



# Category D1 Challenge Booklet 2023

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## SAFMC 2023 CAT D1 CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	17 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 with 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.*

## CONTENTS

SINGAPORE AMAZING FLYING MACHINE COMPETITION 2023 .....	5
1. INTRODUCTION.....	5
2. CATEGORIES.....	5
3. GENERAL SAFMC 2023 RULES .....	6
4. FORMAT OF COMPETITION.....	8
4.1 PRESENTATION .....	8
4.2 CHALLENGE .....	8
5. CATEGORY D1 AWARDS .....	9
5.1 CHAMPIONSHIP AWARD .....	10
5.2 JUDGES' COMMENDATION .....	10
6. CATEGORY D1 MISSION.....	10
6.1 CATEGORY D1 CHALLENGE (tic-tac-toe) .....	11
6.1.1 MISSION TASKS.....	13
7. SCORING .....	21
7.1 AERIAL PLATFORM FACTOR (A) .....	21
7.2 CREATIVITY FACTOR (C).....	22
7.3 LEARNING JOURNEY AND INSIGHT (L) .....	23
7.4 TEAM CHALLENGE VIDEO (V) .....	23
7.5 MISSION FACTOR (M) .....	24
8. FLOW OF EVENTS.....	24
8.1 PRESENTATION SEGMENT .....	24
8.2 TEAM CHALLENGE VIDEO.....	24
8.3 COMPETITION SEGMENT .....	26
8.4 KEY POINTS TO NOTE .....	27
9. TECHNICAL RULES & REGULATIONS.....	29
9.1 AVIONICS SYSTEM .....	29
9.2 BATTERY.....	29
9.3 REMOTE CONTROL (RC) RADIO .....	30
9.4 DATALINK / VIDEOLINK / OTHER WIRELESS LINK TYPES .....	30
9.5 CAAS REGULATIONS .....	32
10. PANDEMIC RESTRICTIONS .....	33

# **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](mailto: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 D1 AWARDS**

Award winners will be selected based on either presentation scores, performance on the competition day, or a combination of both.

There is no limit to the number of awards that a team can win, but there may not be a winner for every award. Awards may not be given out if the teams do not meet the minimum standard determined by the SAFMC organising committee, or if there are insufficient participants for each category.

All scoring decisions made by the judges are **final**. For arbitrary cases, the organising committee will have the **final** say.

The list of awards for Cat D1 is listed in the subsequent sections.

### **5.1 CHAMPIONSHIP AWARD**

This is the pinnacle award any team can win, and is bestowed on the team that achieves the highest total score across all areas. For category D1, there will be **THREE (3)** Championship Awards: a winner and **TWO (2)** runners-up. The scoring and weightage can be found in Section 7.

### **5.2 JUDGES' COMMENDATION**

This award is given out to Category D1 teams exhibiting a high quality in design and/or performance, but did not win the Championship Award or the runners-up prizes. Teams that have won any of the Top 3 prizes will not be considered for the Judge's Commendation Prizes. Overall scores may be taken into consideration for this award. Up to **TWO (2)** awards may be given for the whole Category D1, but there may not be a winner for this award.

## **6. CATEGORY D1 MISSION**

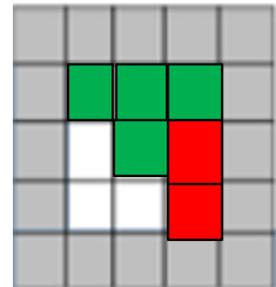
Category D1: Teams are required to design a system of **UP TO THREE (3)** small flying machines, where the system is controlled through intuitive means with the use of **wearable technologies**. The flying machines are to be piloted by a single designated pilot through a course designed with a series of obstacles. The system of flying machines can consist of customised or commercial off-the-shelf product (COTS product) that is capable of semi-autonomous or fully autonomous flight, and need not be homogeneous.

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.

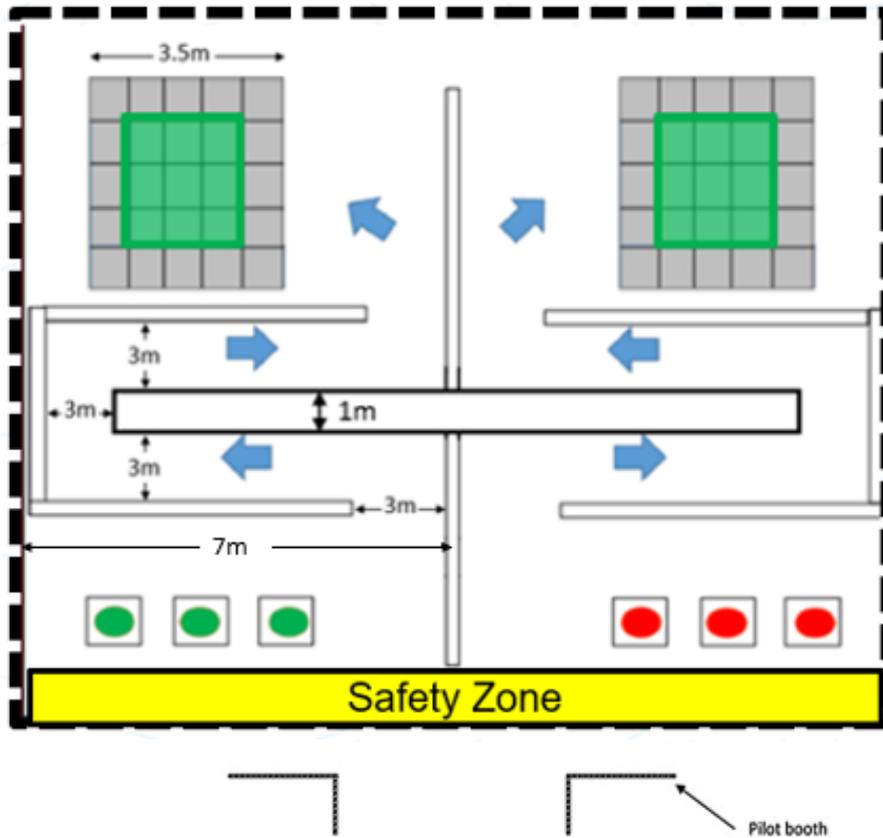
## 6.1 CATEGORY D1 CHALLENGE (TIC-TAC-TOE)

**Category D1** participating teams are required to design a system of flying machines that can pick up and release a payload, and can be controlled using intuitive control through the use of wearable devices. Two teams will race against each other through a maze obstacle, playing the “Tic-Tac-Toe” game by the precise and strategic dropping of their payloads.

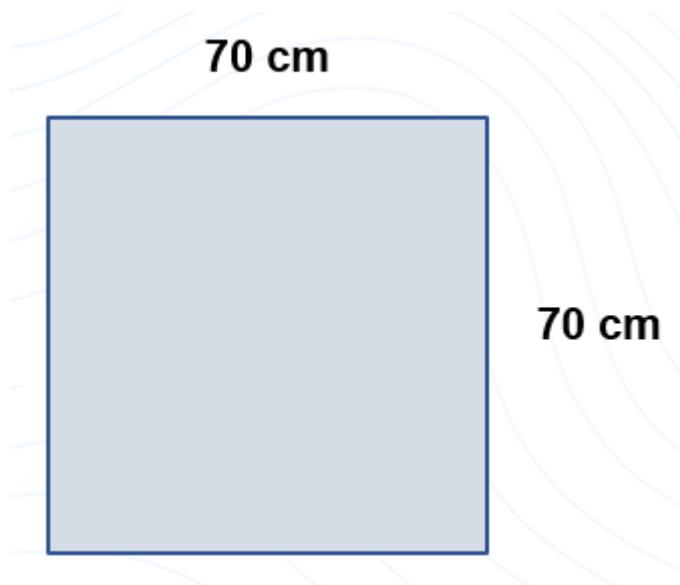
The competition set-up for Category D1, and a plan-view schematic are shown on the next page. The entire playing field is divided along its length by system partitions to allow two teams to compete in real-time. The progress of the Tic-Tac-Toe game, as depicted in an example on the right, will be seen on the LED boards which are on the ground inside the competition zone, and will light up green/red for each team depending on their allocated colour.



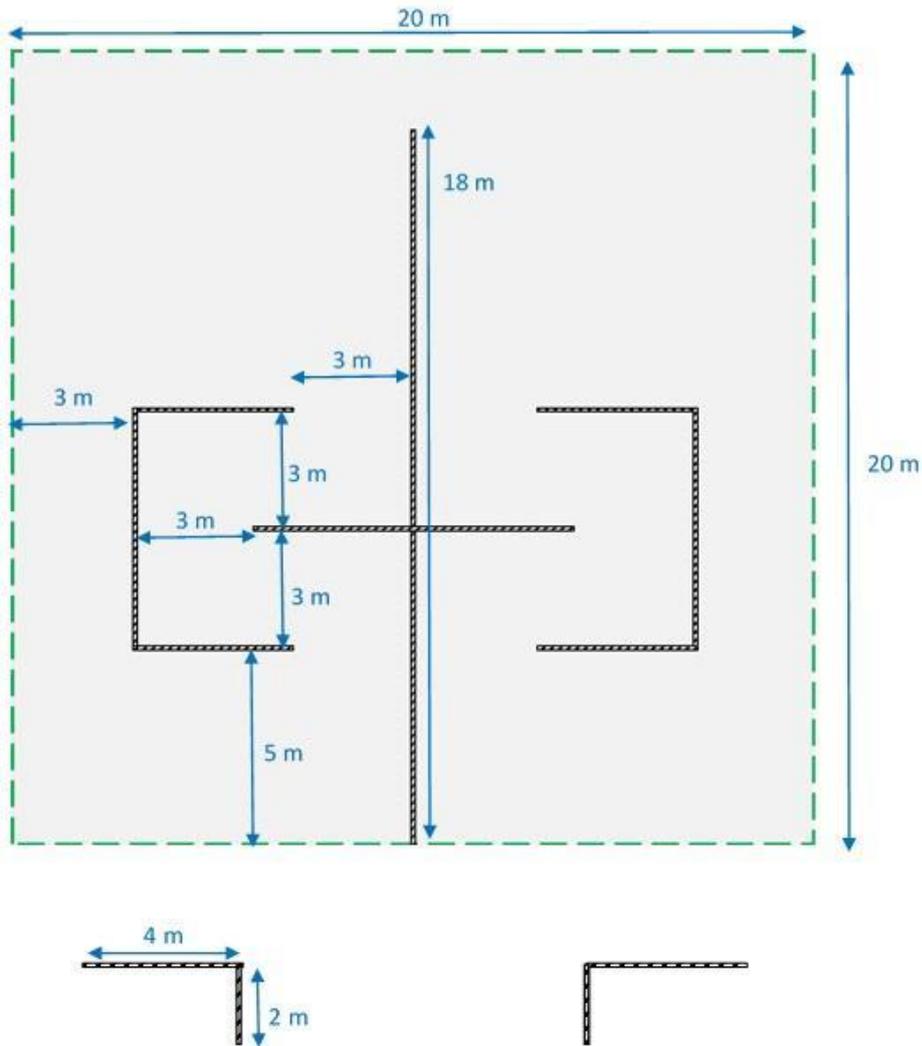
**Plan View of Playfield (blue arrows depict general gameplay)**



**Dimensions of Each Grid on LED floorboard at Drop-Zone**



## Dimensions of Maze Structure and Pilot Booths



The category D1 challenge is divided into two stages, the regular and knockoff stages. The top 8 teams (by score) from the regular stage will move into the knockoff stage. The mission is to pick up and drop off the payloads and be the fastest team to form a row of 3, in the vertical, horizontal, or diagonal direction, for their team.

## 6.1.1 MISSION TASKS

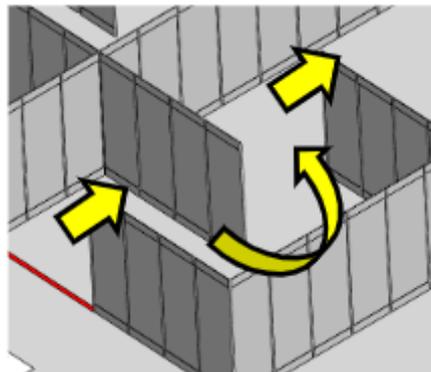
### Start Point

Teams will be provided with 5 standardised payloads (85g bean bag with 1 metal clip) on the competition day. Teams would be given 10 minutes set-up time to prepare their pilot booth and launchpads. Each launchpad will house up to a single drone pre-loaded with a payload, with 1 additional payload at the side. A horn will sound at the end of 10 mins, to indicate the end of set-up time. All participants are required to exit the competition area and competitive gameplay will commence at the sound of a horn, once the referee ensures no one is in the competition area.



### Task 1: Navigate through the Maze

Controlling the drone(s) using wearable devices, the pilot will command the drone(s) to take off, fly and navigate through the winding course to the drop zone.



### Task 2: Releasing Payloads at Drop-Zone

Having sight of the progress of the Tic-Tac-Toe game on the LED floorboards, the pilot will command the drone(s) to navigate to its desired grid. The drone(s) will drop their payload(s) into the desired grids from the air before leaving the drop-zone.

A successful drop of a payload into the drop zone will see the respective grid light up red/green according to the team's allocated colour. If the same grid was contested by both teams, the first payload that lands and touches the grid first will claim that grid for the team.

### Task 3: Reloading of Payload

Each team will control their drone(s) to fly back to the launchpad(s) / loading pad(s) via the winding course to retrieve one payload per drone. Teams are allowed to use any method to pick up the payload without direct human interaction. After retrieval of payload(s), the drone(s) can proceed to navigate through the maze and repeat the tasks.

#### 6.1.2 MISSION RULES

##### Flight

- Teams can use up to three (3) small flying machines.
- Each flying machine must weigh less than 2kg, and measure less than 1m in any direction (includes maximum diameter of propeller circles).
- Teams are to control their flying machine(s) using wearable devices, which are items that are either worn around the body, such as hands (like gloves) and arm/wrists. Motion controllers that sense movement using a piece of equipment placed on the floor/table are also allowed. **Devices/equipment that requires hand grip such as joysticks are not allowed.** In case of doubt, the Chief Referee and/or the Category D1 Technical Chairperson has the final decision. For any use of touchscreens, teams are to write in, explain and check with the Category D1 Technical Chairperson.
- Pilots are allowed to fly their aircraft using remote sensors (video or otherwise). The pilot will be confined to the pilot box and will not have line of sight to the aircraft. Any ground aids must not leave any markings or traces for the next race.
- The drones can fly through the maze together.
- Other than the launchpads, the drones are not allowed to be in contact with the floor or platform.
- Drones cannot fly over the walls.

##### Payload Pickup and Carriage

- Each payload (bean bag) will come with an optional binder clip. 5 bean bags will be placed onto the loading platforms in any order of choosing.
- Each team is free to determine its own payload pick-up strategy, as long as no human intervention is required in the pick-up. Each drone can only carry one payload at a time.

- The payload may be placed on a structure (e.g. to erect the bean bag) but the payload's lowest point must not be more than 1 inch off the ground.
- Each drone is permitted to pick up payload without landing.
- Payload modification is strictly NOT ALLOWED. This means that any payload attachments or mechanisms must not be delivered along with the payload.

### Payload Release

- There are no restrictions on the number of drones entering the drop zone.
- Payloads must be released while the drone is in the air.
- In the event that the payload is released when the drone has landed, no points will be awarded.
- Once the payload is dropped or released under any circumstances outside of the safety zone, teams are NOT allowed to retrieve the dropped payload with their aircraft. They are required to fly back to the launchpads to pick up a new payload.
- Teams are allowed to use pre-made attachments to carry the payloads as long as it is within the MTOW and the integrity of the payloads are preserved. Any ground aids or attachments that help in the picking and release of payloads will be allowed with the following conditions:
  - Removable (no damage or marks on the take-off pad after removal)
  - A size no more than 150mm (L) by 150mm (W) by 100mm (H)
  - Must not be delivered together with the payloads.
- In the event that the payload does not land cleanly within a grid, it is up to the referee's discretion to determine the intended grid.
- If both teams release their payload on the same grid at the same time, it will be up to the referee's discretion to determine which payload touched the surface first.

### Safety and Admin

- Each team should consist of TWO (2) to FIVE (5) members.
- All drones must follow CAAS regulations (e.g. CAAS registration sticker must be visible on drone). Any disregard for CAAS regulations will result in disqualification.
- Drones have to be inspected by designated event staff 30mins before the team's competition slot.
- Teams are allowed to change flight batteries during the game only if the aircraft has landed on the launch pad AND there are no other airborne drones within the safety zone.

- There will be a charging space allocated to charge flight 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.
- The drones can only take-off when there are no people within their side of the playfield.
- If the drones malfunction/crash no disruptions to the match. Teams are only able to retrieve their malfunction/crashed drones after match ends. No troubleshooting of drones is allowed during the match.
- In the case where all the flying machines in one of the teams are taken out of the game, the opponent has to continue to attempt to win the game. In the event that the opponent's flying machine system is also inoperable or if the mission time is up, the scores up to that point will be considered.
- On the competition day, each team will have **only ONE (1)** attempt per race. Each team will have a **fixed duration of 15 minutes of mission time** to compete in the playing field.
- There will be allocated playing fields for the two teams, separated by system partitions. In the event that **any part** of the team's aircraft crosses to the other team's playing field, the offending team will be disqualified for the race.
- Teams that are competing against each other can decide the side of the field that they want, or to flip a coin.
- Both teams will then be given **10 minutes of set-up time** prior to the mission start time. During this time, teams are allowed to set up their pilot booth and launchpads. No additional markers and/or hardware is allowed inside or outside of the playfield except at the pilot booths.
- Each competing team will be allocated half of RaceBand frequencies (either Ch1 to Ch 4, or Ch 5 to Ch 8).

	Frequency (MHz)							
Band	Ch1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6	Ch 7	Ch 8
Raceband	5658	5695	5732	5769	5806	5843	5880	5917

- Teams are required to set their video transmitter (VTX) to broadcast at their allocated RaceBand frequencies. Other teams (not competing) are not allowed to turn on their VTX when a competition match is ongoing.
- Teams are permitted to power on their drone(s) and VTX for testing during the set-up time, but are not allowed to fly out of the safety zone. No one is to be in the playfield while there are any airborne aircraft during this time. Offending teams will be disqualified.
- Once the 10 minutes of set-up time is up, the mission time will automatically start. Any drones that are not at the launchpad will have to return to the launchpad first before any action will be recorded. The mission time will continue to run throughout and will **not** be paused in the event of any landing, maintenance or repair works, etc.
- To qualify for the number of drones used multiplier, the operator has to fly all the drones together from the take-off point towards the payload area and each drone has to drop their payload in the release zone at least once (regardless if it scored).
- The radio transmitter must have an emergency switch to terminate the operation of all the drones, and teams are required to demonstrate this during inspection.
- Teams with inoperable aircraft are allowed to repair in between races. In the event that the aircraft is deemed incapable of flight, a new identical copy of the aircraft can be used for the next race. There will be no restriction on the number of spare aircrafts the team can prepare so long as the aircraft is replaced by another aircraft of the same design, at the discretion of the Chief Referee or Category D1 Technical Chairperson.
- In case of doubt, the Chief Referee or the Category D1 Technical Chairperson has the final decision.

### 6.1.3 MISSION SCORING

The referees will make all scoring decisions and their decision is **final**. For arbitrary cases, the Chief Referee will have the **final** say. Mission scores take up 40% of the total Championship Score.

There are two stages in the competition, the regular and knockoff stages. In the regular stage, teams will be playing in a league with round-robin format. The number of leagues and teams in each league will depend on the number of participating teams.

In regular stages, points will be given according to the following table:

Task	Points
Successfully take off	1 / drone
Successfully flown to the drop zone	1 x multiplier / drone
Successfully drop payload onto grid	1 x multiplier / payload
Win / Lose / Draw	5 / 1 / 0

The multiplier is computed based on the number of drones that drop the payload according to the rules:

Number of drones	Multiplier
1	1x
2	1.2x
3	1.5x

The best 8 teams will proceed to the knockoff stage, where the teams will be grouped in a snake format. (i.e. 1<sup>st</sup> team vs 8<sup>th</sup> team, 2<sup>nd</sup> team vs 7<sup>th</sup> team, and so on). Teams will be awarded 20 points for each win.

At the end of the competition, the points accumulated by the teams will be summed up (including the knockoff stages). The team with the highest number of points will receive the full mission score (40%). This will be followed by the 2<sup>nd</sup> team with 35%, 3<sup>rd</sup> with 30%, 4<sup>th</sup> with 25%, 5<sup>th</sup> to 8<sup>th</sup> with 20%, and the others 15% each.

## 6.2 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.

### 6.2.1 LIST OF MISSION PENALTIES

S/N	DESCRIPTION	PENALTY
1	Exceeding the 10 minutes setup time for D1.	Mission time will start regardless.
2	Use of external markers/hardware outside of the playing field and pilot booths.	Referee's discretion or <b><u>disqualification</u></b>
3	No additional Internal markers/hardware within the playing field	Referee's discretion or <b><u>disqualification</u></b>
4	Interrupting the competition by potentially interfering with other competitors, e.g. switching on your platform's VTX, transmitters, etc.	Referee's discretion or <b><u>disqualification</u></b>
5	Aircraft crossing into opposing team's playing field.	Referee's discretion or <b><u>disqualification</u></b>
6	Attempting to subvert competition rules or gain an unfair advantage over other teams, e.g. receiving assistance from spectators, etc.	Referee's discretion or <b><u>disqualification</u></b>
7	Any ground aids used to help in the picking of payloads are <ol style="list-style-type: none"><li>1) Having a size more than 150mm (L) by 150mm (W) by 100mm (H)</li><li>2) Delivered together with the payloads. (i.e. left remaining on the payload wells or elevated platforms in the drop-zone)</li></ol>	Referee's discretion or <b><u>disqualification</u></b>

## 7. SCORING

There are a total of **FIVE (5)** 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 D1 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:

<b>Segment</b>	<b>Factor</b>	<b>Weightage</b>
<b>Presentation</b>	Aerial Platform	20%
	Creativity	20%
	Learning Journey and Insight	10%
<b>Competition</b>	Team Challenge Video	10%
	Mission	40%
	<b>Total</b>	<b>100%</b>

For **CAT D1** the total score **T** is computed as:

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

### 7.1 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 20% weightage to the overall score.

- No points will be deducted for wholesale usage of COTS products with little or without modifications

1) Platform choice

a) If COTS product is used, teams are to explain:

- Choice of COTS products
- Modifications to COTS products, if any are made

b) For custom-built drones, teams are to explain:

1) Aerodynamic design

- Centre of gravity placement
- Design factors affecting platform's flight stability, responsiveness, and controllability
- Sizing for lift / thrust

2) Mechanical design

- Quality of fabrication, workmanship, materials used
- Platform weight optimisation
- Lower points for usage of commercial off the shelf products

3) 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

## 7.2 CREATIVITY FACTOR (C)

The Creativity Factor (C) is based on:

- what type of wearable technology is used and how it is integrated with the flight control to tackle the obstacle course
- how the payload is carried and how successful payload release/retrieval is achieved

The above two criteria carry a 20% weightage to the total score. Teams are to explain in detail about the above during the presentation.

Teams are also encouraged to utilise and present unique concepts which capitalize on the usage of wearable technology to enhance semi-autonomous flying machines.

### **7.3 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) Time management
  - Finishing within the allotted time, with enough time allocated for each segment
- 2) Delivery
  - Speakers are clear and concise
  - Speakers are able to answer questions smoothly
- 3) Content
  - Information presented is relevant to the flying machine and the team's project progress
  - Team is able to explain the rationale behind design choices and major decision
  - Team is able to express what they have learnt through the process and their learning journey
- 4) Teamwork
  - Presentation should highlight the work of all the team members, and how they have contributed and cooperated to the team
- 5) Fun
  - Should be able to capture the attention of the judges
  - The judges should enjoy your presentation

### **7.4 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
  - Aircraft must be shown to perform stable, sustained flight
  - Video of drone(s) performing roll/pitch/yaw/ascending and descending upon input by pilot through the use of wearable technology

## 2) Mission-readiness

- Demonstrate that drone(s) is/are shown to be able to fulfil mission requirements; fly a route while carrying a payload and when the drone is hovering at a fixed point, able to release the payload successfully.
- Explain the on-board sensor suite for each unique drone used in the challenge

## 3) Creativity

- How the wearable tech is worn on the user? Ease of putting on and removing once worn
- Delivery of video (i.e. how it is filmed/presented)

## 7.5 MISSION FACTOR (M)

The mission attempt scores will form the **Mission Factor (M)** score. Please refer to Section 6 for the mission scoring and penalties. This carries a 40% weightage to the overall score.

## 8. FLOW OF EVENTS

### 8.1 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 D1, 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 presentation
- 2) Teams are to prepare **ONE (1)** presentation in a form of **TWO (2)** posters

### 8.2 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](mailto:SAFMC@science.edu.sg) with title subject: “[CAT D1] - [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 in 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).

### 8.3 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 the platform should not exceed **2kg**.
  - 2.2 The platform **should not exceed 1m** 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.
  - 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 run will last up to **FIFTEEN (15)** minutes depending on the total number of participating teams and the competition schedule. The game will end when the time is up, either team manages to form 3 in a row, or when all drones on both teams are no longer operational.
  - 4) Each team will be granted up to **TEN (10)** minutes to set up (including loading their drone with a single payload) within the play field. A horn will sound at the end of 10 mins, to indicate the end of set-up time. All participants to exit the competition area and competitive gameplay will commence at the sound of a horn, once the referee ensures no one is in the competition area.
  - 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.

#### **8.4 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 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. One team member is allowed to follow the referee from the edge of the 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. All other teammates are 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 stop 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 done 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 Category D1 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 **TEN (10)** minutes before any allocated timing. Latecomers may have their mission times shortened or may be **disqualified**.

## 9. 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 the flying machine **cannot exceed 2.0kg**.
- The platform **should not exceed 1m** in any direction (this measurement includes the maximum diameter of the propeller circles).
- Participants are only allowed to use up to **THREE (3) flying** machines for each mission attempt. Teams can bring similar backup aircraft to replace any aircraft that has become incapable of flight. No changing of aircraft during runs is allowed. Teams can only change aircraft between runs.
- The flying machine must transmit video back to the ground station and/or pilot.
- Only electric-based flight propulsion is allowed. Both brushed and brushless motors are allowed. No modification to the motors is 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 during the setup time.  
For safety considerations, there must be a remote kill switch which powers down the drones in the event the flights go dangerously uncontrolled.

### 9.1 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.

### 9.2 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.

### 9.3 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 or 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.

### 9.4 DATALINK / VIDEOLINK / OTHER WIRELESS LINK TYPES

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 MHz  $\leq$  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 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  $\leq$  1000mW ERP
  - 158.275 / 162.875 MHz  $\leq$  1000mW ERP
  - 158.325 / 162.925 MHz  $\leq$  1000mW ERP
  - 453.7250 / 458.7250 MHz  $\leq$  1000mW ERP
  - 453.7375 / 458.7375 MHz  $\leq$  1000mW ERP
  - 453.7500 / 458.7500 MHz  $\leq$  1000mW ERP
  - 453.7625 / 458.7625 MHz  $\leq$  1000mW ERP
  - 2.4000GHz - 2.4835GHz  $\leq$  200mW Equivalent Isotropically Radiated Power (EIRP)
  - 10.500 – 10.550 GHz  $\leq$  117dB $\mu$ V/m @ 10m
  - 24.000 – 24.250 GHz  $\leq$  100mW EIRP
  - 5.725GHz – 5.850 GHz  $\leq$  4000mW EIRP
  - 5.150GHz - 5.350GHz  $\leq$  200mW EIRP
  - 5.470GHz - 5.725GHz  $\leq$  1000mW EIRP
  - 57 – 66 GHz  $\leq$  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.

## 9.5 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.

## **10. 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) 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.
- 4) Video submissions by each participating team will result in team members being automatically awarded a Certificate of Participation for SAFMC 2023.
- 5) Awards and Prizes as listed in Section 5 may be changed and modified at the discretion of the SAFMC 2023 Committee.
- 6) Ensure that the team members' 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.