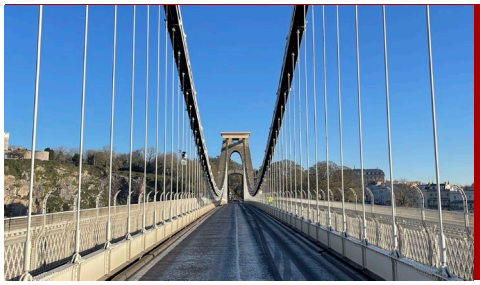

IMAV 2024

University of Bristol
September 16th-20th

Micro Aerial Vehicles Competition
Combined Competition Rules

Changelog:

Version	Changes	Author
1.4	Draft version circulated	T.Richardson
1.5	Updated draft	T.Richardson
1.6	Updated draft	T.Richardson
1.7	First version issued	T.Richardson

Contact Details:

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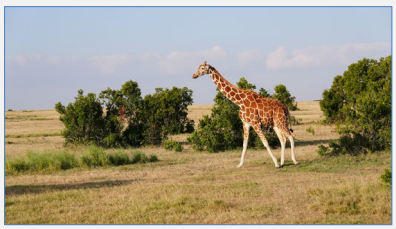
- Conference organiser: thomas.richardson@bristol.ac.uk
- WildDrone website, conference co-hosts: https://wilddrone.eu/

University of BRISTOL · WILDDRONE · BRISTOL ROBOTICS LABORATORY · Bristol Flight Lab

Competition Theme: Nature Conservation


Ol Pejeta Conservancy, Kenya, 2023: https://www.olpejetaconservancy.org/

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Indoor Competition

Outdoor Competition

Please Note

1. Introduction

This document provides the combined information for both the indoor and outdoor IMAV 2024 competitions. Besides general remarks and a schedule, it gives a detailed description of the competition areas, the mission elements, and the scoring rules. For IMAV 2024, the competitions will be supported by the WildDrone team and will have a conservation theme. https://wilddrone.eu/

The **indoor competition** focuses on precise operation in an unknown environment. The main challenges for this competition are:

- Precise MAV operations in unknown environments.
- MAV physical interaction with the environment.
- Autonomous operations.

The **outdoor competition** focuses on conservation support operations using drones in an unknown environment. The main challenges for this competition are:

- Aircraft performance and information-gathering.
- Real-time mission planning.
- Autonomous operations.

Schedule and dates	
Initial Team Expression of Interest:	**31st May 2024**
Final Registration:	**10th July 2024**
Practice Date for both Competitions:	**Monday 16th September 2024**
Outdoor Competition Date:	**Tuesday 17th September 2024** (Wednesday 18th bad weather backup option)
Indoor Competition Date:	**Wednesday 18th September 2024** (If the outdoor competition moves to the Wednesday, the indoor competition will move to the Tuesday)
Conference Dinner:	**Wednesday 18th September 2024**
Paper Presentation Sessions:	**Thursday 19th and Friday 20th September 2024**

2. Safety and Security Requirements

For safety and security details see the latest version of the *IMAV 2024 safety regulations document* which is published on the website (https://2024.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 will need to demonstrate that all MAVs can sustain the security and airworthiness check. For the outdoor teams, this ideally takes place on the practice day.

For the outdoor competition, even if the MAV performs all the challenges automatically, the pilot/operator must be operating within VLOS, be observing the aircraft and be ready to take manual control if required at any point.

3. Indoor Competition

3.1 Location - Indoor

This year's indoor competition will be held at the Bristol Robotics Laboratory in Bristol, UK.

Address: **Bristol Robotics Laboratory,**
University of the West of England, T Block
Frenchay Campus, Coldharbour Lane
Bristol, BS16 1QY, United Kingdom

https://www.bristolroboticslab.com/

BRISTOL ROBOTICS LABORATORY

Figure 1: Bristol Robotics Laboratory

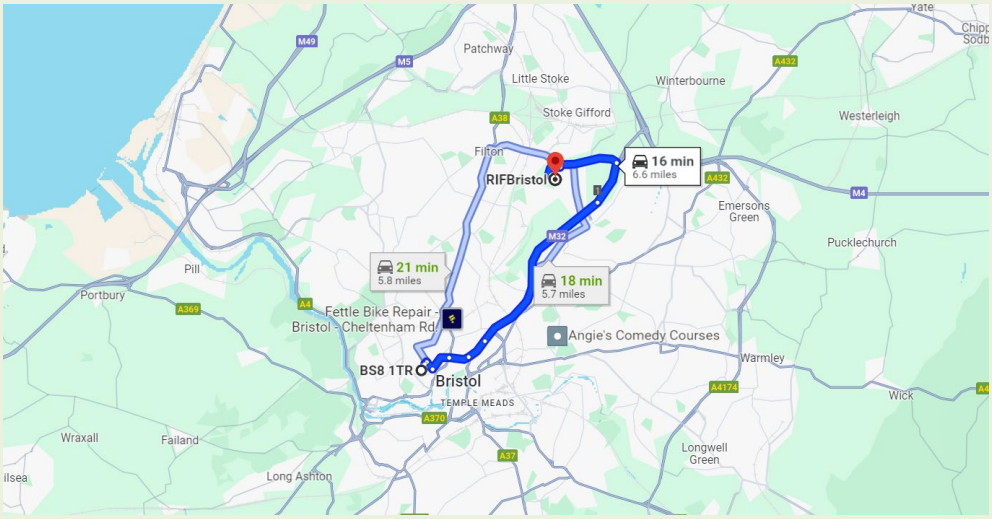

Figure 2: BS8 1TR University of Bristol, to BRL, BS16 1QY, ~20 minutes (no traffic)

3.2 Practice Day - Indoor

On Monday, 16th of September 2024 a practice day will be on offer. 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 whether they want to attend the practice day.

3.3 Competition Slot - Indoor

Each team will be assigned a time slot to set up their equipment, prepare the flights, 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.

The order of the teams' slots will be drawn by lot on the morning of the competition 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.

Should a person need to enter the flight area, all MAVs must land and stop motors before they enter.

The competition timeslots for the indoor autonomy missions are 25 minutes per team.

3.4 Indoor Competition Details

The competition this year focuses on MAV tasks that could be used to support *conservation operations*. There is a circuit to be flown around in which there are several tasks to be performed, each of which will generate points for the team. Note that the arena will be decorated with a conservation theme.

Only one MAV may be in the air at one time carrying out the tasks, however this vehicle may be replaced by a team should they wish to do so. There is a strong emphasis on autonomy within the marking scheme, and teams are encouraged to fly as much of the mission automatically as possible. The Tasks within the circuit are as follows:

- **Task 1:** Take-off automatically and transition to the first task zone. A blue tape (width 19 mm) will be on the ground marking the whole circuit. Capture an image of a screen located at 1.5 metres above the ground. This screen will be displaying a wildlife image which must be positively identified by the team at the end of the circuit.
- **Task 2:** Progress to the second task zone passing through a choice of gates. There will be three gates to choose from located above each other: 100 cm clearance, 50 cm clearance and 25 cm clearance. There will be 50 cm ground clearance below the three gates.
- **Task 3:** Progress to the fourth task zone and land on a choice of three different zones. These will be of three different sizes: 50 cm across, 35 cm across and 20 cm across, all located 1 metre above the ground. Motors must be stopped to indicate a successful landing.
- **Task 4:** Progress to the third task zone, collect a wildlife sample and deposit within the adjacent collection box.
- **Task 5:** Transition to the starting point and land automatically, either returning through a clear acrylic window or a free-return path.
- Teams may repeat the circuit multiple times within the 25 minutes to maximise their points.

Teams may choose to pass on tasks they are unable to complete.

Additional notes for indoor competition teams:

- Following the blue tape is optional since it only serves for navigation purposes.
- ArUco markers are positioned at the task locations, and all will have a size of 15x15 cm except for the ArUco markers on the raised landing platforms which will be 10x10 cm.

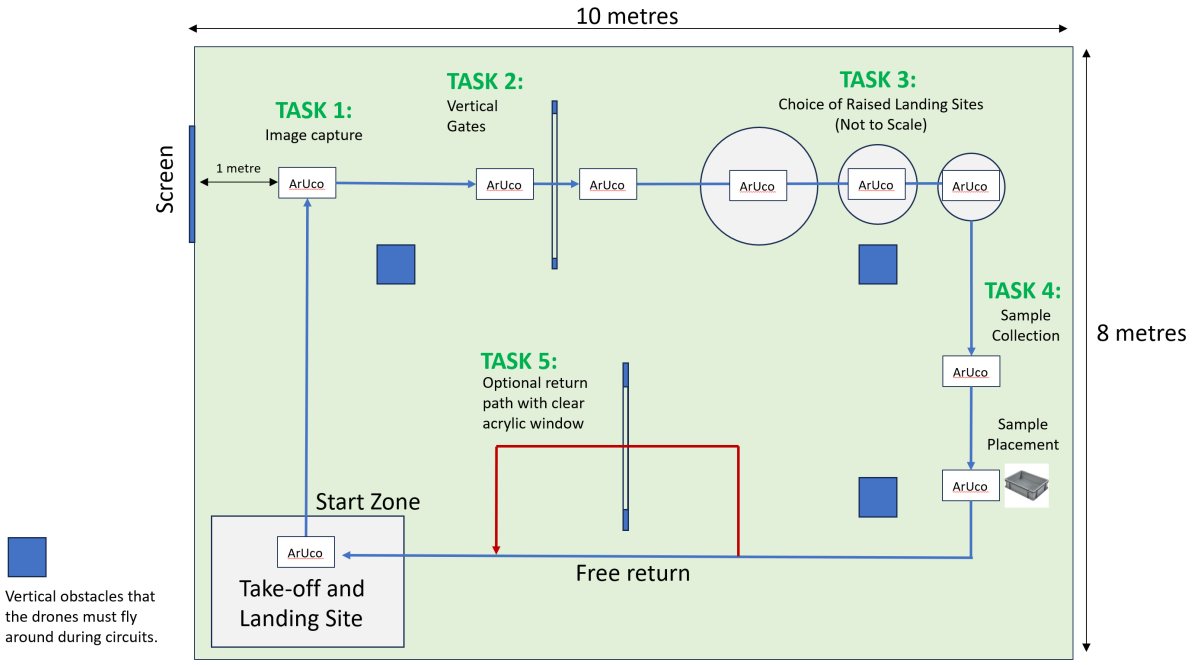

Figure 3: Indoor Competition Circuit

Start zone.

At the beginning of the competition, the MAV must be placed in the start zone. The take-off and landing point will be identified with the ArUco 5x5 ID 100 marker.

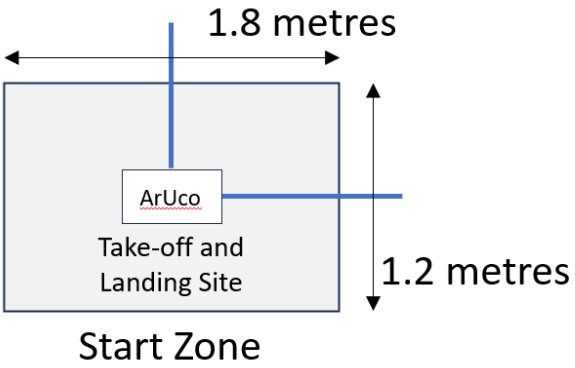

Figure 4: Start Zone/Take-off area in the Indoor Flight Arena

Task 1: Take-off automatically and transition to the first task zone. A blue tape (width 19mm) will be on the ground marking the complete circuit. Capture an image of a screen located at 1.5 metres above the ground. This screen will be displaying an image which must be positively identified by the team at the end of the circuit. The identification of the image is not expected to be automated.

The screen with the image on it will be a Dell Ultrasharp U3219Q monitor with a 5 cm red border. The image capture point will be identified with the ArUco 5x5 ID 105 marker on the ground.

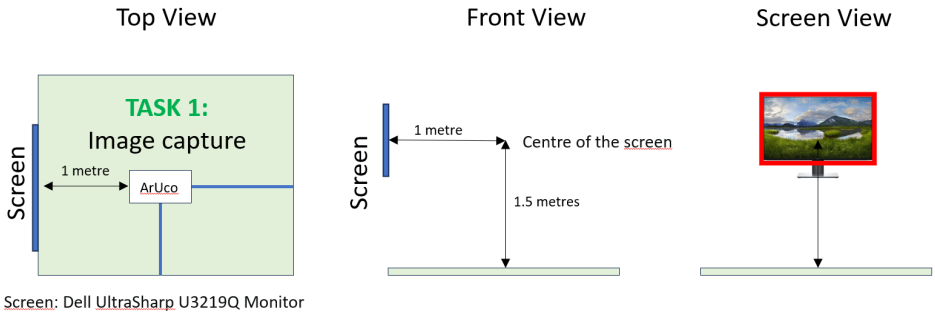

Figure 5: Task 1: Image Capture

Task 2: Progress to the second task zone passing through a choice of gates. There will be three gates to choose from located above each other: 100 cm clearance, 50 cm clearance and 25 cm clearance. There will be 50 cm ground clearance below the three gates.

The Gates will be identified with the ArUco 5x5 ID 200 marker 50 cm before the gates and the ArUco 5x5 ID 205 marker 50 cm after the gates, on the ground and in line with the centreline. All gates will have a 5 cm red border around them.

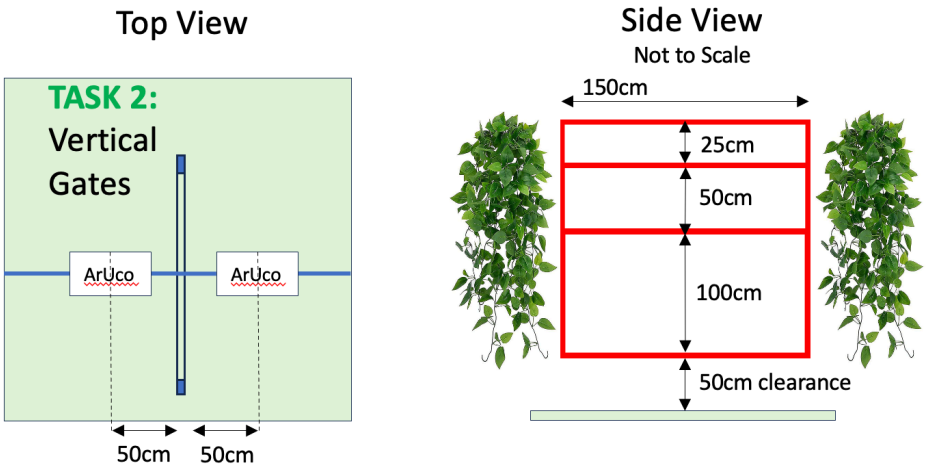

Figure 6: Task 2: Flight Restriction

Task 3: Progress to the third task zone and land on a choice of three different zones. These will be of three different sizes: 50 cm across, 35 cm across and 20cm across, all located 1 metre above the ground. Motors must be throttled down to indicate a successful landing.

The 50 cm, 35 cm and 20 cm landing sites will be identified with the ArUco 5x5 ID markers 300, 301 and 302 respectively. These will be 10 cm by 10 cm in size.

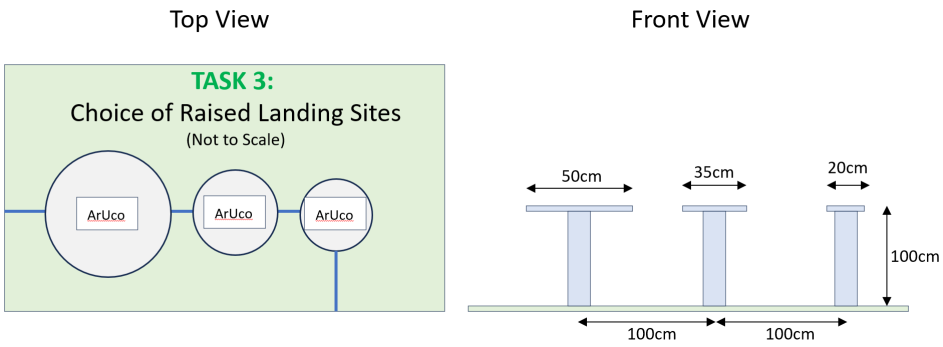

Figure 7: Task 3: Raised Landing Sites

Task 4: Progress to the fourth task zone, collect a wildlife sample and deposit within the adjacent collection box.

For the purposes of the task, the default wildlife sample will be a cone from IMAV 2023. See later section for a picture of this cone that will be provided by the IMAV2024 organising team.

NOTE: Teams may propose their own 'sample' for this part of the challenge. This 'sample' may be of any size and shape but must be a physical object with no electronics and no active component.

There will be one sample available for each circuit, placed 40 cm after the point identified with the ArUco 5x5 ID 400 marker. The sample will then need to be deposited in a standard 10 L Euro Container identified which will have an ArUco 5x5 ID 405 marker. The sample will be returned to the collection point at the start of each circuit by a member of the IMAV2024 team.

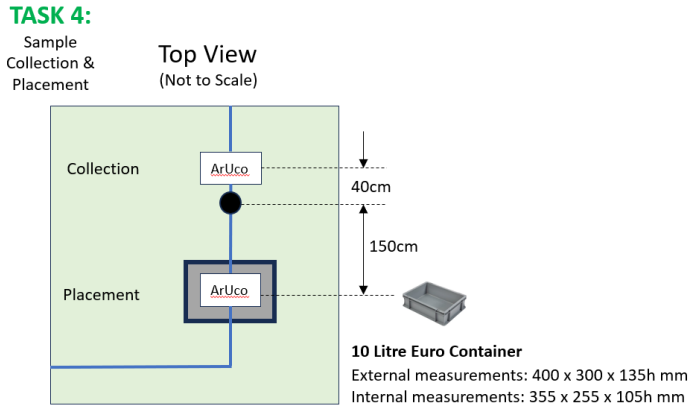

Figure 8: Task 4: Sample Collection and Placement

Task 5: Transition to the starting point and land automatically, either returning through a clear acrylic window or a free-return path.

The optional return path will be designated with a red tape (19 mm) and will take the team through a 100 cm-by-100 cm clear acrylic window which will be set at an undefined height from the ground. This window height may be varied between circuits and will not be clearly identifiable visually.

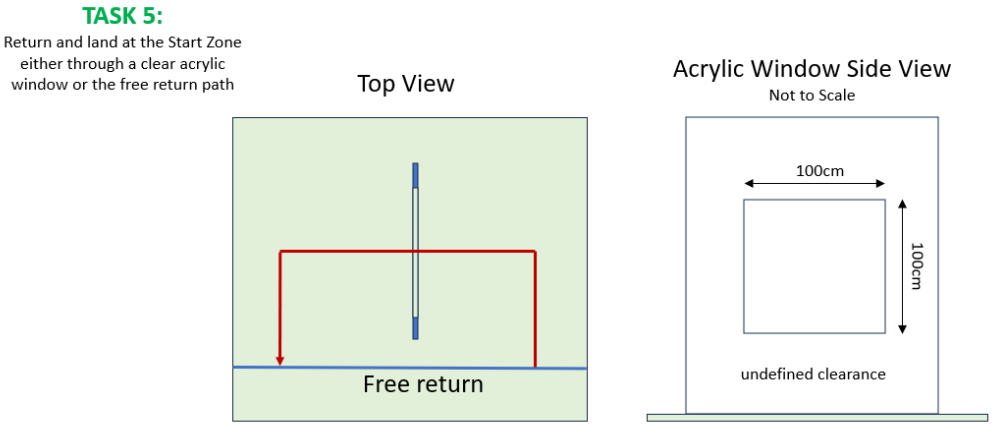

Figure 9: Task 5: Return and Land with Optional Clear Window Path.

3.5 Scoring – Indoor competition

Total score

During the competition slot, teams will be allowed to have repeated attempts at the circuit, each time attempting the tasks they choose. The team will only be allowed to score marks for each task once during each circuit. The score of a team will be the cumulative score from all the circuits carried out within the allotted time. Each circuit must start from the take-off and landing site. The final score for a team will be determined using the following formula:

$$S = \left[\sum (T_1A_1 + T_2A_2 + T_3A_3 + T_4A_4 + T_5A_5) \cdot D_n\right]$$

T_1: image identification.

T_2: MAV gate pass through.

T_3: raised platform landing.

T_4: score for sample collection and placement.

T_5: return home and landing.

Task 1: Image Identification T_1

The participating team must correctly identify the image for the IMAV2024 adjudicator at the end of the circuit.

Image Identification	T_1
No image identified by the team	0
Image identified correctly by the team	3

Task 2: MAV Gate Pass Through T_2

The participating team may choose to pass through either of the three openings, or bypass during the circuit.

Gate Pass Through	T_2
Bypass the gates	0
Pass through the 100 cm high gate	1
Pass through the 50 cm high gate	3
Pass through the 25 cm high gate	5

Task 3: Raised Platform Landing T_3

The participating team must attempt a landing on only one of the raised platforms per circuit. On landing, the motors must be powered down to the satisfaction of the IMAV2024 adjudicator before the drone takes off again.

Raised Platform Landing	T_3
No landing	0
Successful landing on the 50 cm diameter platform	1
Successful landing on the 35 cm diameter platform	3
Successful landing on the 20 cm diameter platform	5

Task 4: Sample Collection and Placement T_4

Sample Collection and Placement	T_4
No collection or placement	0
Successful collection	3
Successful collection and deposit in the container	5

Task 5: Return and landing in the Start Zone T_5

Return to Home and Landing in the Start Zone	T_5
Free return home and landing	2
Return through the clear acrylic window and landing	5

Level of autonomy A_n:

The level of autonomy describes how a MAV is operated to fulfil the mission elements. The teams have to announce the intended MAV and autonomy level before the flight. The IMAV2024 adjudicators will confirm at the end of each circuit the level of autonomy that has been used for each task.

Autonomy Level	A_n
Line of sight or piloted through a video link/FPV.	1
For each task that is carried out with elements of autonomy such as path following but requiring some manual intervention an Autonomy level of 10 will be awarded.	10
For each task that is carried out fully automatically an Autonomy level of 20 will be awarded. Autonomous mission control: All aspects of the task are automated. Typically, the operator does not touch the controls: hands-off control.	20

Design factor D_n:

The design factor is introduced to reward teams with the self-made design of their aircraft system. The IMAV2024 adjudicators will decide on this individually.

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

3.6 Sample Cone

The standard cones for the indoor IMAV2024 competition will be provided at 30 g. The final designs can be found as 3-D printable files at https://2023.imavs.org/index.php/indoor-competition including printing instructions.

NOTE: Teams may propose their own 'sample' for this part of the challenge. This 'sample' may be of any size and shape but must be a physical object with no electronics and no active component.

Teams must notify the organisers of their chosen sample design when registering their teams.

The cone will be able to be lifted by a strong magnet. Teams can modify the cones after consultation with the organizers and can fix a physical loop or other such attachment point to the top of the cone.

Figure 10: Picture of the 30 gram Cone.

3.7 ArUco 5x5 ID Examples

Figure 11: ArUco ID 100; 105; 200; 500.

Reference: https://chev.me/arucogen/

4. Outdoor Competition

4.1 Access to the Outdoor Test Location

For the outdoor flight test access will only be possible during IMAV on Monday, Tuesday and (Wednesday if judges decide to postpone due to weather) from 9.00 am – 5.00 pm.

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

Note: All Micro Air Vehicles (MAVs) that take part in the outdoor competition must be under 4 kg take-off mass. MAVs can be fixed wing or multirotor.

There will be **two categories** for the competition, pure multirotor and those that undertake the performance challenge in a pure fixed wing mode.

For safety and regulatory reasons, no motors are to be started outside the flight area on the practice day as well as on the competition day (except motors without propellers attached).

There is a strong emphasis on autonomy within the marking scheme, and teams are encouraged to fly as much of the mission automatically as possible. The Tasks within the circuit are as follows:

4.2 Setting

The outdoor location in Bristol, UK has recently been set up as a wildlife preserve. The reserve is keen to use the latest in drone technology to monitor and gather information on the animals that are present on the site. Your team has been asked to do the following:

- **Task 1**: To perform 3 circuits for which the efficiency of your aircraft will be calculated.
- **Task 2:** To carry out an automated search of a given area identifying how many animals are present.
- **Task 3:** The location of three animals will then be given to you, and you are to automatically capture clear images of each animal.
- **Task 4:** You will then be given an alternate location where the adjudicator team would like to install a camera trap. You are to autonomously deploy the camera trap.

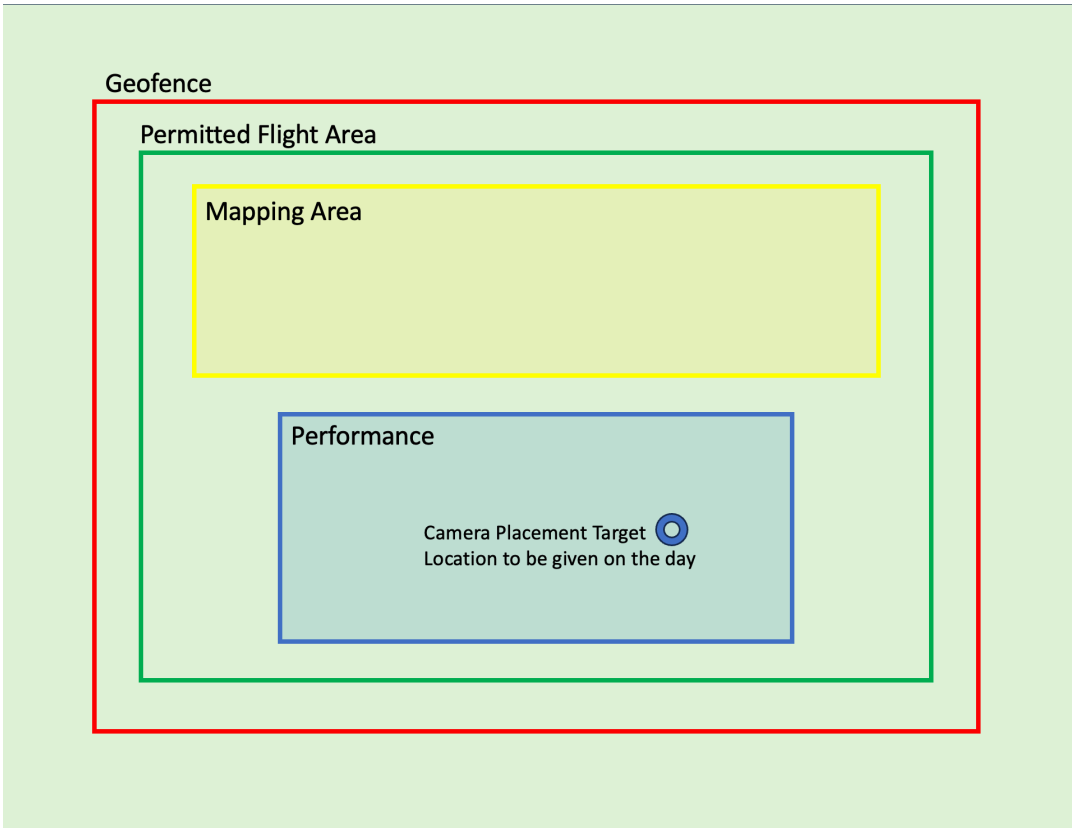

Figure 12: Outdoor Competition Schematic

Coordinates

The following coordinates will be provided to teams one month before the competition. All locations will be within 500 metres of the take-off location:

- Geofence coordinates (red outline)
- Permitted flight area coordinates (green outline)
- Mapping area (yellow area)
- Performance circuit (blue outline)
- The co-ordinates for the camera placement points
- Take-off and landing site

4.3 Practice Day - Outdoor

On Monday the 16th of September 2024 a practice day will take place from 9.00 am to 5.00 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.

4.4 Competition Slot

Each team will be assigned a time slot to set up their equipment, prepare their flight, fly for 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: **25 minutes** per team.

Note that it is the responsibility of each team to make sure that all communications and data links are operating on allowable frequencies and power levels for the UK.

4.5 Scoring - Outdoor

The scoring formula is designed to award efficient and fully autonomous information gathering with the final overall score determined using the following formula:

$$S = \sum_{n=1}^{4} S_n \cdot A_n \cdot D_n$$

S_n: is the score each team receives for each of the given four tasks.

A_n: is linked to the level of autonomy that the team is operating at.

D_n: is linked to the design of the MAVs used, i.e. COTS or self-made aircraft frame.

4.6 Mission Task Score

A single MAV must attempt the first two tasks without landing. Each may be attempted 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 task 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 conservation can be absolved during the competition.

- Task 1: Flight to the Search Area (efficiency): In this mission element, the task is to fly as efficiently around a given circuit. Note that this task must be combined with Task 2, the animal survey. Points are awarded for the most efficient three continuous circuits (no break between the three). To check whether the course has been successfully flown, a CSV log file from the task designated MAV has to be emailed to the judges 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, current, voltage]** a maximum of 30 minutes after the timeslot has ended.
- Data must be recorded at a minimum of 5 Hz. Note that the IMAV2024 adjudicating team may choose to re-charge your battery post flight to check the calibration of your current sensor.
- A delayed submission will lead to no points being awarded for this mission element. Maximum points are awarded for the team with the most efficient circuits as defined by *Mass (kg)/Total Energy Used (watt-hours)* and reduced points for all following teams according to the following table:

Mass (kg)/Total Energy Used (watt-hours)	S_1
Most efficient	8
Second most efficient	7
Third most efficient	6
Fourth most efficient	5
Fifth most efficient	4
Sixth most efficient	3
Seventh most efficient	2
Eighth most efficient	1
All further teams	0

- Task 2: Animal census (mapping and identification): In this task, teams will have to search a given area and locate as many animals as they can within the area, creating an ortho map to identify where these are. The map has to be emailed to the judges no later than 30 minutes after the end of the mission time. 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 the animals should be identifiable. An animal is counted as detected when it is located within 10 m of its correct location and is provided in decimal latitude and decimal longitude coordinates to the judges.

$$S_2 = \frac{(Number\ of\ Animals\ Found)}{2}$$

See later this in this document for details of the animals.

- Task 3: Dynamic imaging of animals: In this task, four waypoints have to be reached in an a priori 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 way-points 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 emailed 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.
- **Photos** must also be sent of the animals which are clearly identifiable. A delayed submission will lead to no points being awarded for this task. A waypoint counts as successfully overflown when the maximum distance between the 3D waypoint and the drone is less than 20 m. 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.

$$S_3 = No.of\ successful_{waypoints}$$

- Task 4: Place a camera trap at a specified ground location: In this mission element, the task is to fly to a given position and deposit/place a camera trap. For the purposes of this task, the camera trap will be represented by the cone detailed later in these rules. This location will consist of a single point in the format [decimal Latitude, decimal Longitude, altitude above start point] where the camera trap needs to be placed. The placement location will also be marked with an ArUco 5x5 ID 100 marker 15cm by 15cm.
- Points are awarded for accuracy of the camera trap placement relative to the given location.

Camera trap placement	S_4
Closest to the target location	8
Second closet	7
Third closest	6
Fourth closest	5
Fifth closest	4
Sixth closest	3
Seventh closest	2
Eighth closest	1
All further teams	0

4.7 Performance Scoring

Level of autonomy A_n:

The level of autonomy describes how a MAV is operated in order to fulfill each individual task. For each task, 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 IMAV2024 adjudicators will decide which level of autonomy the team's MAV used.

Autonomy Level	A_n
Line of sight or piloted through a video link/FPV.	1
For each task that is carried out with elements of autonomy but requiring some manual intervention such as for the animal identification, an Autonomy level of 5 will be awarded.	5
For each task that is carried out fully automatically an Autonomy level of 20 will be awarded. Autonomous mission control: All aspects of the task are automated. Typically, the operator does not touch the controls: hands-off control.	20

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*

In the case of a rough landing, the team may be asked to demonstrate the airworthiness of the (remaining) vehicle. Points are only awarded for an element if the vehicle is still airworthy at the conclusion of the element. All take-offs and landings must be completed within the pre-defined take-off and landing area.

Hand-launched MAVs have to be launched from within the take-off and landing area. The area can be used for a fixed-wing, undercarriage-based take-off and landing, however it should be noted that it is likely to be a grass runway.

4.8 Animal Markers

Top-down images of zebra will be used for the animal census. The marker will be approximately 2.0 m x 0.7 m and placed on the ground. There will be a maximum of 10 animals to locate.

Figure 13: Examples of Top-down Images of Zebra for the Census Task: © Yauheniya Piatrouskaya

4.9 Camera Trap Placement

The ArUco marker for the precision placement of the camera trap is depicted in the following figure. The marker will be 10 x 10 cm.

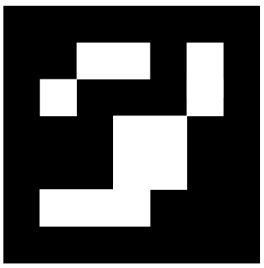

Figure 14: ArUco Marker for Precision Placement of the Camera (5x5 ID 800)

4.10 Camera Trap

The camera trap for the placement Task 4 at IMAV2024 will be represented by a stacked weighted cone and will only be provided in one total weight, 200 g. The final designs can be found as 3-D printable files at https://2023.imavs.org/index.php/indoor-competition including printing instructions. On the practice and on the competition day cones will be provided by the organizers.

The cone will have a small loop attached to it. Teams can modify the cones after consultation with the organizers to modify this attachment point.

Figure 15: Stacked Cones with Dummy Weight Between (200 g)

Competition Theme: Nature Conservation

WildDrone, Kenya, 2023