



CAT D CHALLENGE BOOKLET 2018

JOINTLY ORGANISED BY:

SUPPORTED BY:



PARTNERS:



SAFMC 2018 CAT D CHALLENGE BOOKLET CHANGE LOG

Version	Release Date	Description
1.0	06 Nov 2017	Official challenge booklet release
1.1	20 Dec 2017	<ol style="list-style-type: none"> 1. Addendum in Section 6.4 <ol style="list-style-type: none"> a. Task A: Specified number of moulds and bottles on playing field b. Task D: Clarification that no parts from the flying machine should be left inside any water basin 2. Added Section 10 (Annex), with sample photographs of mission props and markers used in mission tasks.

CONTENTS

SINGAPORE AMAZING FLYING MACHINE COMPETITION 2018	4
1. INTRODUCTION.....	4
2. CATEGORIES.....	4
3. GENERAL SAFMC 2018 RULES	6
4. FORMAT OF COMPETITION.....	7
4.1 PRESENTATION	7
4.2 CHALLENGE	8
4.3 COMPETITION SCHEDULE	9
5. CATEGORY D AWARDS	9
5.1 CHAMPIONSHIP AWARD	10
5.2 JUDGES' COMMENDATION	10
5.3 BEST PRESENTATION AWARD	10
5.4 PRIZES	11
6. CATEGORY D MISSION.....	12
6.1 CATEGORY D CHALLENGE	12
6.2 DIFFERENTIATION BETWEEN CAT D1 AND D2	13
6.3 COMPETITION SETUP.....	14
6.4 MISSION TASKS	16
6.5 SCORING FOR MISSION TASKS.....	23
6.6 MISSION PENALTIES.....	25
7. SCORING	27
7.1 AERIAL PLATFORM FACTOR (A)	28
7.2 SMART FACTOR (S)	29
7.3 PRESENTATION FACTOR (P)	30
7.4 MISSION ACCOMPLISHED FACTOR (M)	30
8. COMPETITION DAY FLOW OF EVENTS.....	31
8.1 PRESENTATION SEGMENT	31
8.2 COMPETITION SEGMENT	32
8.3 KEY POINTS TO NOTE	35
9. TECHNICAL RULES & REGULATIONS.....	36
9.1 AVIONICS SYSTEM	37
9.2 BATTERY.....	37
9.3 REMOTE CONTROL (R/C) RADIO	37
9.4 DATALINK / VIDEOLINK / OTHER WIRELESS LINK TYPES	38

SINGAPORE AMAZING FLYING MACHINE COMPETITION 2018

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

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

Category A1: Paper Planes (*Primary Schools*)

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

Category A2: Paper Wonders (*Primary Schools*)

Design and fold paper wonders to demonstrate showmanship and creativity.

CATEGORY B - UNPOWERED GLIDERS

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

Category B1: Furthest Distance (*Secondary Schools / Integrated Programme*)

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

Category B2: Longest Time Aloft (*Secondary Schools / Integrated Programme*)

Design and build small unpowered gliders to be hand launched in a bid to stay aloft the longest.

CATEGORY C – RADIO CONTROL FLIGHT

Category C1: Fixed Wing Radio Control Flight (*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 (*All Schools*)

Each team should consist of **ONE (1)** to **THREE (3)** members.

Bring or design a FPV (first-person view) air platform to navigate an obstacle course.

CATEGORY D – SEMI-AUTONOMOUS / AUTONOMOUS

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

Category D1: Semi-Autonomous (*Polytechnics/Universities*)

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

Category D2: Autonomous (*Polytechnics/Universities*)

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 2018 RULES

- The deadline for the competition registration is 31 January 2018.
- 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 awarded to the designated recipient(s), stated in the registration form.
- 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 2018 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

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 A2, B2 and C2 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 2018 Awards Presentation Ceremony on **7 April 2018**.

4.1 PRESENTATION

During the presentation, teams will be allocated a specific time slot to present about their flying machine in Science Centre Singapore. 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 in the Presentation.

4.2 CHALLENGE

For the Challenge aspect, teams (*except Category C2 which allows commercial off-the-shelf products*) are to design and build, and fly their flying machines to overcome different challenges for different categories of the SAFMC events. Their flying machines will compete with one another during the challenge week.

For Category C, D and E participants, tables may be provided within the main competition hall as common areas for teams to work on their flying machines. Alternatively, teams may be assigned a dedicated 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 spectator hall and they are not permitted within the competition zone (playing field and team booths).
- No trial runs will be allowed in the flying area. For Category C, D and E participants, all transmitting devices **must** be surrendered to SAFMC officials. No transmitting devices, including spares, will be allowed in the competition hall.
- For Category C, D 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.

4.3 COMPETITION SCHEDULE

Date	Event
20 October 2017	Challenge Announcement (Category D and E)
26 October 2017	Challenge Announcement (Category A, B and C)
November 2017 - March 2018	Workshops. For more details, please visit www.safmc.com.sg
31 January 2018	Deadline for registration
29 March 2018	Category A
2 April 2018	Category B
3 April 2018	Category C1
4 April 2018	Category D1
5 April 2018	Category D2 and E
6 April 2018	Category C2
7 April 2018	Awards Presentation Ceremony

The venue of the competition, from 29 March 2018 to 7 April 2018, will be Science Centre Singapore Annexe Hall. Participants will be informed of any changes to the above schedule for the various categories by **15 March 2018**.

5. CATEGORY D AWARDS

Award winners will be selected based either on 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 winning flying machine may be displayed in Science Centre Singapore for public viewing after the Award Presentation Day.

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 that 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 BEST PRESENTATION AWARD

This award is presented to the team that best exhibits creativity, fluency, confidence, and flair in the presentation of their team's work, and demonstrates that "WOW" factor during the interview sessions. There will be only **ONE (1)** presentation award for the whole Category D.

5.4 PRIZES

CATEGORY D				
Awards	Medals	Trophy	Cash Prize	Remarks
*Cat D2 <u>Autonomous</u> Championship Award	✓	✓	\$5,000.00	**Additional trip prize – see below for details
Cat D2 <u>Autonomous</u> 1 st Runner Up	✓		\$3,000.00	
Cat D2 <u>Autonomous</u> 2 nd Runner Up	✓		\$1,500.00	3 rd and 4 th runners up will receive <u>only</u> medals
*Cat D1 <u>Semi-Autonomous</u> Championship Award	✓	✓	\$3,000.00	
Cat D1 <u>Semi-Autonomous</u> 1 st Runner Up	✓		\$1,500.00	
Cat D1 <u>Semi-Autonomous</u> 2 nd Runner Up	✓		\$1,000.00	3 rd and 4 th runners up will receive <u>only</u> medals
Cat D Judge's Commendation	✓		\$500.00	Up to two teams can win this award
Cat D Best Presentation Award	✓		\$200.00	

* **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 will be **final**.

***** Cat D2 Autonomous Championship - Additional trip prize to represent Singapore in 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 consist of members of the original SAFMC winning team. Winning teams who are interested in taking up this award should notify the organising committee of their interest and the competition they intend to take part in before **7 July 2018**.

6. CATEGORY D MISSION

Disaster has struck a distant coastal city. A Category Five hurricane made landfall a few hours ago, bringing about widespread flooding and destroying critical transportation and communications infrastructure. Hundreds are believed to be missing or injured, and many more are stranded without food and water. To make matters worse, another strong hurricane is expected to hit the same region in a matter of weeks.

A ground-based quick response team was deployed to set up a forward operating base (FOB) near the city, but have encountered difficulties in reaching parts of the disaster site. They have requested for aerial support to aid in their mission.

Your team has now been ordered to prepare an unmanned aerial vehicle (UAV) and fly it out to the disaster site immediately to assist the team at the FOB. Your UAV is expected to be able to **navigate through obstacles, survey / search for objects of interest, and retrieve / store / deliver various payloads.**

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.

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

Each team will be given a **fixed timeframe** per attempt to complete the tasks present in the playing field using a **single flying machine**. The mission time will continue running 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 remainder of 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 two designated landing pads) as desired, reconfigure or repair their platform, etc. Teams are allowed to choose **any** number of tasks to attempt in their **preferred order**. The team's final mission score for the attempt will be compiled from all points and penalties accumulated during this timeframe.

The detailed description of the competition field, available mission tasks, as well as the scoring criteria and penalties 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.

6.2 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 they are switching from RC mode to autonomous mode after the take-off, after which the aircraft must be fully autonomous. 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 will incur a point penalty, and the aircraft will have to restart at a position determined by the Chief Referee.

6.3 COMPETITION SETUP

The competition setup for both Category D1 & D2 is the same. A representation of the field and key sites of interest is shown in Figure 1. The exact locations of these sites, props, and course dimensions are not fixed, and may vary on the actual competition day itself unless otherwise stated.

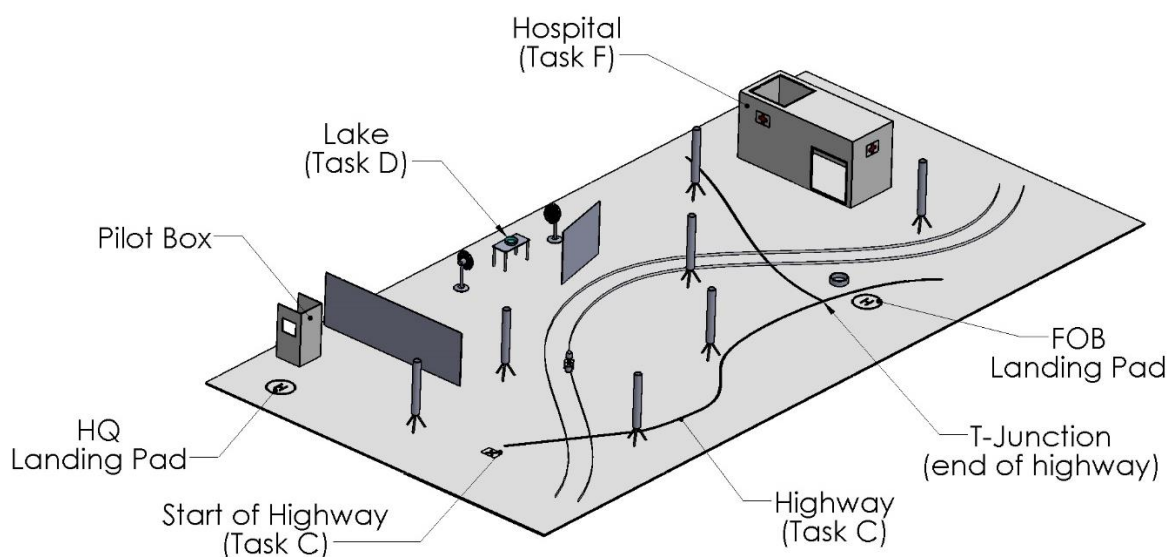


Figure 1: Isometric view of Cat D Competition Field.

There are two (2) usable landing pads in the competition field: one at the HQ (near the pilot box) and the other at the forward operating base (FOB). All teams are required to start from the landing pad at HQ. After which, teams may choose to land at either the HQ or the FOB. The flying machine may **not** be manually ferried between the two landing pads; i.e.: it can only take-off from the location where it last landed.

A variety of obstacles will be placed around the field. These may include tall panels (representing elevated treacherous terrain), poles (simulating regions of strong winds to avoid), and fans (to generate air turbulence). Teams will be penalised for coming into contact with any of these obstacles or props which are not meant to be picked up. Please refer to Section 6.6 for more information on the penalties.

An aerial view of the playing field is shown in Figure 2 with various sectors labelled. Each sector denotes where the prop(s) relevant to that particular task can be found. Additionally, the approximate locations of the FOB landing pad and the cross markers near the start of the highway (relative to the HQ landing pad) are known:

- FOB landing pad: (10.0m, 18.0m)
- Cross Marker: (8.0m, 1.5m)

This information should only be used as a rough guideline to aid teams in locating key sites to accomplish mission tasks.

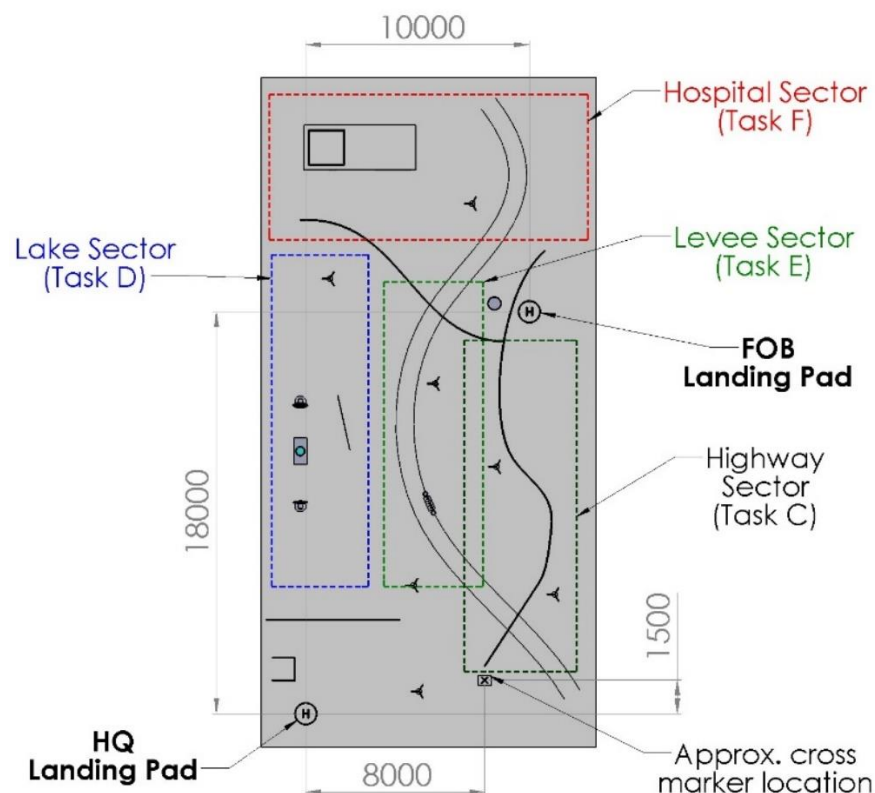


Figure 2: Plan view of Cat D Competition Field (all dimensions in mm).

6.4 MISSION TASKS

The same tasks are available for both **CAT D1** and **CAT D2**. Teams are **not expected to complete all the tasks fully** within the mission timeframe. The available tasks are as follows:

- A. **Locate and recover casualties** – Members of the public have been trapped or stranded in the aftermath of the hurricane. The flying machine is to locate them, rescue them, and bring them safely back to either the HQ or the FOB.
- Casualties are represented by small bottles wrapped with a layer of loop fastener; these will be placed in red circular moulds (internal diameter 12cm, depth 3cm) which are randomly located around the playing field.
 - There will be between **FOUR (4)** to **SIX (6)** moulds on the playing field. Each moulds will be fastened to the ground, and will contain **one** bottle which may be placed in any orientation.
 - Points are awarded for:
 - a) Successfully locating a bottle (showing the bottle clearly on a screen, or by graphic user interface cues to show the flying machine has identified the target) and attempting a retrieval with a designed interface or mechanism.
 - b) Gently placing the bottle(s) onto either landing pad and releasing it, or landing the aircraft safely with the bottle(s) intact so it can be removed manually. Delivered items will then be removed from playing field for the remainder of the attempt.
 - Items will be considered lost and removed from the playing field if these scenarios occur:
 - a) If the flying machine that has item(s) onboard has to be manually recovered from the field (e.g.: in the event of a crash).
 - b) Items released from the aircraft entering a free-fall state (uncontrolled descent) from considerable height.
 - If the aforesaid situation occurs, teams will only be awarded the score for locating the particular personnel, and **not** be able to reattempt recovery of that personnel to a landing pad.

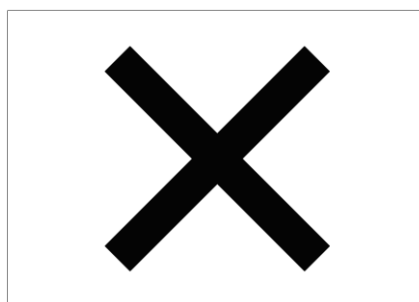
- Each bottle weighs approximately 20g, and has the following dimensions (excluding the loop fastener): 45 x 26 x 16mm (± 5 mm).

B. **Transport rescue personnel** – More rescuers have been readied and need to be sent to the disaster site as soon as possible. The flying machine needs to carry them from the HQ and bring them safely to the FOB.

- Each rescuer is represented by a small round container; a limited number of these will only be provided at the HQ for teams to attach onto their flying machine.
- Points are awarded for gently placing a container(s) onto the FOB landing pad and releasing it, or landing the aircraft safely with the container(s) intact so it can be removed manually. Delivered items will then be removed from playing field for the remainder of the attempt.
- A limited number of containers will be provided at HQ; containers may be positioned beforehand at each landing pad for the aircraft to pick up without outside intervention. Otherwise, the flying machine is required to land and power down before team members attach the container(s) onto the airframe.
- Multiple containers may be carried at once. However, they may **not** be fastened, stuck, tied to each other, or conjoined together in any manner that makes them a single entity. (e.g.: tying two items together with a rubber band).
- Items will be considered lost and removed from the playing field if these scenarios occur:
 - a) If the flying machine that has item(s) onboard has to be manually recovered from the field (e.g.: in the event of a crash).
 - b) Items released from the aircraft entering a free-fall state (uncontrolled descent) from considerable height.
- If the aforesaid situation occurs, teams will **not** be able to reattempt recovery of those personnel to a landing pad.
- Each container weighs approximately 70g, and has the following dimensions: diameter of 55mm, height of 38mm (± 5 mm).

C. **Survey damaged highway** – The advance team reported that they had to take a detour after discovering the main highway into the city was unusable. The flying machine is needed to follow a segment of a highway to check for the extent of the damage.

- The highway is represented by a ~5cm wide strip of black tape that will be pasted onto the playing field. An A2 sheet of paper with a black cross printed on it will be placed on the ground, near the start of the highway to be surveyed. A schematic of the marker is shown below.



- The tape may be curved at certain segments, and objects might be present on the ground that completely or partially obstructs the tape.
- The full length to be surveyed starts from the end of the tape near the cross marker, and ends at the T-junction near the FOB.
- To ensure sufficient detail is captured, teams are not allowed to fly higher than 1m above the ground during the surveillance attempt.
- Points are awarded for:
 - a) Successful line following of each segment (showing the tape segment length in a continuous video feed, by graphic user interface cues, or by subsequent stitching of images to map out the entire line).
 - b) Reporting of any objects of interest (should be clearly visible in video footage or images) discovered during surveillance.

D. **Freshwater delivery** – Floodwaters have contaminated the local water supply, and potable water at the FOB is running low. Freshwater from a nearby lake in the mountains needs to be ferried to a water tank at the FOB for the quick response team and disaster victims.

- The lake is represented by a rectangular basin (inner dimensions approximately 30 x 20 x 8cm) of water filled to a depth of 4 - 6cm. The basin will be placed on a 70 - 80cm tall table.
- The water tank for collection is located near the FOB, simulated by a basin (of similar dimensions as the lake) that is placed on a weighing scale.
- The flying machine is to retrieve water from the basin, fly back to the FOB, and release the water into the collection basin.
- Only the designed collection interface or mechanism should come into contact with the water; the rest of the flying machine is prohibited from touching or landing in the water.
- Parts of the flying machine (e.g.: parts of the water collection interface or mechanism) should not be permanently jettisoned or released from the aircraft and left behind in any of the water basins.
- Strong winds are expected in mountainous terrain.
- Points are awarded for:
 - a) The first 100g of water collected
 - b) Every subsequent 100g of water

E. **Repair the levee** – Part of the river levee has been breached. The breached area needs to be repaired immediately by building up a wall with blocks to prevent further occurrences of flooding.

- The area to be repaired is denoted by **THREE (3)** adjacent sheets of paper, each with a blue triangle printed on it.
- The sheets will be located in between two objects used as markers. A plan view of the setup is shown in Figure 3:

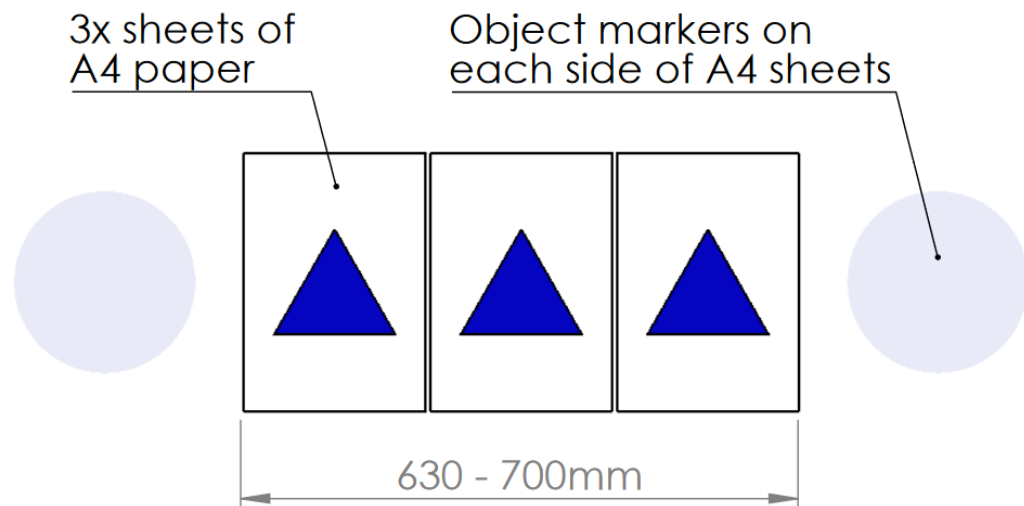


Figure 3: Plan view of markers used for Task E.

- The blocks to be used for repair will be simulated by rectangular containers, which are to be placed on the paper sheets. Containers may be placed in any orientation, but each one must lie fully within the perimeter of the three sheets. Only the **final** resting position and orientation of the containers will be taken into account for scoring.
- Additional points are awarded if at least **ONE (1)** container is placed on **each** and **every** sheet of paper, fully within the perimeter of each sheet, to simulate an ideal containment of the waters.
- A limited number of containers will be provided at HQ or the FOB; containers may be positioned beforehand at each landing pad for the aircraft to pick up without outside intervention. Otherwise, the flying machine is required to land and power down before team members attach the container(s) onto the airframe.
- Multiple containers may be carried at once. However, they may **NOT** be fastened, stuck, tied to each other, or conjoined together in any manner that makes them a single entity. (e.g. tying two items together with a rubber band).

- Points are awarded for:
 - a) Each container delivered to the area to be repaired
 - b) Placing at least one container on each and every sheet of paper to close off the breached area
 - c) Additional points per elevated container placed on top of another to form **ONE (1)** higher level; elevated containers should not touch the ground at any point
- Each container weighs approximately 120g, and has the following dimensions: 115 x 80 x 50mm (± 10 mm)
- Refer to Section 6.5.1 for scoring examples for this task

F. Enter and search hospital – The city hospital has been blocked off by floodwaters, and little is known about the state of staff and the patients trapped inside. HQ has given authorisation to enter the building premises to check on the occupants.

- The hospital is represented by a walled structure. There are two openings in the structure: one 1.5 x 1.5m square opening on the roof, and another 1.5 x 1.5m opening on one of the walls. The boundaries of the openings are lined with red tape. A schematic of the structure is shown in Figure 4.

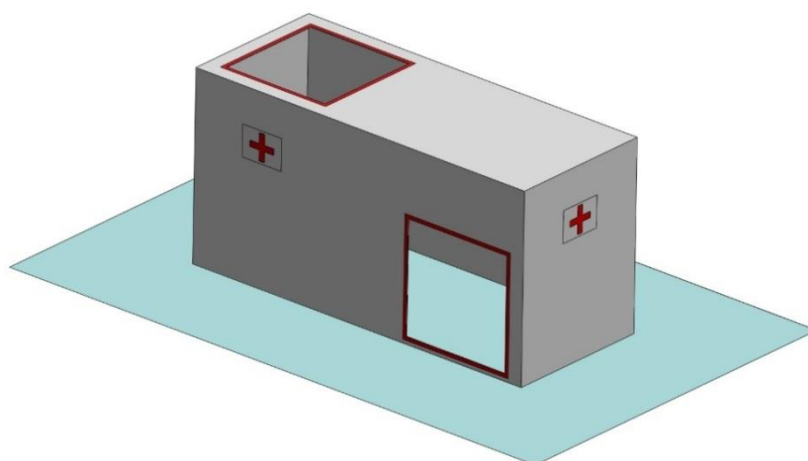
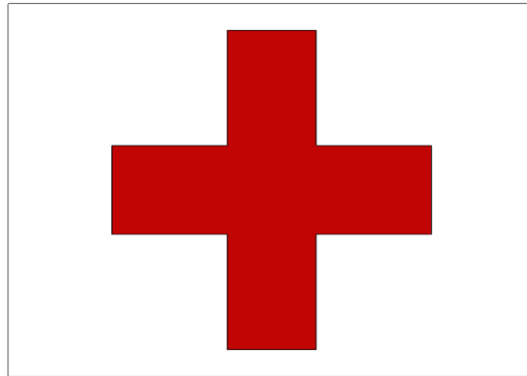


Figure 4: Isometric view of walled structure for Task F.

- Markers are pasted on the exterior faces of the structure. The markers are A2 sheets of paper with a red cross printed on it. A schematic of the marker is shown below:



- Due to the power outage, lighting conditions inside may not be desirable. Flying machines should manoeuvre cautiously as there may be obstacles or obstructions inside.
- Points are awarded for:
 - a) Safely passing through the roof opening
 - b) Safely passing through the wall opening
 - c) Reporting of any objects of interest inside the structure (should be clearly visible in video footage or images) discovered during surveillance

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.

Task	Sub-task	Awarded Points	Max Score
A	Locate and attempt recovery of casualty	1 to 3 per object	20
	Deliver casualty to landing pad safely	2 per object	
B	Deliver rescuer to FOB landing pad safely	2 per object	10
C	Successfully line follow each highway segment completely	3 / 6 / 9	15
	Report observations along highway	1 to 6	
D	Retrieve and deliver first 100g of water into collection point	4	10
	Deliver every subsequent 100g of water into collection point	2 per 100g of water	
E	Every block placed within designated area	2 per object	20
	Additional bonus for each block placed at a higher level (on top of another block within area)	2 per object	
	Completely closing off the breached area	4	
F	Passing through roof opening once	6	15
	Passing through wall opening once	4	
	Report observations inside	1 to 5	
<i>Bonus</i>	<i>Bonus / Hidden task(s)</i>	<i>1 to 10</i>	<i>10</i>
TOTAL			100

6.5.1 Task E – Repair the Levee

Six containers in various positions and orientations are shown in Figure 5 with the scoring criteria explained:

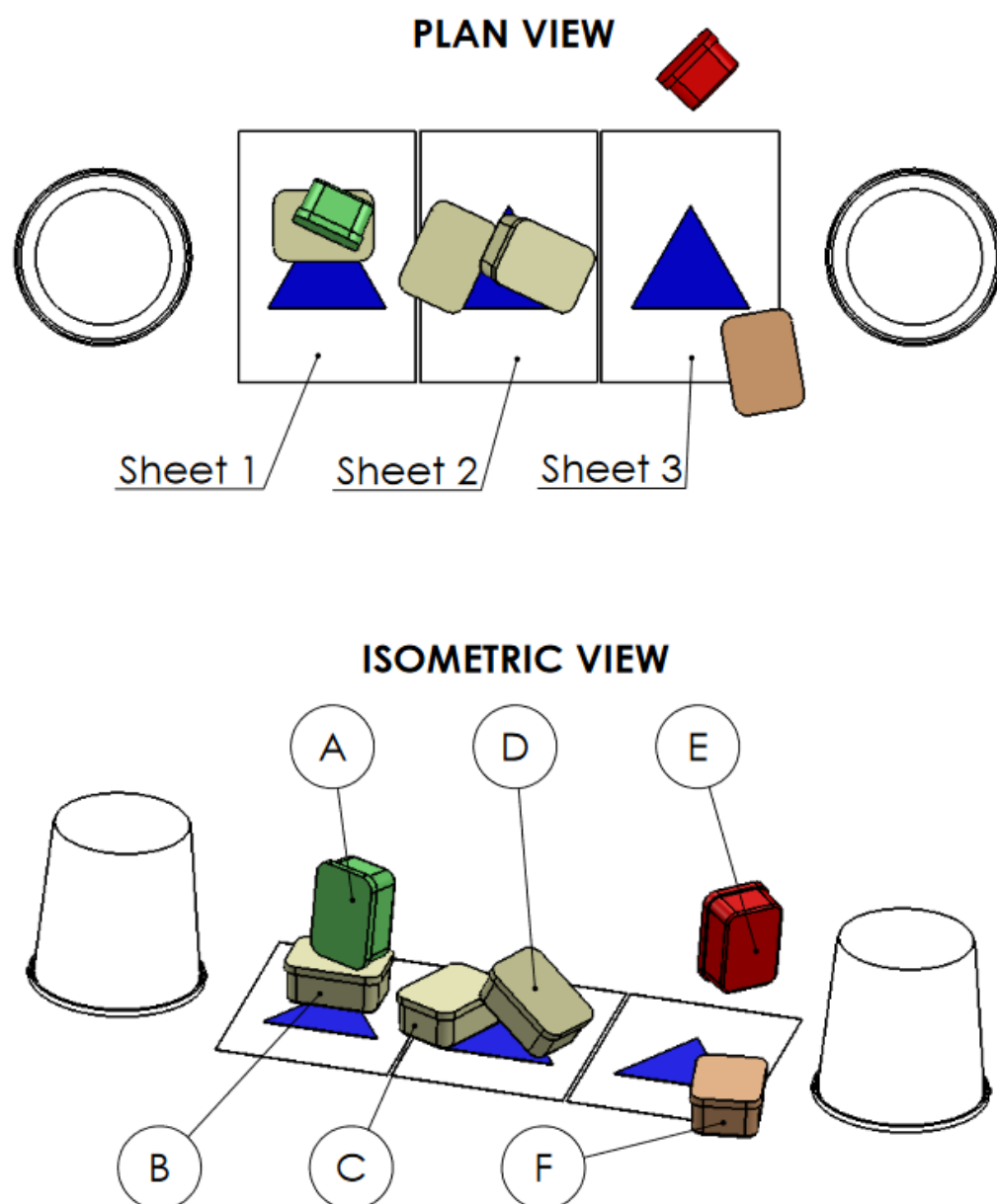


Figure 5: Plan (top) and isometric (bottom) view of Task E container placements

CONTAINER	DESCRIPTION	POINTS AWARDED
A	Rests atop Container B without touching the ground at any point, and is completely within sheet 1. Points awarded for placement and the higher level bonus.	4
B	Sits fully within sheet 1 on ground level. Points awarded for placement.	2
C	Sits on sheet 1 and 2 on ground level. Points awarded for placement.	2
D	Sits fully within sheet 2. Partially elevated by Container C, but one edge is in contact with ground. Points only awarded for placement.	2
E	Not within designated area. No points awarded.	0
F	Partially within sheet 3 on the ground level. Points awarded subject to referee's discretion.	0 / 1 / 2
-	Points awarded for closing off the area subject to referee's discretion. Sheets 1 and 2 have at least one container fully within the area, but sheet 3 does not completely satisfy this requirement.	0 to 4

6.6 MISSION PENALTIES

The sum of these 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. Unreasonable arguments with any of the SAFMC officials may result in additional points lost.

S/N	DESCRIPTION	POINT PENALTY
1	Collision with obstacles – A penalty will be awarded every time the flying machine comes into contact with any structure or obstacle.	-1 point per occurrence (up to a max of -10)
2	Excessive maintenance requirement – After the initial take-off, a penalty will be awarded every subsequent time the team needs to physically touch / repair / modify their flying machine before the next take-off attempt.	-2 points per occurrence (up to a max of -20)
3	Downed aircraft – Teams will be penalised every time they have to manually retrieve the flying machine and move it to the nearest landing pad. This penalty applies on top of penalty no. 2 (excessive maintenance requirement).	-5 points per occurrence
4	Realism factor – A one-off penalty will be given if the team requires external markers or aids to be placed in the field.	-7 points
5	Interrupting the competition by potentially interfering with other competitors, e.g.: switching on your platform's transmitters, etc.	Referee's discretion or <u>disqualification</u>
6	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 <u>disqualification</u>
7	CAT D2 ONLY Point penalty will be given for every operator input to the aircraft via GCS or RC transmitter (including emergency take-over by safety pilot).	-1 point per occurrence (up to a max of -10)

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:

Segment	Factor	Weightage
Presentation	Aerial Platform Factor	20%
	Smart Factor (Creativity)	10%
	Presentation Factor	10%
Competition	Mission Accomplished Factor	60%
	Total	100%

Table 5.1: Scoring weightage

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

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

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

$$T = (A \times WF) + S + P + M$$

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 commercial off the shelf products

2) Mechanical and aesthetic design

- Quality of fabrication, workmanship, materials use
- 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.

For **CAT D2 only**, the Aerial Platform factor (A) component will be multiplied by a **Weight Factor (WF)**, which is calculated as

$$WF = \frac{2}{(Platform\ Weight(kg) + 1)}$$

This WF will be multiplied to the overall Aerial Platform factor (A) score in calculating the total score (T). For example, if a platform weighs 3kg and scores 20 points in A, WF = 0.5, and the weighted A component in T would be 20 x 0.5 = 10.

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 will form the **Mission Accomplished Factor (M)** score. Please refer to Section 6.5 and 6.6 for the mission scoring and penalties.

8. COMPETITION DAY FLOW OF EVENTS

Both the **presentation segment** and **competition segment** for both CAT D1 and D2 will take place from **4 - 5 April 2018**.

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 an 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 enables 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 entries. 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 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. An 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)**. The combined payload mass to be carried by the aircraft is included in this weight.
 - 2.2 The platform **should not exceed 1.3m** in any direction (this measurement includes the maximum diameter of the propeller circles).

- 2.3 R/C / datalink / videolink transmitter and receiver are operating on allowed frequencies. Refer to Section 9.3 and 9.4 for more details.
- 2.4 Electrical harnessing should be appropriately insulated and should not be chafed or broken. No exposed wires 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 propeller(s) circle.
- 2.6 For platforms operating on semi-autonomous / autonomous modes, the platform should allow complete manual pilot over-ride on demand via R/C.
- 2.7 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 **FIVE (5)** minutes to setup 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 a maximum of **FIVE (5)** 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. 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 present in the playing field.
 - 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 the playing field near the landing pads or be behind the safety net when the aircraft is airborne.
 - 6.6 Team members may only enter the field to modify or repair their flying machine (including changing batteries) **after** it has landed and powered down at either the landing pad at HQ or the FOB. 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 receivers (including backups) in the competition hall. All such devices are to be surrendered to SAFMC officials. Non-compliance may lead to **disqualification**.
- 2) 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. Non-compliance may lead to **disqualification**.
- 3) Teams are to bring a sufficient number of batteries for the mission attempts. **No team is allowed to charge batteries within the competition hall.** Non-compliance may lead to **disqualification**.
- 4) Teams shall make sure their designated representatives are contactable and should arrive at least **FIVE (5)** 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 1.3m** 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 subject to a point penalty.
- For safety considerations, the platform must be able to perform full RC manual pilot over-ride on demand.

**Note: for CAT D2, heavier flying machines will be disadvantaged in scoring (please see Section 7.1 for more details).*

***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 onboard 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 2.7 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.

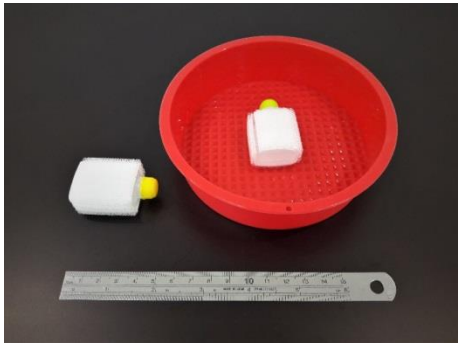
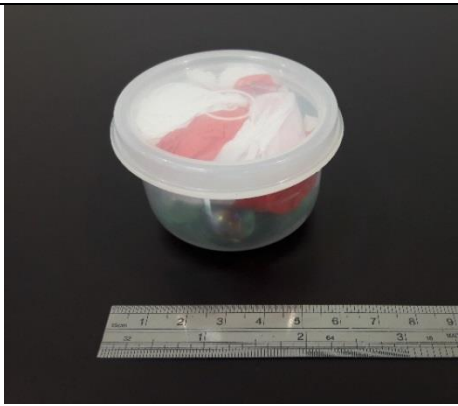

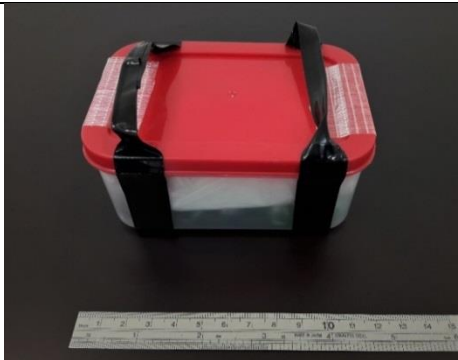
9.4 DATALINK / VIDEO LINK / OTHER WIRELESS LINK TYPES

- 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

- $2.4000\text{GHz} - 2.4835\text{GHz} \leq 200\text{mW}$ Equivalent Isotropically Radiated Power (EIRP)
 - $10.500 - 10.550 \text{ GHz} \leq 117\text{dB}\mu\text{V/m}$ @ 10m
 - $24.000 - 24.250 \text{ GHz} \leq 100\text{mW}$ EIRP
 - $5.725\text{GHz} - 5.850 \text{ GHz} \leq 4000\text{mW}$ EIRP
 - $5.150\text{GHz} - 5.350\text{GHz} \leq 200\text{mW}$ EIRP
 - $5.470\text{GHz} - 5.725\text{GHz} \leq 1000\text{mW}$ EIRP
 - $57 - 66 \text{ GHz} \leq 10\text{W}$ 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

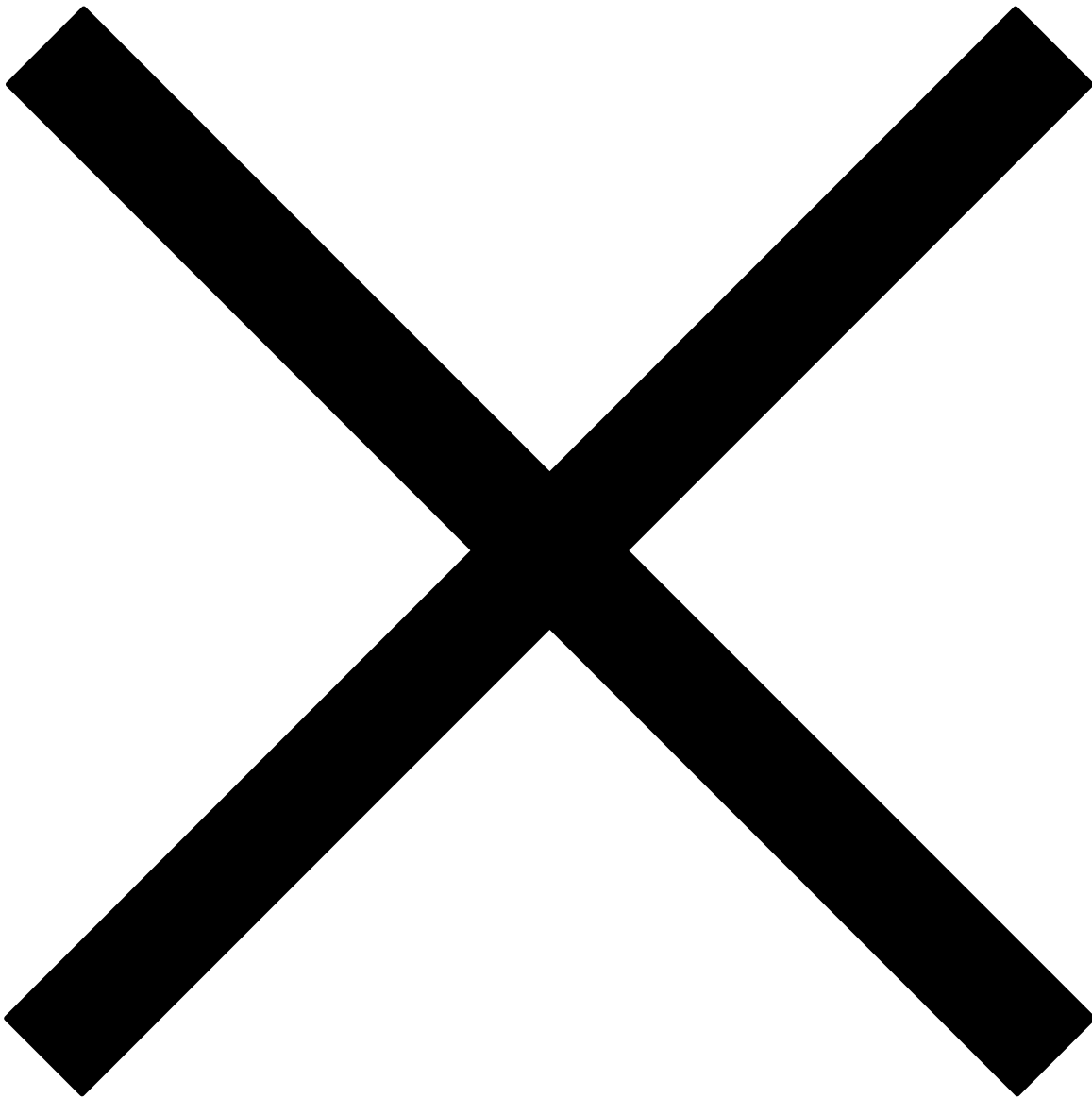
10.1 PICTURES OF MISSION TASK PROPS

MISSION TASK AND PROP(S) DESCRIPTION	SAMPLE PICTURES*
<p><u>Task A: Locate and recover casualties</u></p> <ul style="list-style-type: none"> - Small bottle dimensions: 45 x 26 x 16mm (± 5mm), ~20g. - Loop fastener only wrapped on the bottle sides; the base and the area around the cap remain exposed. Teams may choose to utilise the fastener to carry the prop. - Red mould dimensions: inner diameter 12cm, depth 3cm. - One bottle will be placed in each mould. 	
<p><u>Task B: Transport rescue personnel</u></p> <ul style="list-style-type: none"> - Round container dimensions: diameter 55mm, height 38mm (± 5mm), ~70g 	
<p><u>Task D: Freshwater delivery</u></p> <ul style="list-style-type: none"> - Basin internal dimensions: 30 x 20 x 8cm, filled with water to a depth of 4 – 6cm. - Lake and collection basin both have the same dimensions. 	
<p><u>Task E: Repair the levee</u></p> <ul style="list-style-type: none"> - Rectangular container dimensions: 115 x 80 x 50mm (± 10mm), ~120g - Black handles / straps will be part of actual prop. Teams may choose to utilise this to carry the prop. 	

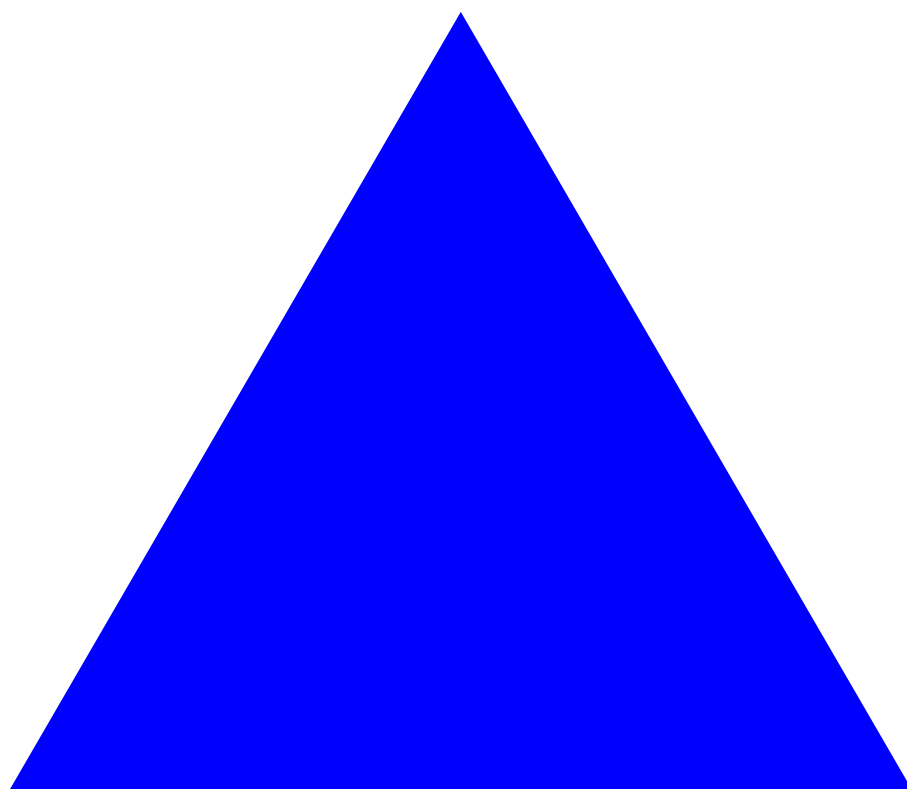
* Note: 15cm ruler and measuring tape shown in photographs for scale. Colours and appearance of props may vary, unless otherwise stated.

10.2 MISSION TASK MARKERS

TASK C: Survey Damaged Highway – A2 marker



TASK E: Repair the levee – A4 marker



TASK F: Enter and search hospital – A2 marker

