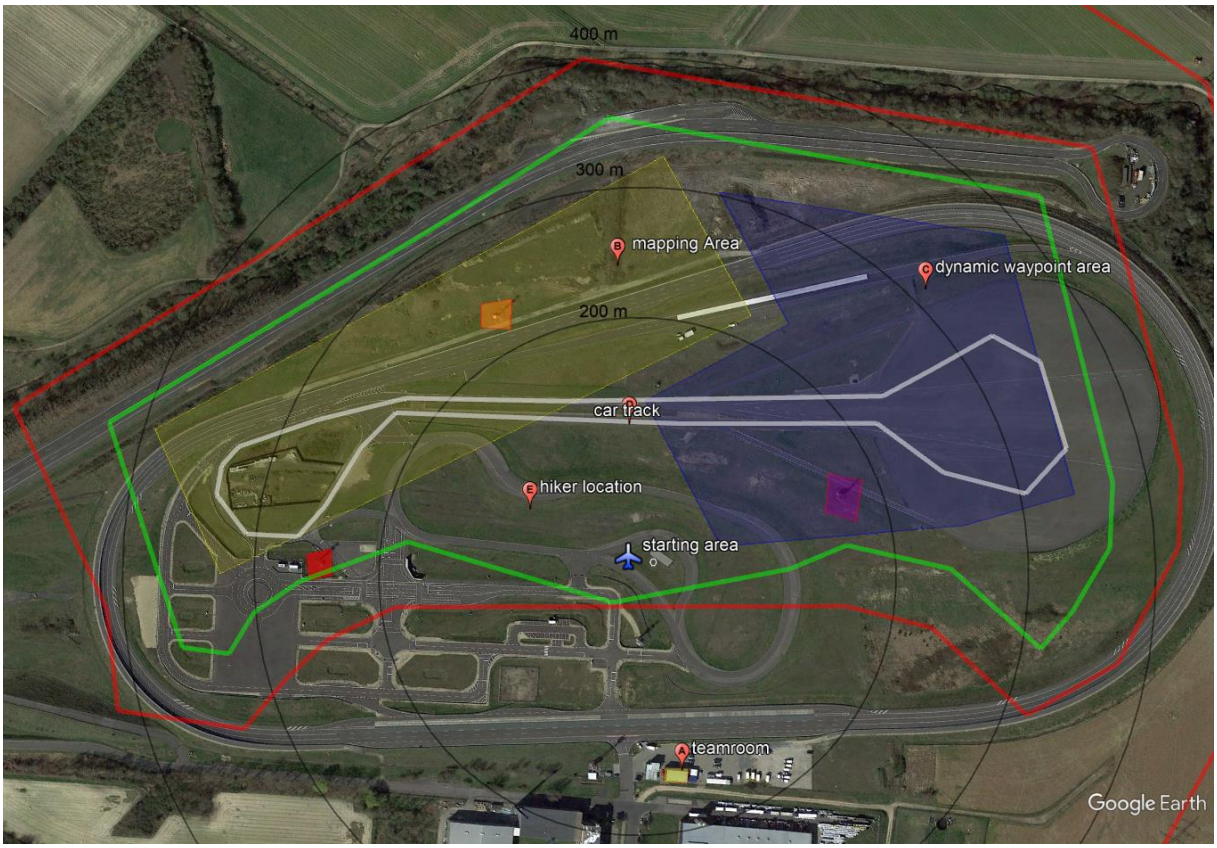


Figure 1: Outdoor location ATC

Geofence coordinates (red line):

	Latitude	Longitude
F1	50.906376°	6.223196°
F2	50.910998°	6.223086°
F3	50.913740°	6.226769°
F4	50.913135°	6.230278°
F5	50.912821°	6.231021°
F6	50.912073°	6.231793°
F7	50.911361°	6.231674°
F8	50.911074°	6.230432°
F9	50.910664°	6.229780°
F10	50.907942°	6.227214°
F11	50.907432°	6.227156°
F12	50.906610°	6.227501°
F13	50.905917°	6.226675°
F14	50.906223°	6.225644°

Flight area coordinates (green line):

	Latitude	Longitude
G1	50.906886°	6.223927°
G2	50.910946°	6.223798°

G3	50.913247°	6.226908°
G4	50.912701°	6.229972°
G5	50.912425°	6.230648°
G6	50.911652°	6.231214°
G7	50.911392°	6.229977°
G8	50.910842°	6.229131°
G9	50.909282°	6.228386°
G10	50.908253°	6.226671°
G11	50.907502°	6.226436°
G12	50.907083°	6.226495°
G13	50.906788°	6.226718°
G14	50.906549°	6.226418°

Mapping area (yellow area):

Latitude	Longitude
50.907036°	6.225883°
50.907150°	6.224190°
50.911153°	6.224431°
50.911092°	6.226390°

Dynamic waypoint area (blue area):

Latitude	Longitude
50.910190°	6.226687°
50.911327°	6.226676°
50.911382°	6.225096°
50.912922°	6.227107°
50.912415°	6.229913°
50.910146°	6.228435°

Orange/ red / purple = obstacles (antennas)

At the following coordinates, there are high antennas which may be approached with a minimum horizontal distance of 25 m below an altitude of 30 m. A minimum altitude of 30 m from the starting position has to be maintained while flying over the antennas.

Latitude	Longitude
50.911017°	6.228648°
50.907650°	6.226392°
50.909557°	6.225059°

3.3 Practice Day - Outdoor

On Monday the 11th of September a practice day will be carried out from 11.30 am till 5.30 pm. This will allow each team to prepare for the competition day and become familiar with the local procedures. Upon registration, team leaders will have to indicate if they want to attend the practice day.

On practice day the teams will have the opportunity to record the detailed GPS positions and setup their systems. After a successful security and airworthiness check, teams can apply for a test run on the competition field.

3.4 Competition Slot

Each team will be assigned a time slot to set up their equipment, prepare their flight, fly the competition, land and retrieve the MAVs, clear the flight team area and flight zones, and switch off all radio equipment. After the time slot, all MAVs and equipment must be switched off. Teams will have 5 minutes to set up their equipment, once their competition slot has been called up. Upcoming teams will have the opportunity to wait near the spectator's area, for their competition slot call-up. The order of the teams' slots will be drawn by lot on the morning of the competition and practice day. At any time (before or during the mission) each team can decide once to postpone the rest of its mission. In this case, the flight slot of that team will be shifted to the end. Therefore, all teams must be ready to fly at any time. Failure to comply can lead to a penalty or disqualification.

Any MAVs that get lost during their mission should be retrieved as soon as possible in cooperation with the flight safety officer.

Timeslots for the outdoor mission: **20 minutes** per team.

3.5 Scoring - Outdoor

To avoid a team winning the entire competition only by performing very well at one single mission element, the scoring is divided into mission element scoring and performance scoring.

Total score S

During search and rescue missions, time is a crucial factor, therefore the scoring formula is designed to award fast and fully autonomous information gathering. The final score will be determined using the following formula:

$$S = \frac{\sum_{n=1}^{5} S_n \cdot A_n \cdot P_n \cdot D_n}{T_{Slot}}$$

3.6 Mission Elements Score

The mission consists of diverse elements that can be performed by one or more MAV(s) in any order. Each mission element will be scored individually depending on the MAV's achievement, time, design, level of autonomy, and precision.

Each MAV can attempt to complete the mission elements as many times as needed in the assigned time slot but each mission element will be scored only once per team. If a team attempts a mission element multiple times, only one of the attempts will be scored. In this case, the teams have to indicate which attempt shall be scored.

Five separate tasks inspired by the search and rescue setting can be absolved during the competition.

1) **Flight to the Search Area (endurance):**
In this mission element, the task is to fly as far as possible around an arbitrary course inside the mission area (green area). **This task can be combined with different tasks.** Points are awarded for the longest-flown horizontal track. To check whether the course has been successfully flown, a CSV log file from the task designated MAV has to be submitted to the judges via a USB stick labeled with the team name in an Excel table with format **[UTC time incl. seconds (Format YYYY-MM-DDTHH:MM:SS.sss), decimal latitude, decimal Longitude, altitude above start point]** a maximum of 30 minutes after the timeslot has ended. A delayed submission will lead to no points being awarded for this mission element. Maximum points are awarded for the team with the longest horizontal track and reduced points for all following teams according to the following table:

Track length	S_1
Longest track	4
Second longest track	3.5
Third longest track	3
Fourth longest track	2.5
Fifth longest track	2
Sixth longest track	1.5
Seventh longest track	1
Eight longest track	0.5
All further teams	0

2) **Inspect geographic characteristics (mapping and identification):**
In this mission element, teams will have to locate four apriori known objects on the ground and create an ortho map with which the track of the hikers can be reconstructed. The map has to be handed to the judges no later than 30 minutes after the end of the mission time via a USB stick labeled with the team name. Failure to comply with the submission time will lead to zero points being awarded for this mission element.

The resolution of the map/photo is not taken into account for the scoring, but objects should be identifiable. The known objects on the ground are used to reconstruct the path of the hikers and therefore not only the identification but also the track between the objects has to be visible on the map. (*e.g. if the objects to be identified lie on a street, the entire street from the first object to the last object has to be visible to achieve maximum points*).

An object is counted as detected when the object's position is located within 10 m of its correct location and is provided in decimal latitude and decimal longitude coordinates to the judges. Additional points are awarded for the longest connected track between object locations.

$$S_2 = \frac{(number\ objects\ found + \max(connected\ track))}{2}$$

The objects on the ground will be four blue rectangular plates with the dimensions 1 m x 1 m

3) **Dynamic Inspection of identified potential locations and finding missing groups (dynamic mission planning):**
In this mission element, four waypoints have to be reached in an apriori unknown waypoint sequence. Upon arrival of the task-designated drone at the tasks start/end waypoint, the judge will hand out a waypoint list on paper consisting of four waypoints in the format [decimal Latitude, decimal Longitude, altitude above start point] which have to be flown over. To check whether the waypoints have been successfully overflown, a CSV log file has to be submitted to the judges in the format **[UTC time incl. seconds (Format YYYY-MM-DDTHH:MM:SS.sss) , decimal Latitude, decimal Longitude, altitude above start point]** a maximum of 30 minutes after the timeslot has ended via a USB stick labeled with the team name. A delayed submission will lead to no points being awarded for this mission element. A waypoint counts as successfully overflown when the maximum distance between the 3D waypoint and the drone is less than 10 m. The mission time $time_2$ will be extracted from the log file in seconds and will start once the start waypoint is reached and end once the end waypoint is reached. No negative points will be awarded in this mission element. The speed with which the waypoint is overflown does not affect the scoring but must comply with security and safety regulations.

$$S_3 = succesfull_{waypoint} - 4 \cdot \frac{time_2(sec)}{240}\ or\ \min(0)$$

The average horizontal track length is about 1400 m.

Coordinates of start/end waypoint: Lat: 50.910595° Lon: 6.227356°

4) **Identify the health state and quantity of hikers (object recognition):**
In this mission element, the task is to fly to a known position and identify the number and state (lying on the ground, standing, sitting) the hikers are in. The hikers will be positioned in open and covered locations near the known position. Points are reduced for incorrect state estimation. No overall negative points will be awarded in this mission element. The state and number of detected persons has to be communicated to the judges during the competition slot. For each detected Hiker proof (eg. picture from onboard camera) has to be shown to the judges including proof for automatic pose detection for full autonomy points.

$$S_4 = 0.5 \cdot detected\ person + 0.5 \cdot correct\ state$$

The hikers will be mannequins without a heat signature (see Appendix Figure 4).

Coordinate of known position: Lat: 50.909228° Lon: 6.226700°

5) Aerial support for the rescue force (dynamic flight speeds)

In this mission, a MAV has to follow a rescue and assist the rescue team vehicle marked with an ArUco marker(see Figure 2) at an altitude of at least 5 m above the vehicle. The vehicle waits at the given position marked "D" in Figure 1 and starts driving once the team leader gives the command. Following the drive command, the rescue vehicle will drive on a pre-designed track with speeds ranging from 5 m/s to 15 m/s. Points are only awarded while the rescue vehicle is in motion. Teams will submit a CSV log file to the judges in the format **[UTC time incl. seconds (Format YYYY-MM-DDTHH:MM:SS.sss), decimal Latitude, decimal Longitude, altitude above start point]** a maximum of 30 minutes after the timeslot has ended via a USB stick labelled with the team name. A delayed submission will lead to no points being awarded for this mission element. External aids can be attached to the car immediately before the competition slot. According to the log files of the vehicle and MAV, points will be awarded as follows:

$$S_5 = \frac{\left(\frac{t_5}{16}\right)^2}{360} \; or \; \max(4)$$

A maximum of 4 points can be awarded in this mission element.

t_5 represents the maximum time in [s] the MAV flies horizontally closer to 15 m of the vehicle. t_5 will be paused if the maximum horizontal distance of 15 m is exceeded.

Starting coordinates of the rescue vehicle: Lat.: 50.910031°; Lon.: 6.226726°

3.7 Performance Scoring

Level of autonomy A_n:

The level of autonomy describes how a MAV is operated in order to fulfill the mission elements. For each mission element, the factor associated with the autonomy level is used to compute the mission score. The teams have to announce the intended MAV and autonomy level before the flight. The jury will decide which level of autonomy the team's MAV used.

Autonomy Level	A_n
Line of sight	0
Remote piloted through video link, no line of sight flying allowed	1
Autonomous flight control: Flight is controlled autonomously but the operator is still controlling mission aspects, e.g., commanding mission changes, control of payload, processing perception, and decision-making.	4

Autonomous mission control: 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	5
External aids Using visual markers, beacons, etc. (Except the essential ones provided by the IMAV2023 organization)	*/2* (will be divided from $\boldsymbol{A_n}$)

Timeslot usage time T_{Slot}:

The timeslot usage time rewards teams, which can set up and successfully fulfil their mission quickly. The time starts with the beginning of the timeslot and ends as soon as the last drone has landed or the assigned competition slot time is reached. For each started minute, one point is awarded. (e.g. $T_{slot} = 12\,min\,and\,20\,sec \rightarrow T_{slot} = 13$)

$$5\text{ min} < T_{slot} \leq 20\text{ min}$$

Design factor D_n:

The design factor is introduced to reward teams with self-made designs of their aircraft system. The jury will decide on this individually.

Type of Design	Factor D
Commercial aircraft design	*1*
Self-made aircraft frame	*2*

Precision factor P_n:

The Precision factor takes into account how precise and reliable a MAV can start and land.

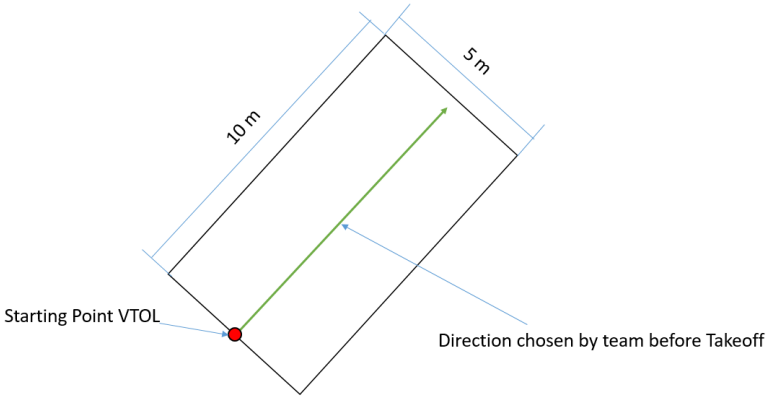
Type of Landing	VTOL	Fixed wing	Factor P
Rough operation	Start and land in the take-off area but MAV is not airworthy due to a rough landing	Start and land in the take-off area but MAV is not airworthy due to a rough landing	*0.5*
Normal operation	Start and land in the take-off area	Start and land in the take-off area	1
Precise operations	Start and land from a platform	Start and land inside the precision area	2

An operation is only valid if both start and landing have been conducted according to the operations criteria. If a criterion is not met, the precision factor is reduced to a lower level. MAVs performing VTHL (vertical take-off, horizontal landing) or similar are also entitled to precise operations.

Points are awarded for the spot at which the MAV is fully stopped. In the case of a rough landing, the team may be asked to demonstrate the airworthiness of the (remaining) vehicle. Points are awarded for the airworthy part of the MAV, located in the landing zone, only (*e.g. if a fixed wing loses a small part of a wing during landing, and the wing by chance ends up in the middle of the landing zone while the airworthy part of the MAV is outside the landing zone, no points are awarded*).

Platform: Teams using a VTOL can start and land from a platform. The circular platform has a diameter of 1.5 m. ArUco markers and GPS coordinates will be provided. The platform will be lying flat on the ground. If the designated landing gear of the MAV is fully inside the platform borders, points for a precision landing will be awarded. (*e.g. if a quadcopter flips over on the platform or tips over in a way that it touches the platform and is still airworthy, no points for a precision landing are awarded)*

Precision area: Teams using a fixed-wing aircraft can start and land in a separate precision area. This area is a 5 x 10 m rectangle (example in figure below)



A start counts as precise if the MAV can perform a controlled steady climb inside the precision area. Hand-launched MAVs have to be launched in the precision area. Run-up can be performed outside the precision area. For the landing, the aircraft must not touch the ground outside the precision area at any time.

4. Appendix

4.1 ArUco marker

The ArUco marker for the aerial support mission is depicted in the following figure. The marker will be 1m x 1m and mounted on a vehicle.

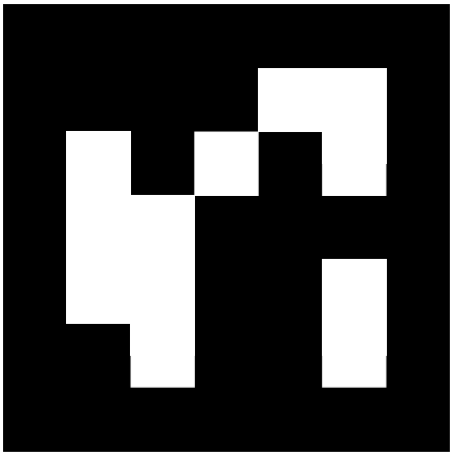


Figure 2: ArUco marker for aerial support mission (5x5 ID 700)

The ArUco marker for the precision landing is depicted in the following figure. The marker will be 20 x20 cm.

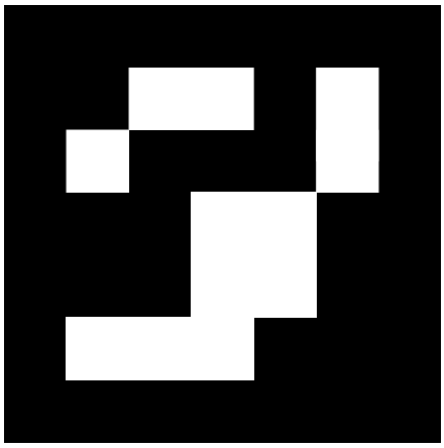


Figure 3: ArUco marker for precision landing (5x5 ID 800)

4.2 Missing Hikers

More pictures of the missing hikers are published at the imav2023 website.

Figure 4: Missing Hiker