



# Category D Challenge Booklet 2019

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# SINGAPORE AMAZING FLYING MACHINE COMPETITION 2019

## 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 students who want 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 accurate flight.

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

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

Design and build small unpowered gliders to be bungee-launched from designated launcher in a bid to fly the furthest.

### **CATEGORY C – RADIO CONTROL FLIGHT** (*Secondary Schools / Integrated Programme / Junior Colleges / Institute of Technical Education*)

#### Category C1: Fixed Wing Radio Control Flight

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 – Tiny Whoop (*All Schools*)

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

Bring or design a FPV (first-person view) Tiny Whoop class drone to navigate an obstacle course.

Category C3: FPV Flight – Micro (*All Schools*)

Each team should consist of **ONE (1)** member.

Bring or design a FPV (first-person view) Micro class drone to navigate 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 a semi-autonomous small air platform to perform a multitude of tasks in an indoor open course.

Category D2: Autonomous

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

Design and build an autonomous small air platform to perform a multitude of tasks in an indoor open course.

**CATEGORY E – UNCONVENTIONAL** (*Open to Public*)

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

Design and build unconventional air platforms or showcase co-operative technology, and demonstrate its flight within a confined indoor area.

### 3. GENERAL SAFMC 2019 RULES

- The deadline for the competition registration is 31 January 2019.
- Participants registered under a school must be a full-time student at the point of competition.
- Home-schooled participants and teams consisting of students from different schools should register as “Independent teams”.
- Participants will be notified upon successful registration within two weeks of the registration deadline. The decision made by the SAFMC organising committee is final, and is subject to the availability of the competition schedule and logistics support.
- Each member 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 for 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 higher than their educational standard, 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.
- Members and family members of the organising committee are not allowed to participate in SAFMC.
- The organisers reserve the right to amend the rules and regulations. In the event of any change, all teams will be informed **FOUR (4)** weeks prior to the start of the competition.
- Prizes will be issued to the Team Manager.
- A safety net will be set up around the perimeter of 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 a safe distance from the netting to avoid accidental entanglement.
- The organisers of SAFMC 2019 will not be held responsible for any damage to, or the loss of, any flying machine(s) throughout the entire competition.

- All participants will be held responsible for the safe flying of their flying machine(s) throughout the entire competition. The organisers reserve the right to ground the flying machine(s) of any team.
- For any queries regarding the competition, please send an email with the title addressed to the relevant category (e.g.: [CAT D] - 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, the Challenge and the Presentation (*excluding Category C2 and C3 which do not require presentation*).

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

The top team from each category will be bestowed with the championship award to be presented at the SAFMC 2019 Awards Presentation Ceremony.

### **4.1 PRESENTATION**

During the presentation, teams will be allocated a specific time slot to present about their flying machine in ITE College Central. 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 bring their flying machines for the presentation will be disqualified immediately. Depending on the category, there may be additional requirements to the Presentation segment.

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

## 4.2 CHALLENGE

For the Challenge, teams (*except Category C2 and C3 which allow commercial off-the-shelf products*) are to design, build and fly their flying machines to overcome various challenges for the different SAFMC categories.

For Category C, D and E participants, tables may 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 course of the competition:

- The competition hall will open at 8 am. Only registered team members of the participating teams can enter the competition hall from 8 am to 6 pm.
- As for spectators, there is a separate entrance to the spectators' viewing gallery and they are not permitted to enter the competition zone (playing field and team booths).
- No trial runs will be allowed in the flying area unless specified by the officials.
- For Category C1, D and E participants, all transmitting devices **must** be surrendered to SAFMC officials.
- For Category D and E participants, no video transmitting devices, including spares, should be powered on in the competition hall unless specified by the officials.
- For Category C1, D2 and E participants, no team is allowed to charge batteries within the competition hall. The team is required to bring sufficient batteries for all the missions.



## 5. CATEGORY D AWARDS

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

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

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.

The list of awards for Cat D1 and D2 are listed in the subsequent sections.

### 5.1 CHAMPIONSHIP AWARD

This is the most prestigious award any team can win, and is bestowed on the team that achieves the highest total score across all areas. For **each** category D1 and D2, there will be **THREE (3)** championship awards: a winner and **TWO (2)** runners-up. The score weightage can be found in Section 7.

### 5.2 JUDGES' COMMENDATION

This award is given out to Category D teams (excluding the top three winning teams from D1 and D2) exhibiting a high quality in design and/or performance. Overall scores may be taken into consideration for this award. Up to **TWO (2)** awards may be given for the whole Category D, but there may not be a winner for this award.

## 5.3 PRIZES

CATEGORY D				
Awards	Medals	Trophy	Cash Prize	Remarks
*Cat D2 <b><u>Autonomous</u></b> Championship Award	✓	✓	\$5,000.00	**Additional trip prize – see below for details
Cat D2 <b><u>Autonomous</u></b> 1 <sup>st</sup> Runner Up	✓		\$3,000.00	
Cat D2 <b><u>Autonomous</u></b> 2 <sup>nd</sup> Runner Up	✓		\$1,500.00	3 <sup>rd</sup> and 4 <sup>th</sup> runners up will receive medals <b><u>only</u></b>
*Cat D1 <b><u>Semi-Autonomous</u></b> Championship Award	✓	✓	\$2,000.00	
Cat D1 <b><u>Semi-Autonomous</u></b> 1 <sup>st</sup> Runner Up	✓		\$1,000.00	
Cat D1 <b><u>Semi-Autonomous</u></b> 2 <sup>nd</sup> Runner Up	✓		\$500.00	3 <sup>rd</sup> and 4 <sup>th</sup> runners up will receive medals <b><u>only</u></b>
Cat D Judge's Commendation	✓		\$400.00	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 meet 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**.

***\*\* Cat D2 Autonomous Championship - Additional trip prize to represent Singapore in an International Flight competition.***

This prize will only be awarded if the judging panel agrees that the platform is suitable and competent enough to take part in the overseas competition. Also, the majority of the team sent overseas must be members of the SAFMC Championship team. The Championship team should notify the organising committee of their interest to take up the additional trip prize and the competition they intend to take part before **1 July 2019**.

## 6. CATEGORY D MISSION

**Category D1** requires its participating teams to race against each other through a series of obstacles and plays the game Tic-Tac-Toe by picking up and releasing payloads with a semi-autonomous platform.

**Category D2** requires its participating teams to complete a series of obstacles and challenges with a fully autonomous platform. The team to complete the competition course with the fastest recorded time wins the competition.

### 6.1 CATEGORY D CHALLENGE

Teams will be required to design and build **ONE (1)** small flying machine or significantly modify or enhance a commercial off-the-shelf product (COTS product) that is capable of semi-autonomous or fully autonomous flight.

The flying machine should also possess various sensors, payloads, and/or mechanisms to complete a variety of tasks in a complex environment without direct line of sight to the operator. The sensors and payloads to be integrated on the airframe can be designed to be modular/reconfigurable.

The detailed descriptions of the competition field, available mission tasks, as well as the scoring criteria are found in Section 6.3 to 6.6. 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.

#### 6.1.1 CAT D1 (TIC-TAC-TOE)

Every team will have **only one** attempt per game. The time cap for each game will be **10 to 15 minutes** depending on the number of participating teams. Teams are not allowed to repair/troubleshoot during the game. Once their aircraft is down, they will not be able to continue the game. The opponent however, has to continue to attempt to win the game. In the event that the opponent's aircraft is also down or the time is up, it will be a draw.

Teams with down aircraft are allowed to repair in between games. In the event that the aircraft is deemed incapable of flight, a new identical copy of the aircraft can be used for the next game. There will be no restriction on the number of spare aircrafts the team can prepare so long as the design of all the aircrafts remains the same.

There will be allocated playing field for the two teams separated by safety panels. In the event that any **part** of the aircraft crosses the safety panels, the team will be immediately disqualified.

### **6.1.2 CAT D2 (RED ALERT!)**

On the competition day, each team will have **TWO (2)** attempts. The **higher of the two attempt scores** will be used for scoring.

Each team will be given a **fixed time frame of 10 minutes** per attempt to complete the tasks present in the playing field using a **single flying machine**. Timing of each attempt will be recorded as well and will be used in the event of a tie in terms of the number of points earned.

Every team will be given 2 minutes of setup time prior to the mission start time. During the 2 minutes of setup time, teams are to ensure that their aircraft is ready for the mission and at any one point; only **2 team members** are allowed into the playing field to do any necessary setup. The 2 team members are to clear the playing field before the 2 minutes are up.

Once the 2 minutes are up, the mission time will automatically start. If the team does not start the mission **after 3 minutes**, the team will face a **penalty of 50 points** and the mission time will still be running. The mission time will continue to run throughout and will **not** be paused in the event of any landing, maintenance or repair works, etc.

A back-up aircraft that is **similar** to the primary aircraft may only be used in the event the primary aircraft has been determined to be incapable of flight for the remaining time left for the attempt.

During each attempt, the playing field will not be reset, and the team may perform as many flights (i.e. take-off and landings at the designated landing pads) as desired, reconfigure or repair their platform, etc.

For the 2<sup>nd</sup> attempt, the team can choose to either

- 1) Take their aircraft, place on the launch pad and straight away start the mission,  
or
- 2) Change some of the setup of the mission before starting the second attempt.

If the team chooses 1), they can start right after the first attempt and the mission time will restart. Do take note that whatever penalty incurred in the first attempt **will be** brought over to the second attempt.

If the team chooses 2), the team will be required to take down all the initial setup and same as attempt 1, they are given 2 minutes to do the setup for the second attempt. The same rules apply to the second attempt in terms of timing and penalty. In this case, the penalty incurred in attempt one **will not** be carried over to attempt 2.

Teams are only allowed to have **one** back-up aircraft that is similar to the primary aircraft.

## 6.2 DIFFERENTIATION BETWEEN CAT D1 AND D2

For **CAT D1**, 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, except during the initial take-off.

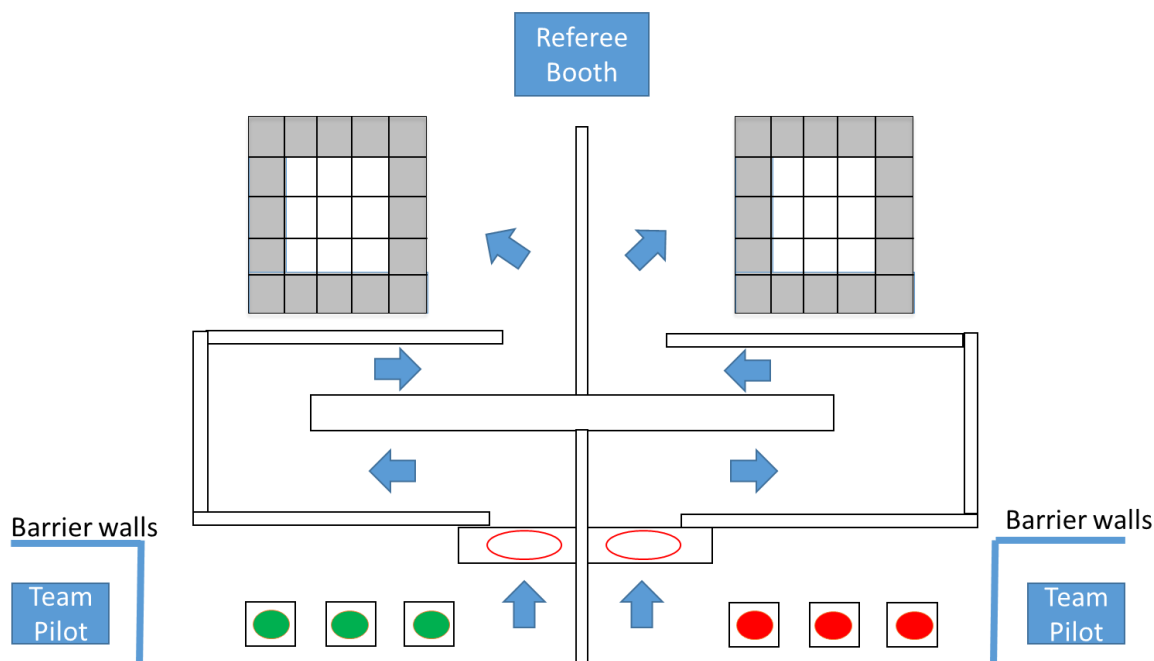
For **CAT D2**, the pilot needs to inform and demonstrate to the referees that the aircraft is in CIC mode before take-off. In this mode, the operators are not allowed to input directional commands to the aircraft via any method. However, they are allowed to enter discrete commands (e.g. mode switching). The Chief Referee is the authority to determine what is considered to be fully autonomous.

D2 teams are encouraged to have a safety pilot, to take over RC control to avoid a crash. The safety pilot may follow the aircraft (line-of-sight) from the edge of the field;

however he/she may not communicate in any way with the actual operator. Any take-over by the safety pilot, the aircraft will have to restart at a position determined by the Chief Referee.

## 6.3 COMPETITION SETUP

### 6.3.1 CAT D1 (TIC-TAC-TOE COMPETITION SETUP)



The competition setup for Category D1 is as shown above. There will be a net dividing the two playing fields. The teams will only know their Raceband channel prior to their game. They are then required to have their VTX broadcast at that channel at 200mW.

All teams are only allowed to use **ONE** VTX. After the game, they are to have their VTX broadcast at Raceband channel 8 at 25mW before leaving the playing field. The possible channels are shown below.

	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

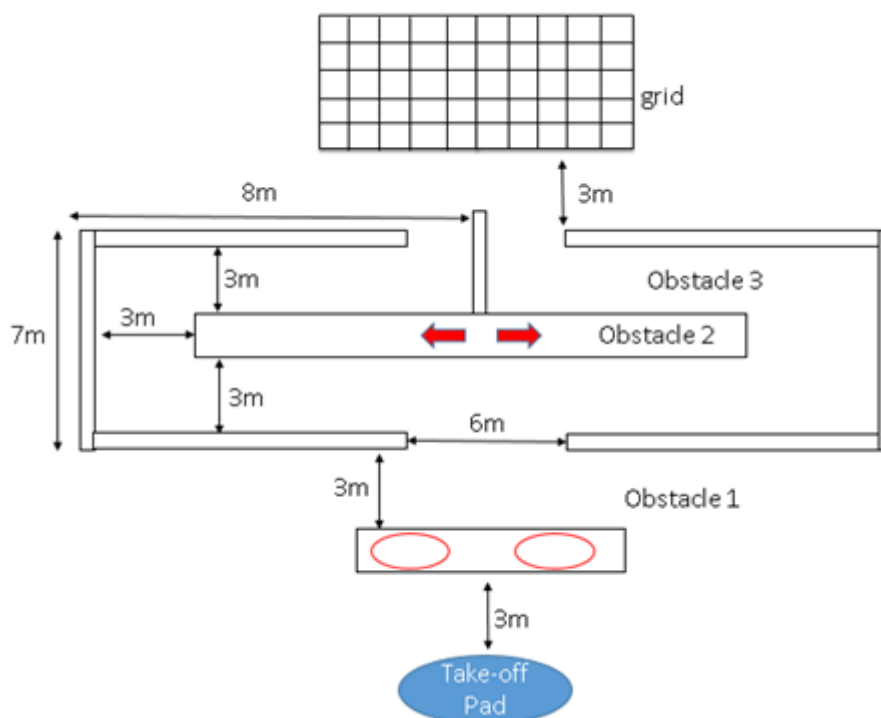
The two teams will have to navigate the aircraft via FPV through the same mini obstacle to drop the bean bag onto the square they want in order to win the game.

In the event that the bean bag does not fall within the square (e.g. bean bag touching the black border), it will not be counted and the square is still available. When the bean bag lands within the square, the team colour will light up (be it green or red), indicating that the square has been taken up.

Once the bean bag is dropped under any circumstances, teams are **NOT allowed** to retrieve the dropped bean bag. They are required to fly back to the launching pad to pick up a new bean bag.

Even though the 2 teams are playing on two different playing fields, there will be a spotter who will provide real time update via the light indicator so that both teams will know which square is taken and what is required to win the game. First team to connect 3 squares (3 same colours) in a row wins the game.

### 6.3.2 CAT D2 (RED ALERT!) COMPETITION SETUP



The competition setup for Category D2 is as shown above. The aircraft is to carry a total of 5 x 13-15g payload which will be dropped on the required square at the grid to plug the leak. There will be 3 main obstacles:

- 1) *Lighted window.* There will be 2 x 1.5m diameter circular windows surrounded with **RED** LED lights. One window will be lighted up after the aircraft takes off, the aircraft will have to fly through the lighted window.
- 2) *Directional change.* 2 **RED** LED arrows will be hung on the wall, pointing to opposite directions. The arrow will be a transparent acrylic case with the LED light in it. After completing the first obstacle, one of the two arrows will light up, the aircraft will have to fly in the direction of the lighted arrow.
- 3) *Narrow corridor.* After completing obstacle 2, the aircraft will need to navigate its way through a narrow corridor into the open area with the grid.
- 4) *The Grid.* A **RED** square will indicate the location of the leak. The aircraft will need to release **ONE** payload at a time on the **RED** square. Only when the payload successfully lands within (**touching of black border invalids that attempt**) the square, will another square be lighted up red. The previous red light will remain on. There will be a total of 5 leaks (maximum 5 red lights) and once all leaks are plugged, or when the aircraft runs out of payloads, a square will be lighted **GREEN** and the aircraft is to perform a precision landing on that **GREEN** square.

In the event that the team needs to repair/troubleshoot the aircraft, they are required (if possible) to land the aircraft either on the launching pad or on the grid. And all repairs/troubleshoot should be done outside of the playing field.



## 6.4 MISSION TASKS

### 6.4.1 CAT D1 (TIC-TAC-TOE)

To be the fastest team to link 3 squares together (3 same colours in a row) and win the game of Tic-Tac-Toe. Teams are to pick up their payload (bean bag – 85g) one at a time and release on an available square on the grid to form 3 in a row.

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 bean bags is preserved.

Teams are **ONLY** allowed to **drop** the payload. Any involvement of releasing the pre-made attachment, with or without the payload, will require the aircraft to **LAND** before releasing it. Payload must land within the black border of the square for it to be counted. (ie. If the payload touches the black border, it is not counted).

### 6.4.2 CAT D2 (RED ALERT!)

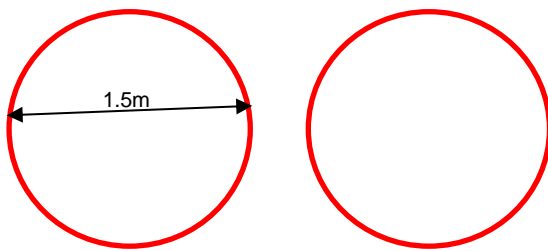
There is a gas leak being detected in the building and the building system has located the source of the leaks. There are a total of 5 leaks found and your team is called upon to deploy your aircraft to plug the leaks by delivering small payloads.

The aircraft has to be fully autonomous from take-off to landing, with some aid of discrete mode switches pre-programmed by the team. The aircraft is also required to manoeuvre through a series of obstacles before reaching the location to plug the leak.

The mission requirements are:

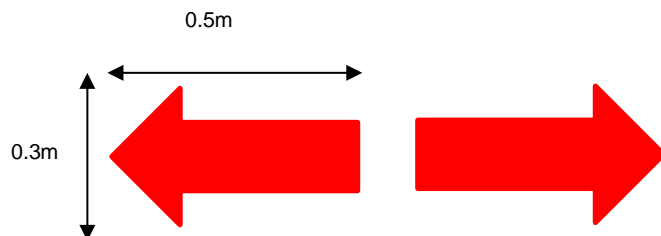
- 1) Autonomous take-off and precision landing
- 2) Vision-based GPS-less navigation and flight
- 3) On-board real-time decision making
- 4) Precision multiple payload delivery – 5 x (13g-15g) payload

First obstacle – Lighted window



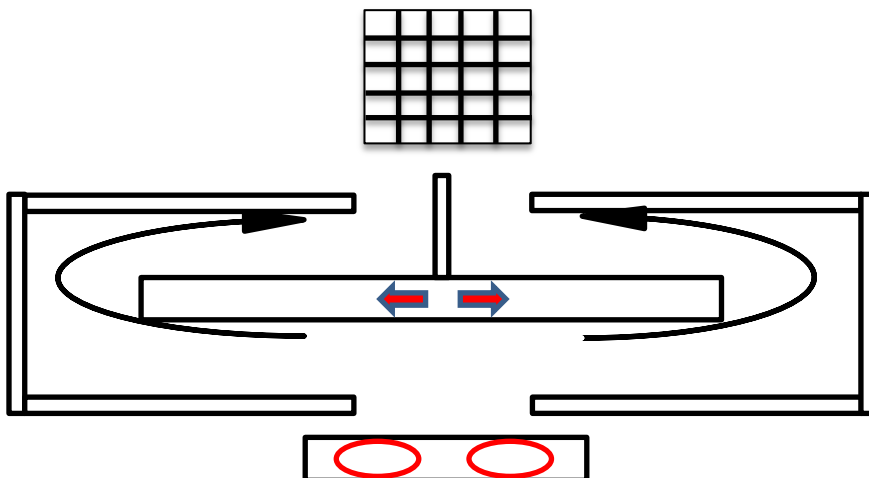
There will be 2 windows. After take-off, the rim of one of the 2 windows will be lighted up red, and the aircraft is to fly through the lighted window.

Second obstacle – Directional change



After flying through the window, **one** of the 2 arrows will light up in red. The aircraft is to fly in the direction of the light arrow.

Third obstacle – Narrow corridor



The aircraft is to navigate through the narrow corridor, either left or right side, depending on which arrow is lighted up.

### Final challenge

After navigating through the narrow corridor, the aircraft will be able to see the grid. One of the square grids will be lighted up in red. That is the location of the leak. The aircraft is to fly over to the lighted square and drop one of the payloads onto the square to plug the leak. Similar to CAT D1, it will only be counted if the payload lands within the black border (i.e. If the payload touches the black border, it is not counted).

Only after the leak is plugged, another red square will light up to indicate another leak location and the aircraft will be required to fly over it to drop the payload to plug the leak. The previous red square will remain turned on. There will be a total of 5 leaks; hence there will be a maximum of 5 red squares.

In the event when there is no more payload left or the team has completed plugging all 5 leaks, one square will be lighted up in green. The aircraft is then required to perform precision landing onto the green square.

## **6.5 SCORING FOR MISSION TASKS**

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.

### **6.5.1 MISSION FACTOR (D1):**

Teams will be playing in round robin (league) format against each other and points will be given according to Tic-Tac-Toe results.

<b>Tic-tac-toe Results</b>	<b>Points</b>
Win	3
Draw	1
Lose	0

## 6.5.2 MISSION FACTOR (D2):

Teams will be given 2 attempts and the better result of the 2 will be taken into consideration.

Mission	Points
Correct Window	20
Correct Direction	20
Each payload delivered	10, 15, 20, 25, 30
Precision Landing	10

## 6.6 MISSION 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.

### 6.6.1 LIST OF MISSION PENALTIES:

S/N	DESCRIPTION	PENALTY
1	Exceeding the 2 minutes setup time.	Mission time will start regardless.
2	Setup time exceeding 3 minutes.	50 points
3	External markers outside of the playing field.	Referee's discretion or <b><u>disqualification</u></b>
4	Internal markers within the playing field unable to be removed or leave a mark after being removed.	Referee's discretion or <b><u>disqualification</u></b>

S/N	DESCRIPTION	PENALTY
5	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>
6	Teams using more than one VTX for D1.	Referee's discretion or <b><u>disqualification</u></b>
7	Aircraft crossing safety panels in the playing field for D1.	Referee's discretion or <b><u>disqualification</u></b>
8	Attempting to subvert competition rules or gain an unfair advantage over other teams, e.g.: receiving assistance from spectators, teammates illegally communicating to the pilot when the aircraft is airborne, etc.	Referee's discretion or <b><u>disqualification</u></b>

## 7. SCORING

There are a total of **FOUR (4)** scoring components for the competition, namely: Aerial Platform (**A**), Smart (**S**), Presentation (**P**), and Mission Accomplished (**M**). The former three will be assessed during the presentation segment while the Mission Accomplished 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:

**Table 5.1: Scoring weightage**

Segment	Factor	Weightage
<b>Presentation</b>	Aerial Platform Factor	15%
	Smart Factor (Creativity)	15%
	Presentation Factor	10%
<b>Competition</b>	Mission Accomplished Factor	60%
	<b>Total</b>	<b>100%</b>

For both **CAT D1 and D2**, the total score **T** is computed as:

$$T = A + S + P + M$$

## 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:

### 1) Aerodynamic design

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

### 2) Mechanical and aesthetic design

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

### 3) Electronics design

- Power / Battery sizing to meet design objectives
- Explanation of choice of sensor suite for the given environment
- Explanation of choice of embedded computer / microprocessor

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

- Explanation of effectiveness of semi-autonomous / flight control strategy
- Explanation of how semi-autonomous design was translated into software
- Explanation of effectiveness of autonomy strategy
- Explanation of how autonomous design was translated into software
- Lower points will be given for unreferenced use of open-source code. Teams should reference the use of open source codes where it is used.

## 7.2 SMART FACTOR (S)

The **Smart Factor (S)** is a measure of the team's creativity in the design of their flying machine and control interface, or any sub-system which aids in their mission strategy. It is not mandatory to adopt unique concepts, but teams that do so will score higher for this factor. Examples of innovative approaches may include:

- More intuitive methods to control the platform / camera to ease pilot workload and reduce human error
- Augmenting the video feed with real-time navigation data to improve situational awareness
- Non-conventional ideas and methods to achieve mission task(s)

## 7.3 PRESENTATION FACTOR (P)

The **Presentation Factor (P)** will be awarded for the quality of the presentation. Examples of factors used to assess this score are as follows:

- 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) Relevant 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
- 4) Teamwork
  - Presentation should highlight the work of all the team members, and how they cooperate
- 5) Fun
  - Should be able to capture the attention of the judges
  - The judges should enjoy your presentation



## 7.4 MISSION ACCOMPLISHED FACTOR (M)

The higher of the two mission attempt scores for D2 will form the **Mission Accomplished Factor (M)** score for D2. Please refer to Section 6.5 and 6.6 for the mission scoring and penalties.

## 8. COMPETITION DAY FLOW OF EVENTS

### 8.1 PRESENTATION SEGMENT

Teams will have to deliver an oral presentation to a panel of judges about the work they have done for this competition and show their actual flying machine. Teams will be given a maximum of **TEN (10)** minutes for this segment (**FIVE (5)** minutes for presentation, **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) Submit **TWO (2)** copies of A4-sized coloured photograph (printed on regular A4 paper) which clearly depicts:
  - An isometric view of the whole flying machine
  - The team's name.
- 2) Declare their mode of flight (semi-autonomous / autonomous)
- 3) Bring the actual flying machine(s) for a visual inspection
- 4) Prepare up to **TWO (2)** A1-sized posters to aid in an oral presentation describing:
  - The mission strategy and the platform design considerations
  - Overall airframe sizing, form factor, configuration
  - Aerodynamics, mechanical, electronics, and software / flight control design
  - Any key or unique features of the aircraft that enable the execution of the mission strategy

- 5) Teams are recommended to prepare a brief video (approx. 1 – 2 mins) that showcases the unique features of their platform, and that it is airworthy and capable of flight.

Teams will **not** be allowed to make major changes to their flying machine design after the presentation. Non-compliance may lead to a severe point penalty or the presentation score being voided.

**Presentations using laptops will not be allowed.** Laptops can be used **only to showcase the video** depicting the flightworthiness of Category D flying machines. Teams will need to bring their own laptop. No setup time will be allocated and the team is expected to load and prepare the presentation videos in the laptop before entering the presentation room.

## 8.2 COMPETITION SEGMENT

Teams shall be expected to comply with the following during the competition segment:

- 1) Upon arrival 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. The team shall surrender their radio control transmitter, datalink transceiver, video receiver and any other wireless device used to communicate with the flying machine. These will be placed in a box provided by SAFMC Organising Committee to be quarantined. If the video transmitter on the aircraft (or a camera with an integrated transmitter) is powered through a separate battery, this battery (and any other spare batteries) shall also be placed in the box and quarantined.
- 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 **2.0kg (Cat D1)** or **3.5kg (Cat D2)**.

- 2.2 The combined payload mass to be carried by the aircraft is included in this weight.
  - 2.3 The platform **should not exceed 1m (Cat D1) or 1.3m (Cat D2)** in any direction (this measurement includes the maximum diameter of the propeller circles).
  - 2.4 R/C / datalink / video link transmitter and receiver are operating on allowed frequencies. VTX used must be able to broadcast in Raceband channels.
  - 2.5 Electrical harnessing should be appropriately insulated and should not be chafed or broken. No exposed wires are permitted.
  - 2.6 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 propeller(s) circle.
  - 2.7 For platforms operating on semi-autonomous / autonomous modes, the platform should allow complete manual pilot over-ride on demand via R/C.
  - 2.8 The platform must demonstrate failsafe capability in the event of a loss of link between the R/C transmitter and the R/C receiver on the aircraft. The failsafe check 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 R/C transmitter 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) After inspection, the flying machine and transmitter will be quarantined.
  - 4) Prior to the mission, the radio control transmitter, datalink transceiver, video receiver and any other wireless device, as well as the flying machine, will be handed back to the team. Each team is then granted up to **TWO (2)** minutes to set up their flying machine inside the playing field. This setup time includes the attachment of any payload to the aircraft.

- 5) Each team will only be given a total of **TEN (10)** minutes per attempt to perform the mission. The **TEN (10)** minutes start after the **TWO (2)** minutes setup time, regardless of whether the setup has been completed. Any extra setup time needed will be accounted for as part of the **TEN (10)** minutes mission time. A further **50 points penalty** will be given to the team if the team is still not ready after 1 minute into the mission time (3 minutes including the first 2 minutes of setup time). Timing will be recorded and will be used as a tie breaker in the event that there are teams that complete the task before the time limit and are tied on the same number of points. Once the time limit is up, no further points will be awarded for the tasks and the pilot will have to land their aircraft immediately.
- 6) Rules for personnel movement and communication during the setup time and the mission attempt are dictated in the following points:
  - 6.1 Only members of the participating team and SAFMC officials are allowed to be in the playfield.
  - 6.2 No outside communication or assistance from the audience / spectators is allowed at any point. Teams who flout this rule may be **disqualified**.
  - 6.3 During the whole attempt, the pilot will have to remain in the pilot box near the HQ, and is not allowed to receive any form of communication from teammates when the aircraft is airborne.
  - 6.4 One team member is allowed to follow the referee from the edge of the field to observe the platform for safety purposes (or as a safety pilot for D2), and may only contact the team if an emergency occurs.
  - 6.5 All other teammates are required to remain outside of the playing field near the landing pads or be behind of the safety net when the aircraft is airborne.
  - 6.6 Team members may only enter the field to collect their aircraft to bring it out of the playing field to modify or repair (including changing batteries) **after** it has landed and powered down **at either the launching pad or the grid**. SAFMC officials will notify the team when it is safe to enter the playing field.

- 7) A SAFMC official will be with the pilot during the attempt. The official may give instructions to the pilot depending on the behaviour of the flying machine (e.g. to land immediately if the aircraft appears to be uncontrollable). The pilot is to **comply immediately** with all such instructions, which may include the activation of the failsafe to ground the aircraft.
- 8) At the end of each attempt, the radio control transmitter, datalink transceiver, video receiver and any other wireless device for the flying machine will be switched off, placed back into the box and surrendered to the organisers.
- 9) 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 without the transmitter in preparation for the next attempt.

### 8.3 KEY POINTS TO NOTE

- 1) No team is allowed to possess any radio control transmitters, datalink transceivers and video transmitters (including backups) in the competition hall. All such devices are to be surrendered to SAFMC officials. Non-compliance may lead to **disqualification**.
- 2) Multiple video **receivers** are allowed.
- 3) Payload used for D1 and D2 and where to source for them can be found in the **ANNEX**.
- 4) 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 pitstop mode. Non-compliance may lead to **disqualification**.
- 5) Teams are to bring a sufficient number of batteries for the mission attempts.
- 6) There will be a charging space allocated for D1 teams (only) 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 team member overseeing the charging. Failure to do so will result in **disqualification**.

- 7) Teams shall make sure their designated representatives are contactable and should arrive at least **TEN (10)** minutes before any allocated timing. Latecomers 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 (Cat D1) or 3.5kg (Cat D2)\***. This includes the combined weight of all payloads to be carried by the aircraft.
- The platform **should not exceed 1m (Cat D1) or 1.3m (Cat D2)** in any direction (this measurement includes the maximum diameter of the propeller circles).
- Participants are only allowed to use a **single** flying machine for the mission attempt. A back-up aircraft that is similar to the primary aircraft may only be used in the event the primary aircraft has been determined to be incapable of flight for the remainder of the attempt.
- The flying machine must transmit video back to the ground station.
- Only electric flight is allowed. Both brushed and brushless motors are allowed. No modification to the motors is allowed.
- No internal combustion or gasoline engines will be allowed.
- No tethering or umbilical wires 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 2 minutes set up time with only 2 team members in the playing field at any point of time during setup.
- For safety considerations, the platform must be able to perform full RC manual pilot over-ride on demand.

*\*Note: Teams are allowed to reconfigure various payloads and mechanisms on the flying machine during the mission attempt, but the main airframe should remain unchanged.*

## 9.1 AVIONICS SYSTEM

- 1) There is no limit on the number of inertial measurement units (IMUs) used in the flying machine.
- 2) There is no limit on the number of on-board flight computers used in the flying machine.

## 9.2 BATTERY

There is no limit on the number of batteries used, in series or parallel.

## 9.3 REMOTE CONTROL (R/C) 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 R/C 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
- 2) The following R/C frequency ranges are allocated for R/C aircraft and gliders:
  - 26.96 - 27.28 MHz  $\leq$  500mW ERP
  - 29.700 - 30.000 MHz  $\leq$  500mW ERP
  - The organiser understands the proliferation of 2.4 GHz R/C systems and will allow its use for this competition. However, the organiser shall bear no responsibility for any loss of control of flying machine due to radio frequency interference. The team is advised to conduct a radio control range check prior to flight.
- 3) In any mode of flight, the team must be able to demonstrate the failsafe capability in their R/C transmitter. All electric motors should come to a complete stop when failsafe is activated **and** when there is a loss of link between the R/C transmitter and the R/C receiver on the aircraft. Please refer to Point 2.8 in Section 8.2 for details on the failsafe check.

- 4) 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.


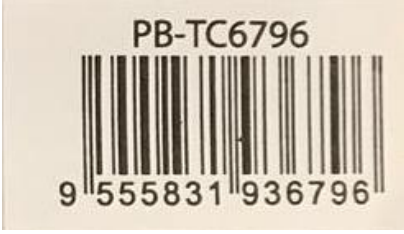

## 9.4 DATALINK / VIDEOLINK / OTHER WIRELESS LINK TYPES

- 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  $\leq$  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.



## 10. ANNEX

### 10.1 PICTURES OF MISSION TASK PROPS

MISSION TASK AND PROP(S) DESCRIPTION	SAMPLE PICTURES*
<ul style="list-style-type: none"> <li>- Cat D2, payload.</li> <li>- From Popular Bookstore</li> <li>- Product code and barcode number as shown.</li> <li>- Dimension: 5cm x 2cm x 1cm</li> <li>- Weight: 13g-15g</li> </ul>	 
<ul style="list-style-type: none"> <li>- CAT D1, payload</li> <li>- <a href="http://javysports.com/tossing/452-bean-bags.html">http://javysports.com/tossing/452-bean-bags.html</a></li> <li>- Dimension: 12cm x 12cm</li> <li>- Weight: 85g</li> </ul>	

\*Note: Colours and appearance of props may vary, unless otherwise stated.