



Category D2 Challenge Booklet 2023

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SAFMC 2023 CAT D2 CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	16 Nov 2022	Official challenge booklet release

SAFMC 2023 COMPETITION SCHEDULE

Date*	Event	Platform/Venue
6 March 2023	Team Challenge video submission	Email
20 - 29 March 2023	Presentation	Challenge day
20 – 29 March 2023	Category Challenges	Science Centre Singapore
1 April 2023	Awards Presentation Ceremony	Science Centre Singapore

** The competition schedule is subject to changes in accordance to the latest MOE guidelines for COVID-19. Any changes will be updated on the SAFMC Website and Facebook. Registered participants will be informed via their registered email address.*

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SINGAPORE AMAZING FLYING MACHINE COMPETITION 2023

1. INTRODUCTION

Singapore Amazing Flying Machine Competition (SAFMC) is an exciting and unique event organised by DSO National Laboratories and Science Centre Singapore, and supported by Ministry of Defence (MINDEF). Open to all schools and participants who are keen to explore the science behind flight and create their very own flying machines, this annual competition promises a fun-filled learning journey with special talks, workshops and live demonstrations.

2. CATEGORIES

CATEGORY A – PAPER PLANES *(Primary Schools)*

Each team should consist of TWO (2) to THREE (3) members.

Design and fold paper planes to achieve the longest, farthest or most unique flight.

CATEGORY B – UNPOWERED GLIDERS *(Secondary Schools / Integrated Programme)*

Each team should consist of TWO (2) to FIVE (5) members.

Category B will be open to a maximum number of 150 registered teams.

Design and build small unpowered bungee-launched gliders to achieve the farthest and most precise flight.

CATEGORY C – RADIO CONTROL FLIGHT / FIRST PERSON VIEW (FPV) FLIGHT (NOVICE, ADVANCED)

Category C1: Radio Control Flight - Fixed Wing *(Secondary Schools / Integrated Programme / Junior Colleges / Institute of Technical Education)*

Each team should consist of TWO (2) to FIVE (5) members.

Design and build a small remote-controlled fixed-wing air platform to navigate an obstacle course.

Category C2: FPV Flight – Novice *(All Schools)*

Each team should consist of ONE (1) to TWO (2) members.

Bring, or design and build, a ducted (shielded propeller) FPV drone to compete in an obstacle course.

Category C3: FPV Flight – Advanced (All Schools)

Each team should consist of ONE (1) member.

Bring, or design and build, a FPV drone to compete in an obstacle course.

CATEGORY D – SEMI-AUTONOMOUS / AUTONOMOUS (*Polytechnics / Universities*)

Category D1: Semi-Autonomous

Each team should consist of TWO (2) to FIVE (5) members.

Design and build up to three semi-autonomous small air platforms, controlled using wearables, to perform a multitude of tasks in an indoor course.

Category D2: Autonomous

Each team should consist of TWO (2) to FIVE (5) members.

Design and build two or three autonomous small air platforms to collaboratively perform a multitude of tasks in an indoor course.

CATEGORY E – SWARM (*Open to Public*)

Each team should consist of TWO (2) to TEN (10) members.

Bring, or design and build, a swarm of TEN (10) to TWENTY-FIVE (25) drones to compete in a search-and-rescue mission.

3. GENERAL SAFMC 2023 RULES

- The deadline for registration is **24 February 2023**.
- Participants registered under a school must be a full-time student at the point of competition.
- Home-schooled participants and teams consisting of participants from different schools should be registered as “Independent teams”.
- Participants will be notified upon successful registration within two weeks of the registration deadline. The decisions made by the SAFMC organising committee are final, and are subjected to the competition schedule and availability of logistics support.

- Each person can only participate in one team within a category. However, the person can participate as a member in different categories, i.e. a person can be a member of a team in Category B and another team in Category C but the person cannot be a member for two teams in Category B.
- Teams are allowed to take part in categories beyond the specified educational level, i.e. Primary school students are allowed to take part in Category B, C, D or E. Secondary school students are allowed to take part in Category C, D or E.
- Participants of Category C1 are also eligible to register for either Category C2 or C3 but not both.
- Participants of Category C2 are not eligible to participate in Category C3 and vice versa.
- Participants of Category D1 are also eligible to participate in Category D2 and vice versa.
- Members and family members of the organising committee are not allowed to participate in the SAFMC.
- The organisers reserve the right to amend the rules and regulations. In the event of changes, all teams will be informed at least FOUR (4) weeks prior to the start of the competition.
- Prizes will be issued to the Team Manager.
- A safety perimeter net will be set up at the competition field for Categories A, B, C, D, and E. There will be a top net approximately EIGHT (8) meters above the ground, which will limit the maximum flight altitude of flying machines. During the challenge attempts, teams are strongly encouraged to fly their aircraft away from the netting to avoid accidental entanglement.
- The organisers of SAFMC 2023 will not be held responsible for any damage to or the loss of any flying machine(s) throughout the entire competition.
- Participants are responsible for the safe flying of their flying machine(s) for the duration of the entire competition. The organisers reserve the right to ground the flying machine(s) of any team at any point in the competition.

- For queries regarding the competition, please send an email with the title stating the category in question (e.g.: [CAT C1] - Clarification about task locations) to the following email address: SAFMC@science.edu.sg

4. FORMAT OF COMPETITION

Once the teams have confirmed their registration for the competition, they are expected to start work on the different aspects of the competition, which consists of the Challenge and the Presentation.

Teams are encouraged to provide equal attention to both the Challenge and the Presentation aspects of the competition.

The top team from each category will be presented with the Championship Award at the SAFMC 2023 Awards Presentation Ceremony.

4.1 PRESENTATION

The teams will be allocated a specific time slot to showcase their flying machine physically during their Challenge day. Teams will present their flying machine design and learning journey in this competition to a panel of judges. These teams will be assessed for a number of awards.

The presentation plays an integral part for teams who wish to compete for the SAFMC Championship Award. Teams that do not show their flying machines during the presentation may be disqualified immediately. The requirements for the Presentation segment will be detailed in Section 8.

The Chief Referee or Judge for each category reserves the right to deduct points if the flying machines used in the Challenge are drastically different from the flying machine presented at the Presentation.

4.2 CHALLENGE

The physical competition will be conducted in accordance with Safe Management Measures (SMM) guidelines, which will be announced closer to the competition.

For the Challenge, teams are to design, build and fly their flying machines to overcome various challenges for the different SAFMC categories. The Challenge consists of a team video challenge submission, and the actual in-venue flight on Competition Day.

The team video challenge serves as a prelude to the team's aircraft capabilities and flight-worthiness. The Competition Day allows teams to accomplish the mission tasks in a live capacity in front of an audience.

On the competition day, tables will be provided within the main competition hall for teams to work on their flying machines. Alternatively, teams may be assigned a designated area instead.

Teams should expect the following during the competition day:

- Only registered team members of the participating teams can enter the playing field and team booths/holding areas.
- Teams are expected to fully comply with safety rules. Failure to comply with safety rules after the initial warning will result in immediate disqualification and potential blacklisting from the competition. The organiser will also not be responsible for any injuries or mishaps if any participant has disregarded the safety rules.
- No trials will be allowed in the flying area unless specified by the officials.
- The participants will acknowledge that there will be variations in environmental conditions between teams, despite best efforts to control them
- For all Category C, D and E participants, all aircraft and their transmitting devices must be presented to SAFMC officials for inspection upon arrival.
- For all Category C, D and E participants, no video transmitting devices, including spares, should be powered on in the competition hall unless specified by the officials. Teams may request from the Chief Referee or the Category D1 Technical Chairperson to perform power-on checks.
- Additional rules and regulations specific to Category E are detailed in Sections 8 and 9. Participants will acknowledge that they have read the rules.

5. CATEGORY D2 MISSION

Teams are required to design, or enhance commercial off-the-shelf products (COTS product), and build a system of at least **TWO (2)** small flying machines that are capable of full autonomous flight. The drones need not be homogeneous. Such operations often involve a suite of integrated systems instead of a standalone machine. Due to the challenging nature of fully autonomous indoor flight, external aids such as visual markers or take-off / landing systems are allowed, subject to technical requirements detailed in Section 6. A safety pilot for remote control takeover in case of flight emergency is required, but the main operation and control must not be from a remote controller.

The detailed descriptions of the competition field, available mission tasks, as well as the scoring criteria are found in Section 6. Teams are advised to read through these sections in detail to develop a strategy and identify key design requirements, before designing the flying machine to execute the mission. The technical rules for the flying machine are found in Section 9.

5.1 CATEGORY D2 CHALLENGE (AUTONOMOUS MISSIONS)

Category D2 requires its participating teams to perform various missions with fully autonomous aerial robots that work dynamically and collaboratively for a resupply delivery operation. The team with the highest number of points accrued for successful missions wins the competition.

The flying machine should also possess various sensors, and/or mechanisms to complete a variety of tasks in a complex environment without inputs from the operator.

5.1.1 COMPETITION SETUP

The playfield and key dimensions are shown in Figure 1, Figure 2

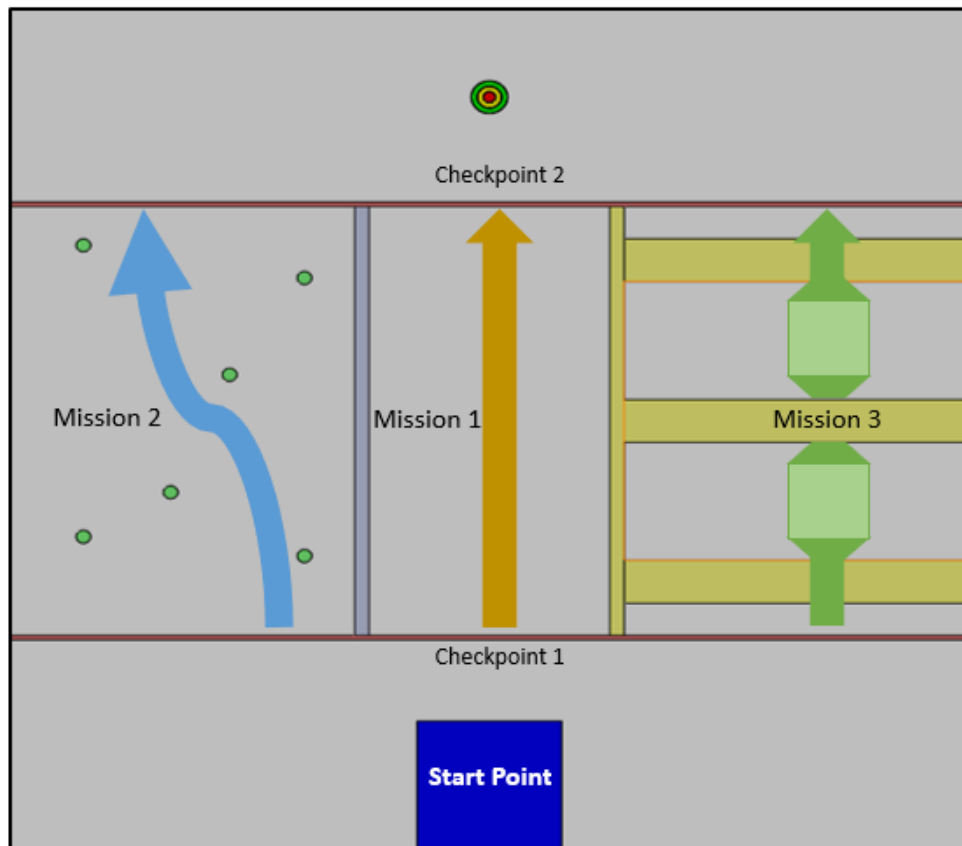


Figure 1: Top view of challenge arena with mission routes highlighted

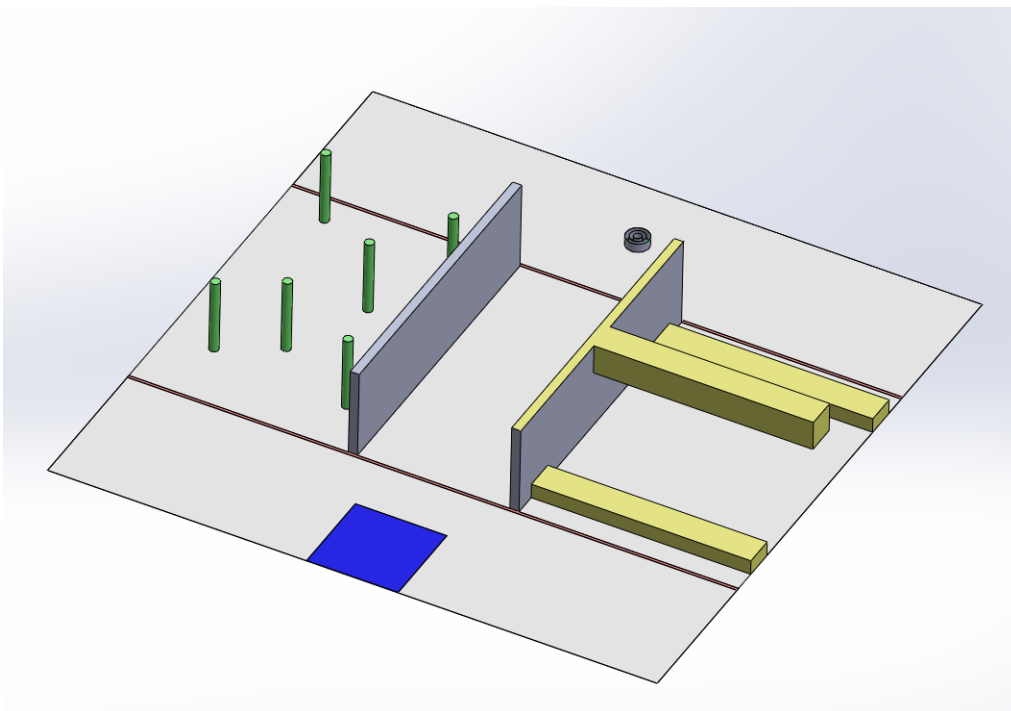


Figure 2: Isometric view of challenge arena

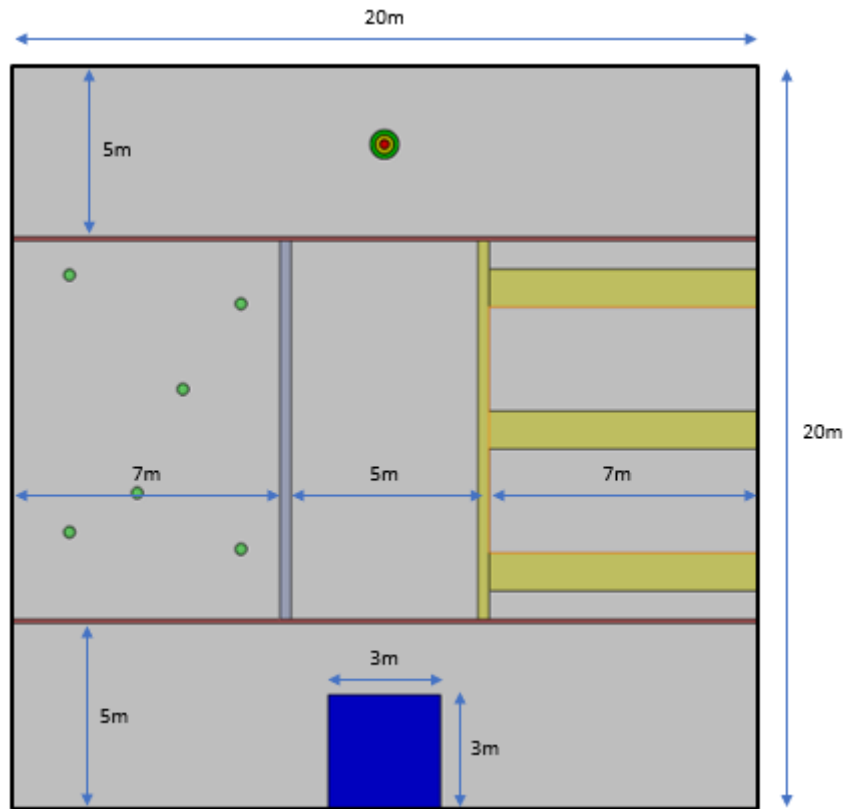


Figure 3: Dimensions of the challenge arena. Dimensions on the actual day may vary slightly from the diagram.

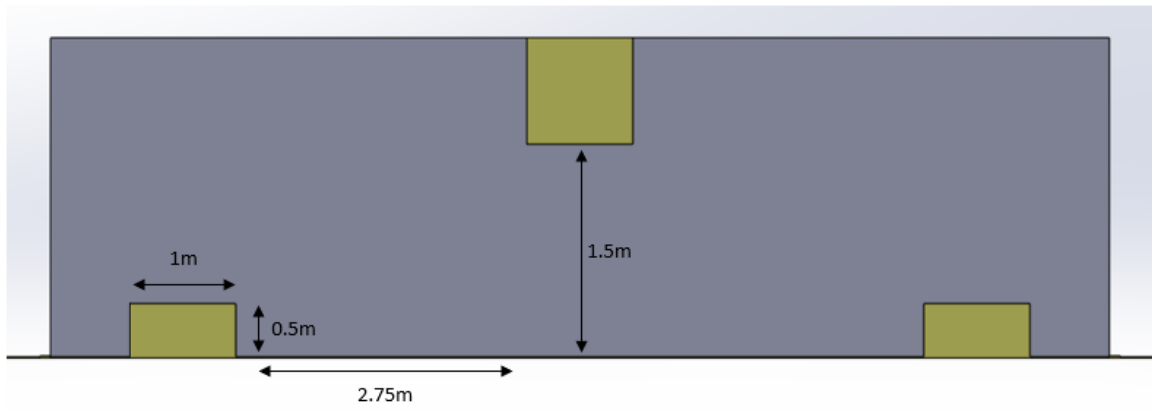


Figure 4: Dimensions of mission 3. Dimensions on the actual day may vary slightly from the diagram.

5.1.2 MISSION TASKS

The challenge comprises of 3 payload delivery missions, each along one of the 3 routes in the arena

- Straight and Narrow
- The Windy Road
- Up and Down

The drones have to take off with the payload, navigate each route, and deliver the payload to the receiver.

Teams are given a single attempt of 45 minutes to prepare and challenge the missions. The time given is inclusive of preparation time.

Teams are allowed to challenge the missions as many times as they wish, in any order, within the allotted time. The highest score for each mission will be recorded for scoring.

Start Point

Teams start the mission with 10 payloads pre-loaded in the carrier. Teams may choose to go to the loading point to get more payloads, or head straight to Checkpoint 1 (CP1). Points will be awarded per payload in the carrier at CP1. Payloads will be typical rubber bouncy balls ($37\pm 5\text{mm}$ diameter, $40\pm 5\text{g}$ mass).



Figure 5: Example of rubber bouncy balls



Figure 6: Example of payload carrier - an A4 paper tray

Mission 1: Straight and Narrow

The team of aircraft will take off from the start point, and proceed to navigate down the central corridor towards the target. The aircraft will then proceed to deliver the payload to the target.

In addition to points awarded for successful payload delivery, points will be awarded per payload in the carrier when it passes the Checkpoint 1 (CP1) and Checkpoint 2 (CP2) line.

Mission 2: The Windy Road

The team of aircrafts will take off from the start point, and proceed to navigate through the course of pillars. The aircraft will then proceed to deliver the payload to the target. The pillars will be placed at random, with at least 2.5m separation between each pillar.

In addition to points awarded for successful payload delivery, points will be awarded per payload in the carrier when it passes the Checkpoint 1 (CP1) and Checkpoint 2 (CP2) line.

There will be no penalty for contact with the pillars. If a pillar is knocked over, 5 points will be deducted from the mission score.

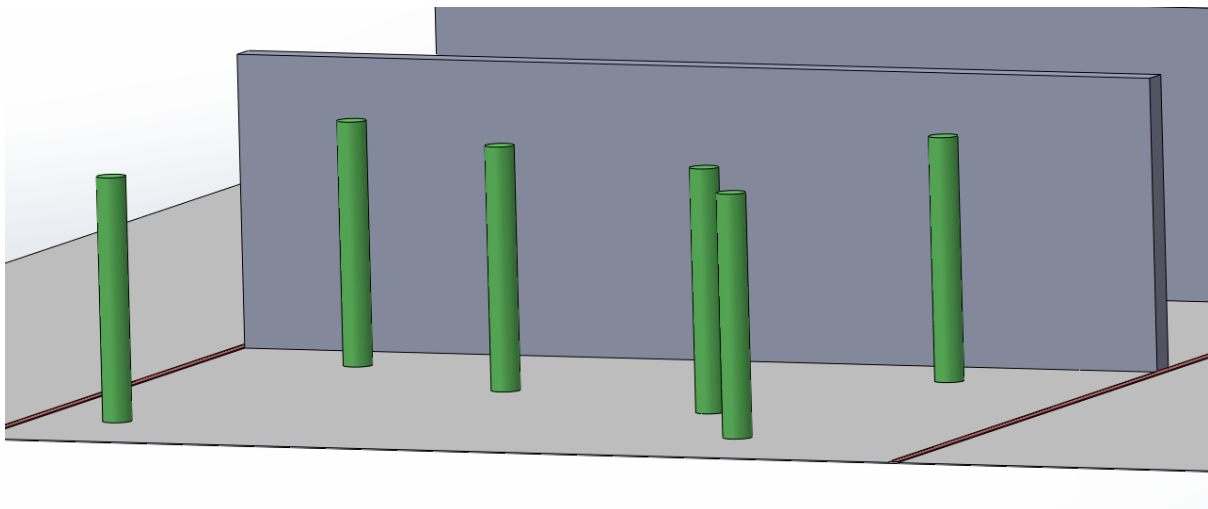


Figure 7: An example of what Mission 2 may look like. Pillars ~2.5m tall, 20-30cm diameter. Colour is not representative of the conditions on the actual day.

Mission 3: Up and Down

The team of aircrafts will take off from the start point, and proceed to navigate above the low walls and under the height restriction. The aircraft will then proceed to deliver the payload to the target. The low walls will be 0.5 m high, while the height restriction will obstruct a region above 1.5m. The aircrafts are required to pass underneath this height restriction to deliver the payload.

In addition to points awarded for successful payload delivery, points will be awarded per payload in the carrier when it passes the Checkpoint 1 (CP1) and Checkpoint 2 (CP2) line.

There will be no penalty for contact with the obstacles. However, teams may be disqualified for damaging the obstacles.

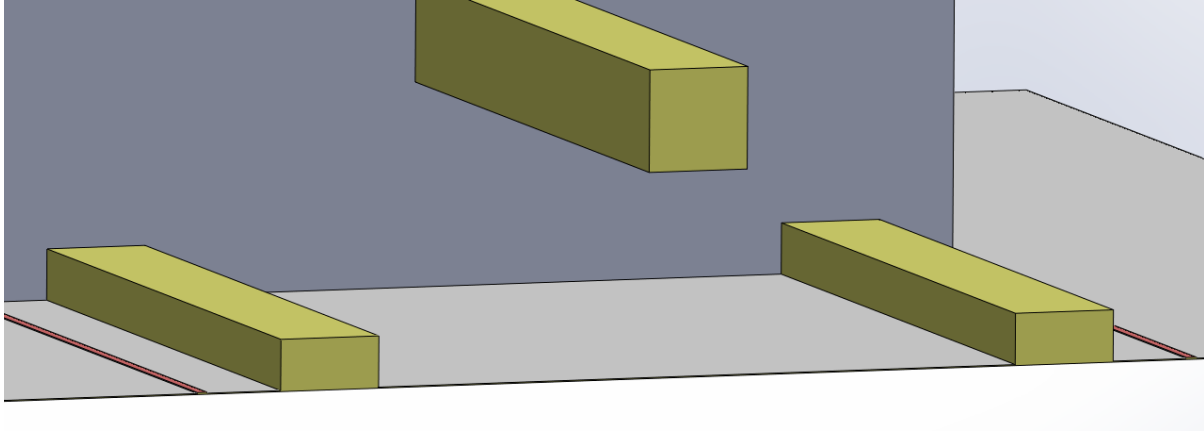


Figure 8: View of the obstacles to navigate through in Mission 3

Payload Delivery

The aircraft will then navigate to the payload receiver to accurately drop the payload into the collection point.

Points will be awarded per payload successfully delivered into the payload receiver. The receiver will be filled with 3cm of sand to prevent balls from bouncing out. There will be no penalty if the aircrafts or carrier touches the receiver.

The payload receiver will consist of three concentric rings, as seen in Figure 9 below.

After the payload has been dropped, teams can land their aircraft and power down their aircraft to manually retrieve the aircraft before attempting the next mission.

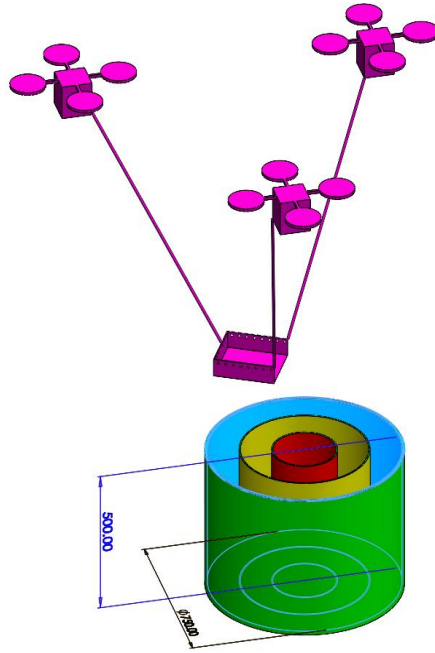


Figure 9: Drones above the payload receiver

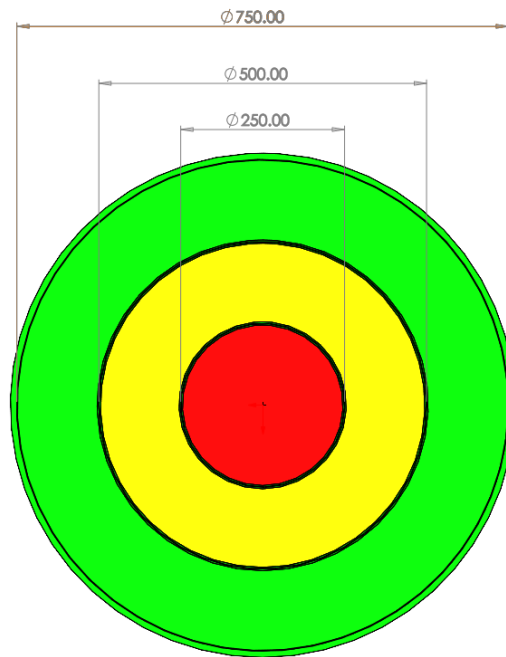


Figure 10: Top view and dimensions of the receiver (given in mm)

5.1.3 MISSION RULES

- Teams must use at least 2 flying machines.
- Each flying machine must weigh less than 2kg, and measure less than 750mm from propeller to propeller.
- On the competition day each team will have a **fixed duration of 45 minutes of mission time** to complete the tasks in the playing field.
- The allotted 45 minutes is **inclusive of preparation time**.
- Teams are to ensure that there is no one in the arena when challenging a mission
- Teams will be granted a **single attempt**. Any additional attempts will be granted at the discretion of the judges'/organising committee.
- The mission time will continue to run throughout and will not be paused in the event of any landing, maintenance, or repair works, etc.
- Teams are allowed to challenge any mission in any order within the 45 minutes given.
- The attempt with the highest score obtained for each mission will be counted for the overall score.
- For payloads to be counted for scoring at CP1, CP2, the carrier must cross the line demarcated on the ground. This will be verified by the referee/judge.
- The maximum height of any aircraft cannot exceed 2m during any mission.
- If the aircraft loses all payload during the mission, the teams may choose to restart from the start point. Best scores at previously reached CPs for that mission will be saved.
- In the event that the team needs to repair/troubleshoot the aircraft, they are required (if possible) to land the aircraft as soon as possible. All repairs/troubleshooting should be done either on the take-off and landing pads or outside of the playing field.
- Teams are allowed to change flight batteries during the game, but only if all the aircraft has landed.
- Any ground aids or external markers used for navigation and guidance of the aircraft have to be easily removable without damaging or leaving visible traces on the ground. These markers must be placed within the playing field only.
- Participants may modify the provided carrier by removing material only (eg can cut, drill, and bend, but no glue).

- Fasteners used to connect the carrier to the aircraft cannot interfere with the payload.
- Payload can only contact the carrier. It cannot touch any fasteners or cables.
- The drone-to-carrier connection can be of any length, rigid or flexible. It cannot come into contact with the payload.
- All parts of the flying machines including the carrier trays must not touch the floor other than at the designated take-off, landing pad, and payload receiver.
- Back-up flying machines that are **similar** to the original flying machines may only be used in the event of the primary aircraft being determined to be incapable of flight for the remaining time left for the attempt, at the discretion of the Chief Referee or Category D2 Technical Chairperson.
- Teams are encouraged to have a safety pilot, to take over control of the aircraft in order to avoid a crash. The safety pilot may follow the aircraft (line-of-sight) from the edge of the field; however, he/she may not communicate in any way with the ground control station operator.
- There should be no command switches made by the safety pilot at any point except to avoid a crash or during an emergency. In case of any take-over or command given via the remote control by the safety pilot, the aircraft will have to restart the mission from a position determined by the Chief Referee.
- The safety pilot needs to inform and demonstrate to the referees that the aircraft is in computer-in-control (CIC) mode before take-off. Once airborne, no directional command inputs are allowed as the aircraft is required to be fully-autonomous. The Chief Referee or Category D2 Technical Chairperson has the authority to determine what is considered to be fully autonomous.
- In case of doubt, the Chief Referee or the Category D Technical Chairperson has the final decision.

5.1.4 MISSION SCORING

The points awarded for completing each task is listed in the table below. The referees will make all scoring decisions and their decision is **final**. For arbitrary cases, the Chief Referee will have the **final** say.

If the scores are tied between teams, the team which achieves the score in the shortest amount of time wins.

Criteria	Points
Points per payload in carrier at CP1	5
Points per payload in carrier at CP2	15
Points per payload in red zone	50
Points per payload in yellow zone	40
Points per payload in green zone	30
Collisions with Static Obstacles	There will be no penalty for collisions with the pillars unless the pillars are knocked down. If the pillars are knocked over, 2 points will be deducted and there will be a short safety pause at the end of the course to re-stand the pillars as quickly as possible.

5.2 PENALTIES

The sum of penalties will be deducted from points acquired in the mission attempt to give a final mission score. The referees will make all scoring decisions and their decision is **final**. For arbitrary cases, the Chief Referee will have the **final** say. Further correspondence will not be entertained.

5.2.1 LIST OF MISSION PENALTIES

S/N	DESCRIPTION	PENALTY
1	Exceeding the 15 minutes setup time for D2.	Mission time will start regardless.
2	Knocking over pillars during the missions	-2 points for each pillar, safety restoration time
3	Use of external markers outside of the playing field.	Referee's discretion or <u>disqualification</u>
4	Internal markers within the playing field unable to be removed or leave a mark after being removed.	Referee's discretion or <u>disqualification</u>
5	Interrupting the competition by potentially interfering with other competitors, e.g. switching on your platform's VTX, transmitters, etc.	Referee's discretion or <u>disqualification</u>
8	Attempting to subvert competition rules or gain an unfair advantage over other teams, e.g. receiving assistance from spectators, etc.	Referee's discretion or <u>disqualification</u>
9	Any ground aids used to help in the picking of payloads are <ol style="list-style-type: none"> 1) Unable to be removed or damaged the take-off pad after removal 2) Having a size more than 150mm (L) by 150mm (W) by 50mm (H) 3) Delivered together with the payloads. (i.e. left remaining on the grid squares) 	Referee's discretion or <u>disqualification</u>

6. SCORING

There are a total of **five** scoring components for the competition, namely: Aerial Platform (**A**), Creativity (**C**), Learning Journey (**L**), Team Challenge Video (**V**), and Mission (**M**). The first four components (A, C, L, and V) will be assessed by our Category D Judges, while the Mission (M) factor will be computed from the highest attained score from the challenge attempts.

Scores will be awarded relative to the performance of other teams. Further details on the scoring components can be found below.

The weightage of the scoring components is listed as follows:

Segment	Factor	Weightage
Presentation	Aerial Platform	10%
	Creativity	10%
	Learning Journey and Insight	10%
Competition	Team Challenge Video	10%
	Mission	60%
	Total	100%

For **CAT D2** the total score (**T**) is computed as:

$$T = A + C + L + V + M$$

6.1 AERIAL PLATFORM FACTOR (A)

The **Aerial Platform Factor (A)** will be awarded based on the ability of the teams to demonstrate a comprehensive understanding of the following areas and apply them when designing and constructing their flying machine. It carries a 10% weightage to the overall score.

1) Mechanical design

- Quality of fabrication, workmanship, materials used
- Platform weight optimisation
- Lower points for usage of commercial off the shelf products
- Design factors affecting platform's flight stability, and payload carrier stability

2) Electronics design

- Power / Battery sizing to meet mission objectives
- Explanation of choice of sensor suite for the given environment
- Explanation of choice of embedded computer / microprocessor
- Neatness of harnessing and aesthetics

3) Software design, in particular describing how their proposed semi-autonomous / autonomous concept will work.

- Explanation of flight control strategy
- Explanation of autonomy strategy

6.2 CREATIVITY FACTOR (C)

The **Creativity Factor (C)** is a measure of the team's creativity in the design of their flying machine and control interface, or any sub-system which aids in their mission strategy. It is not mandatory to adopt unique concepts, but teams that do so will score higher for this factor. It carries a 10% weightage to the overall score.

Examples of innovative approaches may include:

- Non-conventional ideas and methods to achieve mission task(s)
- Innovative mechanisms for payload delivery
- Innovative choice of sensors
- Innovative algorithms.

6.3 LEARNING JOURNEY AND INSIGHT (L)

The **Learning Journey and Insight Factor (L)** is related to quality and content of the presentation. It carries a 10% weightage to the overall score.

1) Learning Journey

- Challenges faced and overcome
- Solutions explored and iterations to get to the final product
- Team is able to explain the rationale behind design choices and major decision
- Key takeaways from the experience

2) Delivery

- Speakers are clear and concise
- Speakers are able to answer questions smoothly

3) Teamwork

- Presentation should highlight the work of all the team members, and how they have contributed and cooperated with the team

4) Fun

- Should be able to capture the attention of the judges
- The judges should enjoy your presentation

6.4 TEAM CHALLENGE VIDEO (V)

The **Team Challenge Video (V)** scores provide a proof-of-flight insight into how the aircraft performs. It carries a 10% weightage to the overall score.

1) Flight-worthiness

- Aircrafts must display their ability to perform stable, sustained flight while carrying a payload together

2) Mission-readiness

- Aircrafts must display their ability to avoid static obstacles
- Aircrafts must display their ability to manipulate the payload carrier to unload payloads

6.5 MISSION ACCOMPLISHED FACTOR (M)

The points obtained in the actual missions will determine the team's **Mission Factor (M)** score. Please refer to [Section 6](#) for the mission scoring and penalties. This carries a 60% weightage to the overall score.

Since the missions can be repeated as many times as possible within the time limit, there is no fixed maximum number of game points attainable. As such, the overall Mission Factor score will be the team's game points as a percentage of the highest achieved game points.

For example, if the highest points obtained by any team is 120 and Team A gets 90 points, Team A's Mission Factor score will be $\frac{90}{120} * 60 = 45$.

7. FLOW OF EVENTS

7.1 PRESENTATION SEGMENT

Teams will deliver their presentation to a panel of judges in person during the Challenge day. Teams will share about their swarm system. For CAT E, the presentation is currently tentatively scheduled for 29 March 2023.

Teams will be given a maximum of FIFTEEN (15) minutes for this segment. TEN (10) minutes are allocated for the team presentation, and FIVE (5) minutes for Questions & Answers.

Please refer to Section 7 for scoring factors for the presentation component.

During the presentation segment, teams are required to:

- 1) Bring each unique flying machine used during the competition
- 2) Teams are to prepare **ONE (1)** presentation in the form of **TWO (2) A0** posters.

7.2 TEAM CHALLENGE VIDEO

Teams are to submit **ONE (1)** team challenge video to the SAFMC committee. The video length should be no longer than **TEN (10)** minutes, and should include the key components as stated in Section 7.

Videos should be uploaded to YouTube and set as “Unlisted”. The link to the video should be sent to SAFMC@science.edu.sg with title subject: “[CAT D2] - [Team Name] – Challenge Video” before the deadline. The deadline for submission is **6 March 2023, 2359hrs**. Video should be uploaded before the deadline, and any re-upload of the video detected past the deadline may result in **penalisation** or **disqualification**. You may write to the SAFMC 2023 Committee to request for a re-upload of the team video if necessary.

The submitted video should adhere to the following guidelines:

- 1) Animations are **NOT** allowed.
- 2) Computer-aided simulations are **NOT** allowed.

- 3) Video must **NOT** be produced by a professional, or with professional assistance.
- 4) No offensive images or audio.
- 5) Narration and/or subtitles are allowed.
- 6) All videos must be original work conceived and created by the Participants. No copyright materials (images, music, etc.) may be used in the video unless the participants own the copyright or have a license to use the material in the video.
- 7) If the participants have gained formal permission to use any copyright materials (images, music, etc.) under terms and conditions stipulated by the copyright owners, acknowledgements/credits must be included at the end of the video.
- 8) The use of logos including known commercial brands, institutional crests or trademarks, unless integral to the project, is not allowed.
- 9) Ownership of the underlying intellectual property of the video remains with the participant(s) of the individual/team project, with the following exception:
 - a. Participant(s) grant the organiser the right to use, distribute and display their videos without further compensation or notification to the participant(s).
 - b. Participant(s) grant the organiser the right to use their images and videos for publicity and advertising without further compensation or notification to the participant(s).

7.3 COMPETITION SEGMENT

Teams are expected to comply with the following during the competition segment:

- 1) Upon arrival, and at the designated reporting time, all teams shall proceed to the reporting point for allocation of their team booth as well as the competition schedule for their teams.
- 2) At the allocated competition schedule, the team shall report to the safety inspection point. A SAFMC official will check the flying machine for any violation of the category rules and regulations. Teams who do not pass the inspection will **not be allowed** to fly their machine in the challenge mission, and may face **immediate disqualification** from the competition. The inspection will include, but is not limited to, the following checks:

- 2.1 The maximum take-off weight (MTOW) of each platform should not exceed **2kg**.
 - 2.2 The platform **should not exceed 0.75m** in any direction (this measurement includes the maximum diameter of the propeller circles).
 - 2.3 RC / datalink / video link transmitter and receiver are operating on allowed frequencies.
 - 2.4 Electrical harnessing should be appropriately insulated and should not be chafed or broken. No exposed wires and connectors are permitted.
 - 2.5 All major assemblies and critical components must be securely fastened to the flying machine; loose items should be tied down and kept away from the propellers.
 - 2.6 For platforms operating on semi-autonomous / autonomous modes, the platform should allow complete manual pilot override on-demand via RC or GCS. Each platform is required to have its own safety pilot.
 - 2.7 The aircraft must demonstrate **failsafe capability** in the event of a loss of link between the GCS and the aircraft. The failsafe check procedure is as follows:
 - (a) All propellers and releasable payloads are to be removed from the platform.
 - (b) Flight motors will be armed and throttled up.
 - (c) While the motors are still spinning in the same flight mode, the Wi-Fi router(s) will be **switched off** to simulate a link loss.
 - (d) All motors should come to a **complete stop immediately**. The aircraft should not attempt a hover / controlled descent / to return home.
- 3) Each attempt will last for **FOURTY-FIVE (45)** minutes. The time will end when the 45 minutes is up, the missions are successfully completed, or when the drones are no longer operational.

- 4) The time given is **INCLUSIVE** of any setup time required by the teams. Once the time limit is up, no further points will be awarded for the tasks, and the team is to land all drones as soon as possible.
- 5) A SAFMC official will be with the operator during the attempt. The official may give instructions to the operator depending on the behaviour of the flying machine (e.g. to land immediately if the aircraft appears to be uncontrollable). The operator is to **comply immediately** with all such instructions, which may include the activation of the failsafe to ground the aircraft.
- 6) At the end of each attempt, the radio control transmitter, datalink transceiver, video receiver and any other wireless device for the flying machine must be switched off.
- 7) After the completion of the first attempt, teams are advised to return to their respective team booth before their next attempt. The team is allowed to repair or make legal modifications to the flying machine in preparation for the next attempt.

7.4 KEY POINTS TO NOTE

- 1) Rules for personnel movement and communication during the setup time and the mission attempt are dictated in the following points:
 - a. Only up to 3 members of the participating team are allowed to be inside the playing field at any one time, when the aircraft is not airborne.
 - b. No outside communication or assistance from the audience / spectators is allowed at any point. No headphones or earpieces are allowed to be worn by the pilot. Teams who flout this rule may be **disqualified**. Communication amongst teammates is allowed.
 - c. Team members are allowed to follow the system from outside the playing field to observe the platform for safety purposes as a safety pilot, and may contact the team if unexpected behaviours or if an emergency occurs.

- d. Everyone is required to remain outside of the playing field and be behind the safety net when the aircraft is airborne.
 - e. Team members may enter the field to collect their aircraft, or to bring it out of the playing field to modify or repair (including changing batteries) **after** it has landed and propellers have stopped spinning. Entry into the playing field is only allowed upon confirmation with SAFMC officials.
- 2) Multiple video **receivers** are allowed. Only **ONE (1)** video transmitter is allowed for each aircraft.
- 3) No radio control transmitters, datalink transmitters and video transmitters and receivers are to be switched on within the competition hall, unless permitted to do so in the holding area or playing field. All repairs / maintenance / troubleshooting should be down in Raceband channel 8 with VTX set to either 25mW or pit-stop mode. Non-compliance may lead to **disqualification**.
- 4) There will be a charging space allocated for teams to charge their batteries. Teams will have to bring their own charger/charging equipment should they plan to charge their batteries. At any point, there **MUST** be at least **ONE (1)** team member overseeing the charging. Failure to do so will result in **disqualification**.
- 5) Teams shall make sure that their designated representatives are contactable and should arrive at least **10** minutes before any allocated timing. Latecomers may have their mission times shortened or may be **disqualified**.

8. TECHNICAL RULES & REGULATIONS

Each team is to design and build a flying machine based on the following guidelines:

- Off-the-shelf products and components are allowed in the competition.
- For safety considerations, the total weight of each flying machine **cannot exceed 2.0kg**.
- Each platform **should not exceed 0.75 m** in any direction (this measurement includes the maximum diameter of the propeller circles).
- Back-up aircraft that are similar to the primary aircraft may only be used in the event the primary aircraft has been determined to be incapable of flight for the remainder of the attempt.
- Only electric-based flight propulsion is allowed. Both brushed and brushless motors are allowed. No modifications to the motors are allowed.
- No internal combustion or gasoline engines are allowed.
- No tethering or umbilical wires to the aircraft are allowed during flight.
- External aids such as markers, indicators etc. will be allowed **only** in the playing field, and can only be placed when there are no platforms flying.
- For safety considerations, the platform must be able to perform full RC manual pilot override and RC failsafe on demand.

8.1 AVIONICS SYSTEM

There is no limit on the number of inertial measurement units (IMUs), flight controllers (FCs), and other electronics used in the flying machine.

8.2 BATTERY

There is no limit on the number of batteries used, in series or parallel. Participants should size their batteries and aircraft appropriately for the respective mission.

Lithium-Polymer (LiPo) batteries are preferred.

Batteries must be properly strapped or locked onto the aircraft before launch.

8.3 REMOTE CONTROL (RC) RADIO

1) Based on the Singapore Spectrum Management Handbook (Chapter 7, Issue 1 Rev 2.9, July 2017) from Infocomm Media Development Authority (IMDA) Singapore for short range devices, the following R/C frequency ranges are allocated for RC cameras / toys / miscellaneous devices:

- 26.96 – 27.28 MHz \leq 100mW Effective Radiation Power (ERP)
- 34.995 – 35.225 MHz \leq 100mW ERP
- 40.665 – 40.695 MHz \leq 500mW ERP
- 40.77 – 40.83 MHz \leq 500mW ERP
- 72.13 – 72.21 MHz \leq 500mW ERP

The following R/C frequency ranges are allocated for R/C aircraft and gliders:

- 29.700 - 30.000 MHz \leq 500mW ERP
- 26.96 - 27.28 MHz \leq 500mW ERP

2) In any mode of flight, the team must be able to demonstrate the failsafe capability in their RC transmitter. All electric motors should come to a complete stop when failsafe is activated **and** when there is a loss of link between the RC transmitter and the RC receiver on the aircraft. Please refer to Point 2.8 in Section 8.2 for details on the failsafe check.

3) Please refer to the *Singapore Spectrum Management Handbook* on IMDA website for more details on the spectrum allocation and for the latest approved range of frequencies.

8.4 REMOTE CONTROL (RC) RADIO

1) The following frequencies are approved by IMDA for radio telemetry:

- 433.05 - 434.79 MHz \leq 10mW ERP
- 866 - 869 MHz \leq 500mW ERP

- 920 - 925 ≤ 2000mW ERP
- 2) Wireless Wi-Fi routers will be allowed in this competition. Participants may choose to bring their own wireless routers.
 - 3) Setup of external wireless device(s) for the purpose of performing autonomous flight is allowed. However, teams can only turn on their wireless routers and transmitters during the setup and flight phases (same restriction as R/C transmitters).
 - 4) The following frequencies are approved by IMDA for wireless data communications / video transmitters / LAN:
 - 72.080, 72.200, 72.400, 72.600 MHz ≤ 1000mW ERP
 - 158.275 / 162.875 MHz ≤ 1000mW ERP
 - 158.325 / 162.925 MHz ≤ 1000mW ERP
 - 453.7250 / 458.7250 MHz ≤ 1000mW ERP
 - 453.7375 / 458.7375 MHz ≤ 1000mW ERP
 - 453.7500 / 458.7500 MHz ≤ 1000mW ERP
 - 453.7625 / 458.7625 MHz ≤ 1000mW ERP
 - 2.4000GHz - 2.4835GHz ≤ 200mW Equivalent Isotropically Radiated Power (EIRP)
 - 10.500 – 10.550 GHz ≤ 117dB μ V/m @ 10m
 - 24.000 – 24.250 GHz ≤ 100mW EIRP
 - 5.725GHz – 5.850 GHz ≤ 4000mW EIRP
 - 5.150GHz - 5.350GHz ≤ 200mW EIRP
 - 5.470GHz - 5.725GHz ≤ 1000mW EIRP
 - 57 – 66 GHz ≤ 10W EIRP
 - 5) Please refer to the *Singapore Spectrum Management Handbook* on IMDA website for more details on the spectrum allocation and for the latest approved range of frequencies.

8.5 CAAS REGULATIONS

- 1) Participants are to ensure that they have registered their aircraft if the weight exceeds 250g.
- 2) For educational purposes, if the total weight of the aircraft exceeds 1.5kg, but is less than 7kg, a UA Basic Training Certificate or a UA Pilot License is required.
- 3) Please refer to the *UA Regulatory Requirements* on the CAAS Website for more details on Unmanned Aircraft regulations.

9. **PANDEMIC RESTRICTIONS**

In the event where pandemic restrictions result in SAFMC 2023 being unable to be held in a physical venue, the following changes will be made:

- 1) As there will be no physical competition on-site, the Mission Factor component of scoring will be based solely on the Team Challenge Video submitted.
- 2) The Team Challenge Video will be scored by the Judges.
- 3) The segment weightages will be as follows:

Segment	Factor	Weightage
Presentation	Aerial Platform	20%
	Creativity	20%
	Learning Journey and Insight	20%
Competition	Team Challenge Video	40%

- 4) Team presentations will be held via Zoom. Presentation details will be communicated to participating teams accordingly. Teams will still need to submit their presentation slides to the SAFMC 2023 Committee before the deadline mentioned in Section 7.
- 5) Video submissions by each participating team will result in team members being automatically awarded a Certificate of Participation for SAFMC 2023.
- 6) Awards and Prizes as listed in Section 5 may be changed and modified at the discretion of the SAFMC 2023 Committee.
- 7) Ensure that the team member's names and contact details are accurate and updated, in order to receive timely updates from the SAFMC 2023 Committee.

The SAFMC 2023 Committee will follow all mandated Safe Management Measures as laid out by the Ministry of Health and Ministry of Education. The safety and health of our participants and event organisers are of paramount importance.