Category E
Challenge Booklet 2023

Organised by:

DSO NATIONAL LABORATORIES

SCIENCE CENTRE singapore

Supported by:

MINDEF SINGAPORE

Partners:

DSTA Defence Science & Technology Agency

THE AIR FORCE ABOVE ALL

ST Engineering Aerospace

SP Singapore Polytechnic

NYP NANYANG POLYTECHNIC

REPUBLIC POLYTECHNIC DISCOVER. TRANSFORM. ACHIEVE

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

NUS National University of Singapore

SINGAPORE YOUTH FLYING CLUB

FLIGHTSCIENCE AERO LABORATORIES

JUST FLY IT

SAFMC 2023 CAT E CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	16 Nov 2022	Official challenge booklet release
1.1	16 Dec 2022	Update of prizes

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 MOH 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

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 the 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 organizer 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 E 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 E 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 E 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 E, 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 E 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 E, but there may not be a winner for this award.

5.3 PRIZES

CATEGORY E				
Awards	**Medals**	**Trophy**	**Cash Prize**	**Remarks**
Cat E Championship Award	✓	✓	$20,000	
Cat E 1st Runner Up	✓		$15,000	
Cat E 2nd Runner Up	✓		$10,000	3rd and 4th runners up will receive medals **only**
Cat E Judge's Commendation	✓		$1,000	Up to two teams can win this award

Note: Prizes may not be given out if minimum standard is not met or if there are insufficient participants. The SAFMC organising committee will have the **final** say and the decision made is **final**.

6. CATEGORY E MISSION

Teams are required to design a system of 10 to 25 flying machines, using either a centralised or de-centralised fully autonomous control system. The system has to possess localisation, obstacle sensing and obstacle avoidance capabilities. The flying machines and localisation system can be customised or commercial off-the-shelf (COTS) products, and need not be homogenous.

The description of the mission tasks and scoring criteria will be detailed 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 machines can be found in Section 9.

CATEGORY E CHALLENGE (SEARCH-AND-RESCUE MISSION)

Category E requires participating teams to design a fully autonomous system of flying machines to navigate through an indoor environment and search for victims. Teams will be awarded points for each victim found and the total time taken to complete the mission.

6.1 MISSION TASKS

The mission requires the system of drones to collaboratively explore an indoor environment and search for victims.

Take-off: A 7.5 x 5m take-off area will be marked on the ground. The drones are to take-off simultaneously within the area. Simultaneous take-off is defined as having all drones take off within 10 seconds of the first drone taking off.

Search: The swarm shall search for victims in the playing area. The number of victims and their positions will be unknown to the teams. Each team shall provide 10 markers to be used as the victims. The markers must be non-electronic and smaller than A4 size. The victims will be placed at least 1 m away from the edge of the netted area.

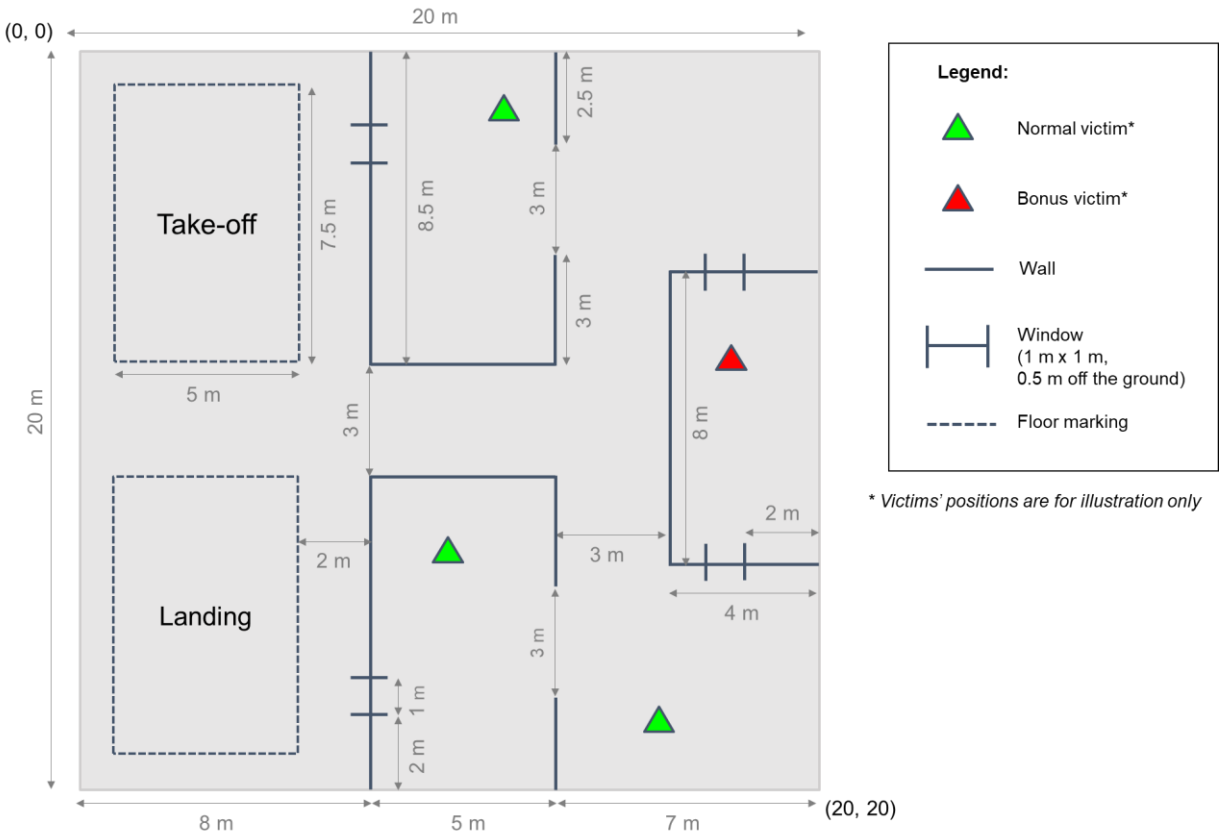
Rescue: Upon finding a victim, rescue is simulated by having 1 drone land within 1 m of the victim. The drone will remain there until the end of the mission (i.e. the drone does not have to return to the Landing area).

Landing: The swarm must decide when it has sufficiently searched the playing area. The remaining drones end the mission by landing within a landing area demarcated on the ground. No part of the drone should be outside the line for points to be awarded for landing. The mission time will be recorded when there are no drones left in flight.

Reporting: The victims' positions shall be reported to within 2m accuracy (from centre of the victim), taking reference from the corner of the playing area.

6.2 PLAYING FIELD

A plan view schematic of the 20 x 20 m playing field is shown below. The playing field is symmetrical, and will be surrounded by netting. The victims' positions shown are for illustration purposes only. A room accessible only via windows will contain **ONE (1)** bonus victim. For reporting of the victim's positions, the corner of the playing area where the take-off area is located will serve as the origin.



Dimensions of specific elements are listed below.

Take-off and landing area: 7.5m x 5 m rectangles marked out on the ground.

Walls: The walls will be 2.5 m high. Refer to the above schematic for the length of the walls.

Corridors/Doorways: Any corridors and doorways will be at least 3 m wide.

Windows: The windows will be 1 m wide and 1 m tall. They will begin at 0.5 m off the ground.

6.3 MISSION RULES

- Every team will have **TWO (2)** runs per stage. The mission time cap for each run will be **FIFTEEN (15) minutes**. The timer will start when the drones take-off and stop when all drones have landed.
- Teams will have **TWENTY (20) minutes** prior to each run to set up their system. The time for their run will start once their setup time is up.
- A minimum of **TEN (10)**, and a maximum of **TWENTY-FIVE (25)** drones are required to participate in each run.

- All drones are required to have LED lights of any colour that is visible 360° around the drone for visibility. These lights have to be switched on throughout the entire duration of the mission.
- Drones are **NOT** to be physically connected to each other.
- Ground robots are **NOT** allowed to be used.
- Drones are not allowed to fly over walls.
- The netted playing area must be clear of persons when any drone is in flight.
- Teams are not allowed to repair/troubleshoot the drones during the run. Any drones that malfunction during the run will be considered to be out for that run. The team may continue the run with their remaining flying machines if they are deemed safe by the Chief Referee or Category E Technical Chairperson.
- Teams are allowed to repair their drones in between runs. There will be no restriction on the number of spare aircraft the team can prepare so long as the drone has passed the scrutineering, at the discretion of the Chief Referee or Category E Technical Chairperson.
- External localisation systems (e.g. ultra-wide band systems) are allowed but they must be set up within the netted arena and can only be set up during the setup time provided at the start of each run.
- Visual fiducial systems (eg AprilTag) are allowed as long as they can be removed without leaving marks on the arena or obstacles.
- Any localisation aids:
    - Must be placed within the netted playing area
    - Can only be placed during the set-up time
    - Must be removable without leaving a mark
    - Must be properly secured, e.g. will not topple over
    - Cannot be secured to overhead structures
- Each team shall provide **TEN (10)** markers to be used as the victims. The markers must be non-electronic and smaller than A4 size.
- The take-off and landing areas will be demarcated on the ground. Teams have to take off and land within these areas.
- Additional drones are not allowed to take off after the initial simultaneous take-off.
- If multiple drones land next to a victim, it will still be counted as only ONE (1) victim rescued.

- The distance between a victim and a drone shall be measured from the nearest edge of the drone to the centre of the marker.
- Teams will submit their reports of victims' positions at the end of the run. The number of reports will be capped by the actual number of victims.
- If all the drones become inoperable before any victim is found, they will be given a Did Not Finish (DNF) timing and **ZERO (0)** points will be awarded for their time score.
- If the mission time cap is reached or all of the drones become inoperable, the scores up to that point will be considered.

6.4 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.

Scoring Criteria	Points Awarded
Number of victims rescued	+10 per normal victim +25 for bonus victim
Correct reporting of victims' position	+5 per normal victim +5 for bonus victim
Number of drones that have taken off simultaneously	$+10 \times \frac{Number\ of\ drones\ that\ have\ taken\ off}{Total\ drones}$ No points will be awarded if less than 10 drones have taken off
Number of drones that returned to landing area	$+20 \times \frac{Number\ of\ drones\ that\ returned\ to\ landing\ area}{Total\ drones - Number\ of\ victims\ rescued}$ No points will be awarded if less than 10 drones have taken off
Mission completion time	+25 for fastest team +5 for slowest team Points for other teams will be scaled accordingly No points will be awarded if no victims have been rescued/reported.
* Total drones refer to the number of drones placed in the take-off area for the run, i.e. including drones that did not take off	

6.5 PENALTIES

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.

LIST OF MISSION PENALTIES

S/N	DESCRIPTION	PENALTY
1	Exceeding the 20-minute setup time	Mission time will start regardless.
2	Use of external markers outside of the playing field.	Referee's discretion or **disqualification**
3	Internal markers within the playing field that are unable to be removed or leave a mark after being removed.	Referee's discretion or **disqualification**
4	Internal markers within the playing field that cause harm to persons or damage to structures, e.g. tripod stands toppling due to improper securing.	Referee's discretion or **disqualification**
5	Interrupting the competition by potentially interfering with other competitors, e.g. switching on your platform's VTX, transmitters, etc.	Referee's discretion or **disqualification**
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 **disqualification**

7. SCORING

There are a total of **FIVE (5)** scoring components for the competition, namely: Aerial Platform **(A)**, Strategy **(S)**, 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 E 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**
Team Live Presentation	**A**erial Platform	10%
	Strategy	20%
	Learning Journey and Insight	10%
Team Challenge **V**ideo	Real-world Performance	10%
Competition Day **M**ission		50%
	Total	**100%**

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

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

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.

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

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

2) Software design, in particular describing how their proposed autonomous concept will work.
    - Explanation of flight control strategy
    - Explanation of swarm autonomy strategy

7.2 STRATEGY FACTOR (S)

The Strategy Factor (S) is based on the team's proposed strategy and algorithms to tackle the obstacle course. Teams are to explain how their drones, sub-systems, and swarm algorithms help in their mission strategy. These include:

- Choice of sensor suite used to tackle the mission
- Obstacle and collision avoidance method
- Localisation method
- Search strategy
- Method of communication between drones and ground control station (GCS)
- Any other algorithms used in completion of the mission

Teams are also encouraged to utilise and present unique concepts, which may include:

- Robust and intelligent methods of swarm control
- Effective utilisation of different kinds of drones in the swarm
- Non-conventional ideas and methods to complete the mission
- Methods to reduce time taken to complete the mission

7.3 LEARNING JOURNEY AND INSIGHT (L)

The **Learning Journey and Insight Factor (L)** is related to quality and content of the presentation.

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 t**eam challenge video (V)** scores provide a proof-of-flight insight into how the aircraft performs.

1) Flight-worthiness
    - Aircraft must be shown to perform stable, sustained flight
    - Video of the swarm taking off simultaneously
2) Mission-readiness
    - Demonstrate that swarm is shown to be able to fulfil mission requirements.

- Explain the on-board sensor suite for each unique drone used in the challenge
- The swarm must be shown to avoid static obstacles
- The swarm must be shown to search a room containing at least TWO (2) victims, and land next to them when detected

3) Creativity
   - Resourcefulness in re-creating competition layout to showcase similar mission requirements.

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.

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 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 presentation

2) Teams are to prepare **ONE (1)** presentation in slides format that caters to a larger audience. The presentation material is to be submitted by **10 Mar 2023, 2359hrs** to SAFMC@science.edu.sg with title subject: "[CAT E] - [Team Name] - Presentation Material"

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 with title subject: "[CAT E] - [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 **1kg**.

   2.2 The platform **should not exceed 30cm** 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 for **FIFTEEN (15)** minutes. The mission time will end when the mission time is up, the mission is successfully completed, or when all drones are no longer operational.

4) Each team will be granted up to **TWENTY (20)** minutes to set up and calibrate their swarm system inside the playing field. At the end of this setup time, the mission time will start immediately regardless of whether the setup has been completed. Any extra setup time needed will be accounted for as part of the mission time. Once the mission 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.

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 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 Category E 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 1.0kg.**
- The platform **should not exceed 30cm** in any direction (this measurement includes the maximum diameter of the propeller circles).
- Participants are only allowed to use up to **TWENTY-FIVE (25)** 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.
- 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, the swarm must be able to stop the mission and power down.

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

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

- 29.700 - 30.000 MHz ≤ 500mW ERP
- 26.96 - 27.28 MHz ≤ 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.

9.4 DATALINK / VIDEOLINK / OTHER WIRELESS LINK TYPES

1) The following frequencies are approved by IMDA for radio telemetry:
   - 433.05 - 434.79 MHz ≤ 10mW ERP
   - 866 - 869 MHz ≤ 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 ≤ 117dBµV/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.

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 2022.
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 2022 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.