



# Category E Challenge Booklet 2022

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## SAFMC 2021 CAT E CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	22 Nov 2021	Official challenge booklet release

## SAFMC 2022 COMPETITION SCHEDULE

Date*	Event	Platform/Venue
7-18 March 2022	Pre-Challenge Submission	Email
16-23 March 2022	Presentation	Teleconference
4-14 April 2022	Category Challenges	Singapore Expo
16 April 2022	Awards Presentation Ceremony	Singapore Expo

*\* 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.*

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# SINGAPORE AMAZING FLYING MACHINE COMPETITION 2022

## 1. INTRODUCTION

In celebration of DSO National Laboratories' (DSO) 50<sup>th</sup> Anniversary in 2022, SAFMC is enhanced in both challenges and prizes [CAT D & E] to allow students to push the boundaries of innovation by designing and creating extraordinary flying machines. The event is organised by DSO and Science Centre Singapore, and supported by Ministry of Defence (MINDEF). Open to all schools and participants, 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, an FPV drone to compete in an obstacle course.

**[ENHANCED] 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 three autonomous small air platforms to collaboratively perform a multitude of tasks in an indoor course.

**[ENHANCED] 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 an obstacle course.

### **3. GENERAL SAFMC 2022 RULES**

- **The deadline for registration is 18 February 2022.**
- 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 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 2022 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 2022 Awards Presentation Ceremony.

### **4.1 PRESENTATION**

The teams will be allocated a specific time slot to showcase their flying machine on a virtual platform. 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 vie for the SAFMC Championship Award. Teams that do not show their flying machines for the virtual 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 is 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 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 D				
Awards	Medals	Trophy	Cash Prize	Remarks
*Cat E <b>Swarm</b> Championship Award	✓	✓	\$20,000	
Cat E <b>Swarm</b> 1 <sup>st</sup> Runner Up	✓		\$15,000	
Cat E <b>Swarm</b> 2 <sup>nd</sup> Runner Up	✓		\$10,000	3 <sup>rd</sup> and 4 <sup>th</sup> runners up will receive medals <b>only</b>
Cat E Judge's Commendation	✓		\$1,000	Up to two teams can win this award

\* **SPECIAL NOTE:** The Championship Award may not be given out if none of the top 3 teams meets the minimum standard determined by the organisers or if there are insufficient participants for each category. The SAFMC organising committee will have the **final** say and the decision made is **final**.

\*\* **PANDEMIC RESTRICTIONS:** The Awards and Prizes are subject to change in case of pandemic restrictions preventing SAFMC 2022 from being held in-venue.

## 6. CATEGORY E MISSION

Teams are required to design a system of 10 to 25 flying machines, using either a centralized or de-centralized, fully autonomous control system. The system has to possess localization, 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 obstacle course, 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 (OBSTACLE COURSE)

**Category E** requires its participating teams to design a fully autonomous system of flying machines to navigate through a series of obstacles. Teams will be awarded points for completing each obstacle and the total time taken to complete all the obstacles.

#### 6.1.1 MISSION TASKS

The mission requires the system of drones to take off in formation, navigate and manoeuvre through an obstacle course as a coordinated swarm, and land in formation.

Take-off: A 6x6m take-off area with the outline of a circle of 5m diameter printed on it will be placed on the ground. The drones are to form a formation that is the circumference of this circle during take-off. They can be placed within the area enclosed by the circle as long as a clearly discernible circle has been formed by the drones in the outer perimeter.

Obstacle 1: The swarm is to hold the take-off formation as they move towards and over the high wall. The drones are to hold this formation until the last drone passes the trailing edge of the wall.

Obstacle 2: The swarm is to navigate through a series of standing poles. Drones have to enter from the front and exit from the end of the obstacle. Any drone that does not enter from the starting line or exits along the sides of the obstacle will not be counted

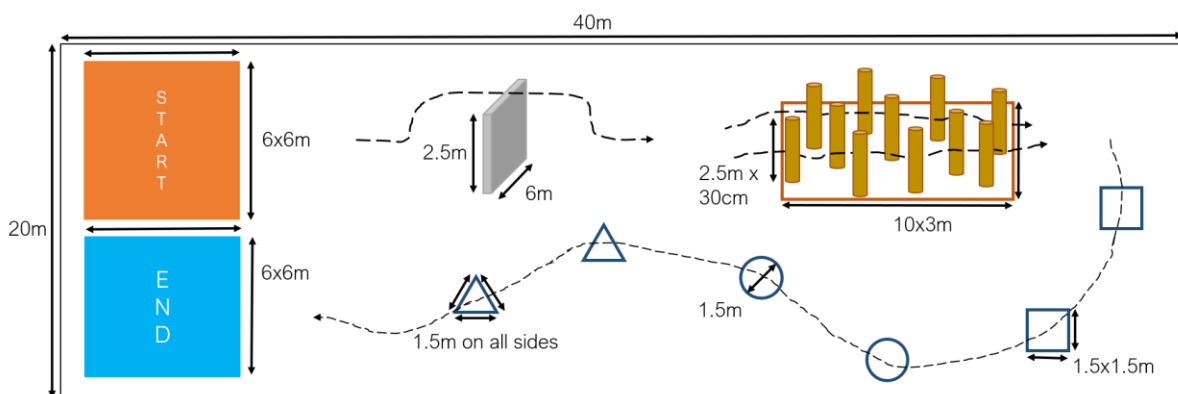
as having completed the course. The positions of the poles will not be known to the teams before the competition.

**Obstacle 3:** The swarm is to fly through 6 hula hoops. A drone will be considered to have successfully completed this obstacle only if it has flown through **ALL** the hula hoops.

**Landing:** The swarm is to land within the marked landing zone. A landing area identical to the take-off area will be demarcated on the ground, and the swarm is to land within the area enclosed by the circle. No part of the drone should be outside the line for points to be awarded for landing.

## OBSTACLE COURSE

A plan view schematic of the obstacle course is shown below. All the obstacles will have LED lights installed on them in a variety of colours. During each run, the lights in the event hall will be dimmed.



The dimensions of each obstacle are listed below.

**Take-off and landing pad:** 6m x 6m square with the outline of a 5m diameter circle printed on it.

**Obstacle 1:** The high wall will be 2.5m high, with a width of 6m and a thickness of approximately 10cm.

**Obstacle 2:** The poles are 2.5m tall with a diameter of 30cm. They will be placed in an area covering 3m by 10m, with at least 50cm distance between each pole. The exact position of each pole will not be known to the team before the competition day.

Obstacle 3: Three different kinds of hula hoops will be used. The height between the ground and the bottom of each hoop is 1m, and the hoops will be positioned roughly 2m apart from each other, in a manner that the next hoop will be visible once the previous hoop is completed.

- Square hoop: 1.5m x 1.5m
- Circular hoop: diameter of 1.5 m
- Triangular hoop: 1.5m on all sides

### 6.1.2 MISSION RULES

- Every team will have **TWO (2)** runs per stage. The mission time cap for each run will be **TEN (10) to FIFTEEN (15) minutes** depending on the number of participating teams. The timer will start when the first drone takes off and stop when the last drone lands.
- 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. The total number of drones used in scoring will be the total number of drones that successfully take off in formation. Points will be deducted for setting up or taking off with less than the minimum number of drones.
- All drones are required to have LED lights of any colour that is visible 360° around the drone from a distance of **TEN (10) metres**. 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.
- If the mission time cap is reached or all of the drones become inoperable, the scores up to that point will be considered.
- If all the drones become inoperable before completing the obstacle course, they will be given a Did Not Finish (DNF) timing and only **FIVE (5)** points will be awarded for their time score.
- 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 aircrafts 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 localization 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 (e.g. AprilTag) are allowed as long as they can be removed without leaving marks on the arena or obstacles.
- The take-off and landing areas will be demarcated on the ground. Teams have to take off and land in a **CIRCULAR** formation that covers these areas.
- The circular formation for taking-off and traversing of obstacle 1 will be judged using transparencies overlaid onto a top-down video of the run. This transparency will have rings that define the  $\pm 15\text{cm}$  margin of error allowed for the drones when in the formation. Any drones that exceed this margin of error will be counted as not successfully completing the obstacle.
- **NO** points will be awarded for the drones that skip or miss any of the obstacles. Skipping or missing of obstacles is defined as:
  - Travelling around the left or right side of obstacle 1
  - Traveling over or around the left or right side of obstacle 2
  - Travelling anywhere but within the area enclosed by the hula hoops of obstacle 3

### 6.1.3 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.

The scoring rubric is constant throughout all stages, unless otherwise stated.

Mission Scores	
Rubric	Points Awarded
Time score: Time taken to complete the obstacle course	+15 points for Fastest Team +5 points for Slowest Team Points for other teams will be scaled accordingly
Number of drones to successfully take off	+1 / drone
Percentage of drones* to complete each obstacle	+20 x percentage of drones
Percentage of drones* that landed within the landing zone	+20 x percentage of drones

\* Percentage of drones is calculated using the total number of drones that had successfully taken off in that run.

### 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 15 minutes setup time	Mission time will start regardless.
2	Use of external markers outside of the playing field.	Referee's discretion or <b><u>disqualification</u></b>
3	Internal markers within the playing field that are unable to be removed or leave a mark after being removed.	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	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>
8	Skipping/missing of any number of hula hoops	No points given
9	Exiting the 3 <sup>rd</sup> obstacle via the sides	No points given
10	Skipping/missing of the obstacles	No points given

## 7. SCORING

There is 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 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
<b>Presentation</b>	Aerial Platform	10%
	Strategy	30%
	Learning Journey and Insight	10%
<b>Competition</b>	Team Challenge Video	10%
	Mission	40%
	<b>Total</b>	<b>100%</b>

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. It carries a 10% 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

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. It carries a 30% weightage to the total score. Teams are to explain how their drones, sub-systems, and swarm algorithm help in their mission strategy. These include:

- Choice of sensor suite used to tackle the mission
- Obstacle and collision avoidance method
- Localisation strategy
- Method of formation holding and creation
- How communication is done between drones/ground control station (GCS)
- Any other algorithms used in completion of the obstacle course

Teams are also encouraged to utilize 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 obstacle course
- Methods to reduce time taken to complete the obstacle course

## 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 the swarm taking off and landing in formation synchronously
  - Video of swarm moving together left, right, up, down, and vertically.
- 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
  - For Cat E, the completion of each obstacle must be shown clearly.
- 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. 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 on a teleconference platform such as Zoom. Teams will share about their swarm system. For CAT E, the presentation is currently tentatively scheduled for **16 March 2022**.

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 2022, 2359hrs** to [SAFMC@science.edu.sg](mailto: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](mailto:SAFMC@science.edu.sg) with title subject: “[CAT E] - [Team Name] – Challenge Video” before the deadline. The deadline for submission is **10 March 2022, 2359hrs**. Video should be uploaded before the deadline, and any re-upload of the video detected past the deadline may result in **penalization** or **disqualification**. You may write in to the SAFMC 2022 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 WiFi 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 **TEN (10) to FIFTEEN (15)** minutes depending on the total number of participating teams and the competition schedule. 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 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 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.

- 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, 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  $\leq$  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 ≤ 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 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  $\leq$  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 2022 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 2022 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 2022 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 2022 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.