IMECHE UAS CHALLENGE COMPETITION RULES 2025

UAS Challenge 2025
Mission and Competition Rules
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Issue 1.2

Institution of MECHANICAL ENGINEERS

Amendment 2

Clarification

Section 4.5.1 added clarification that any launch devices must be contained within the storage box.

Correction

Section A.4.3 under 'Automatic Payload Mass and Distance' removed the penalty example

Section A.4.3 under 'Energy Efficiency' replaced "endurance" with "return navigation"

Amendment 1

Correction

- Section 4.4.1 external aid package dimensions updated. Cardboard box is 30cm tall not 20cm.

Contents

Acronyms and Abbreviations

ADB	Air Drop Box
AGL	Above Ground Level
AI	Artificial Intelligence
BMFA	British Model Flying Association
BVLOS	Beyond Visual Line Of Sight
CAA	Civil Aviation Authority
CDR	Critical Design Review
CG	Centre of Gravity
COTS	Commercial Off The Shelf
FMC	Flight Management Computer
FPV	First Person View
FRR	Flight Readiness Review
FSO	Flight Safety Officer
FTS	Flight Termination System
FW	Fixed Wing
GCS	Ground Control Station
GPS	Global Positioning System
Kts	Nautical miles per hour (Knots)
KIAS	Knots Indicated Air Speed
KTAS	Knots True Air Speed
LiPo	Lithium Polymer
LLM	Large Language Model
LMA	Large Model Association
MTOM	Maximum Take Off Mass
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
PRP	Payload Release Point
QFE	Q-code Field Elevation
RC	Radio Control
RF	Radio Frequency
RIN	Royal Institute of Navigation
STEM	Science, Technology Engineering & Maths
UA	Uncrewed Aircraft
UAS	Uncrewed Aircraft System
UASC	Uncrewed Aircraft System Challenge
VFR	Visual Flight Rules
VLOS	Visual Line Of Sight
WP	Waypoint

1 Introduction

The IMechE Uncrewed Air System (UAS) Challenge ('The Challenge') will engage University Undergraduate and taught Postgraduate teams in the design, construction, development and demonstration of an autonomous UAS. The Challenge is held annually over the duration of an academic year, with the competition commencing in October, and the flight demonstration being held in the following summer. This period will be structured into design, development and demonstration stages[1] with documentation of engineering review stages, a business presentation, as well as the flying demonstration contributing to the final scores.

1.1 Education and Development Objectives of the Event

The Challenge has a number of education and development objectives, in particular to:

- Provide an opportunity for students to learn practical aerospace engineering skills for their future careers;
- Provide an opportunity for students to explore innovative airframe and systems engineering design of a complex system;
- Require them to follow an industry-recognised engineering development lifecycle (design, development, review and demonstration) against a demanding mission requirement;
- Provide an opportunity for students to develop and demonstrate team working, project management, manufacturing, leadership and commercial skills as well as technical competence;
- Provide an opportunity to demonstrate professionalism when exposed to real life flight safety considerations and live flight environments;
- Enhance employment opportunities in the sector;
- Stimulate interest in the civil UAS field;
- Foster inter-university collaboration in the UAS technology area, and to provide a forum for interdisciplinary research; and
- Enable students to interact with knowledgeable and experienced aerospace engineers on an aerospace project, through mentoring, webinars and feedback throughout the project.

1.2 Mission Scenario

The Uncrewed Aircraft (UA) will be designed to undertake a representative humanitarian aid mission. The system will be required to perform a series of tasks such as take-off and landing, navigating waypoints and gates, dropping the Aid Package, and returning to base via a defined route. The mission scenario is provided for scene setting purposes only and is as follows:

"A natural disaster has occurred with a large, populated area devasted. Several thousand people are cut-off, without power, fresh running water, food or medicines. In built-up areas buildings have come down and rubble is hampering efforts to deliver emergency supplies. Time is critical. A UAS supply mission is launched from the Rescue Centre some distance away at the end of the current logistics trail. The UAS operate automatically, launching, transiting rapidly, navigating via pre-planned waypoints in a tight urban environment with rapid changes of direction, delivering aid safely and accurately to

[1] Teams that do not manage to build a flyable air vehicle are invited to deliver the Simulation (X-Plane) and to attend the Demonstration Event and showcase their STEM engagement and compete in the Business Presentation (if they wish).

where it is most needed. They return via a different route and remain at low level to de-conflict from incoming UAS and overflying crewed aircraft. This requires them to fly through the streets of the damaged communities – this will involve narrow corridors and rapid changes of direction. The UAS repeats the mission in all weather conditions until the need to drop aid subsides, sustaining a vital lifeline until a large scale rescue mission can be mounted to evacuate people from the devastated area."

1.3 Publicity

The IMechE publicises the competition during the year to encourage participation and to promote the role of the Institution. Please note that Participants hereby agree that all content submitted to the IMechE may be used for promotional purposes, unless otherwise agreed prior to submission. Images and video taken at the flying demonstration event may be used for promotional purposes by the IMechE and its partners.

During the period of the competition, teams are encouraged to publicise the competition and their participation – via the media, social media, and for example by talking to local schools or other universities, either locally or nationally. A prize is awarded for the most effective use of publicity to promote the competition.

1.4 STEM Outreach

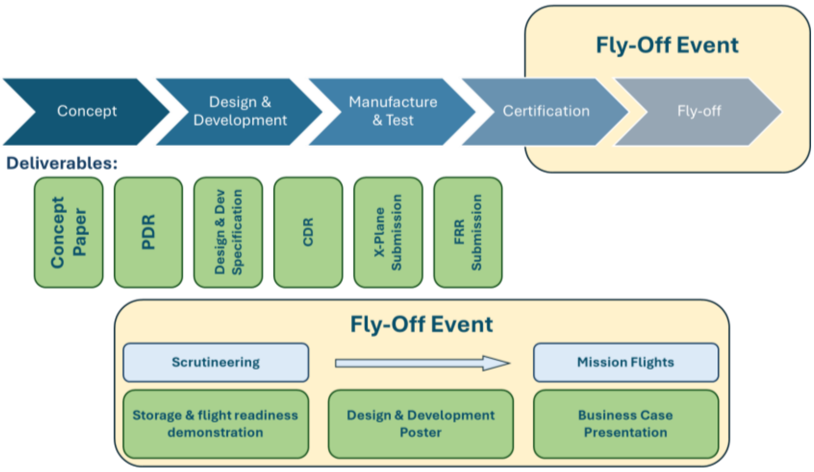
During the Demonstration Event, there will be an invitation extended to local schools to see the event, and participate in appropriate Science, Technology, Engineering, Maths (STEM) events, to be organised by the IMechE. Part of the STEM event is a hangar tour, during which UAS Challenge Teams will be expected to interact with the students and talk about their system, the design process and engineering challenges, or engineering as a career path. In addition, throughout the course of the competition's timeline the teams are encouraged to engage with their local communities to promote science, technology, engineering and maths – this is a scored aspect of the competition.

1.5 Structure of this Document

Section 2 & 3	overview of the Challenge, setting out what is involved for participating teams, the schedule of key activities, eligibility and funding;
Section 4	the requirement specification for the UAS;
Section 5	the 'Statement of Work' for the Challenge, outlining what is required in each of the stages, including the design review deliverables;
Section 6 & 7	the Scoring, Prizes and Awards for both the Design and Demonstration elements.
Annex A	provides the representative missions to be flown, and around which the UAS is to be designed, together with the scoring criteria;
Annex B	technical details of the GPS tracker to be fitted to the UA;
Annex C	provides some general guidance to help the teams develop a practical and competitive UAS;
Annex D	gives the requirements for completion of the deliverables.

2 Competition Overview

The Challenge is to design, build and demonstrate a UAS to include a small, fully automatic air vehicle to fly a mission modelled on the real life humanitarian aid scenario outlined in section 1.2, a storage and transport container, and ground control station. In line with the objectives of The Challenge, it is structured to replicate a real-world aircraft system development programme. A phased 9-month design and development process intended to be achievable over the course of an academic year, and culminating in the build, test and demonstration of the UAS. Deliverables have been carefully specified to maintain reasonable technical rigour whilst aiming to keep the workload manageable for teams. The 5 principal phases are outlined in the diagram below.



2.1 Challenge Schedule

The Challenge will formally be launched at the start of the academic year in October and will end with the demonstration event 'fly-off' 30th June to 3rd July. There will be a Welcome Workshop webinar in November to help teams with guidance on the factors for success. It should help teams with their planning and technical decisions. There will be further webinars[2] in February, April and June to help with later stages. More information will be posted on the IMechE webpage in October.

The schedule of deliverable items and activities is as follows:

Deliverable	Date	Reference
Concept Paper	15th November	Annex D.1
Design & Development Specification	7th March	Annex D.3
X-Plane Model	4th April	Annex D.6
Flight Readiness Review	13th June	Annex D.5
Design & Development A0 Poster	At the fly-off	Section 5.2.9
Business Presentation	At the fly-off	Section 5.2.10

[2] Dates to be confirmed

Adherence to deadlines is <u>not</u> a prerequisite for continuation in the competition, however **penalties will be applied if deliverables are not submitted on time.** If you believe that you won't be able to meet a deadline, please let us know as early as possible and we will endeavour to assist where we can.

2.2 Engineering Challenges

The Challenge has been designed to give students exposure to a number of disciplines that they will need in their engineering careers, and the requirement provides a number of engineering challenges. Factors for which the judges will be looking include:

- A methodical **systems engineering approach** to identify the requirements, selection of the concept with a design to meet those requirements, and then integration and test to confirm that the actual system meets the requirements in practice;
- An elegant and efficient **design** solution, supported by an appropriate depth of analysis and modelling;
- **Innovation** in the approach to solving the engineering challenges;
- Due consideration of the **safety and airworthiness** requirements which shall be addressed from the early concept stage right through into the flying demonstration;
- Appreciation of the **practical engineering** issues and sound design principles essential for a successful, robust and reliable UAS; e.g. adequate strength and stiffness of key structural components, alignment of control rods/mountings, servos specified appropriately for the control loads, consideration given to maintenance, ease of repair in the field;
- **Construction quality**, paying attention to good aerospace practice for such details as connection of control linkages, use of locknuts, security of wiring and connections, resilience of the airframe and undercarriage;
- Good planning and **team-working**; organising the team to divide up roles and responsibilities. Good communication (both within the team and with the IMechE organisers) and good planning will be essential to achieve a successful competitive entry, on time and properly tested prior to the Demonstration Event;
- Automatic or **autonomous operations**; the UAS shall be able to operate automatically, without pilot intervention from take-off to touchdown;
- A strong **business proposition** for your design, demonstrating good commercial understanding of how your design might be developed to generate revenue for an operator.
- Attention to **environmental impact**, including developing an efficient aircraft design that minimises energy consumption, and attention to minimising use of hazardous materials, and maximises recycled/recyclable materials.

The prize categories (see Section 7) recognise merit in meeting these engineering challenges.

3 Competition Entry

Details on team registration can be found at:

> https://www.imeche.org/events/challenges/uas-challenge/team-resources/register-your-team

3.1 Eligibility and Team Structure

3.1.1 Team Composition

The Competition is open to **Undergraduate or taught Postgraduate students** over the age of 18, from any University. Opportunities to interact with industrial partners throughout the duration of the competition will likely be of particular interest to penultimate year students but are open to all.

3.1.2 Team Supervisors

Each team **must** appoint an Academic Lead **or** a Team Supervisor.

- The ***Academic Lead*** is a member of the academic staff that is offering support, guidance and advice throughout the duration of the project. If your team does not have academic support, you can assign a Team Supervisor.
- The ***Team Supervisor*** must be CEng qualified and may be one of your sponsor representatives. It is preferred that your Academic Lead or Team Supervisor attends the final fly-off event.
- All delivered documents **must** be approved and signed by the Academic Lead or Team Supervisor.

Each team **must** also appoint a Team Leader.

- The ***Team Leader*** will be the **primary contact** for IMechE staff for the duration of the project and is deemed responsible for all competition deliverables and deadlines.

At the fly-off, the Team Leader must be the main point of contact for the duration of the event and is responsible for:

- communicating any issues with the aircraft to IMechE volunteers
- attending regular meetings with competition organisers
- ensuring the team adheres to the event schedule and turn up for scrutineering, business case presentation and flight line on time

3.1.3 Limits on Team Size at Demonstration Event

Please note that team attendance at the fly-off event is currently limited to **no more than 10 members per team**[3], plus your Academic Lead **or** Team Supervisor. This is because of the logistics constraints at the BMFA Buckminster site. This rule does not limit the team size for the pre-demonstration phases. **All 10 members attending the fly-off event must attend the safety briefing on the first day of the fly-off event.**

Note: The IMechE may or may not allow additional team members at the fly-off event this will be confirmed closer to the fly-off event. However once they have ruled on additional members the ruling is final and teams may be penalised points for breaking the limit.

[3] You are not allowed to switch members through the course of the fly-off.

3.1.4 University Alliances

A pair of universities may form an alliance to enter a joint team. The numbers of students in the team will be entirely determined by each University. This is so that the educational objectives can be determined to meet the needs of each University's degree programme. The Challenge, whilst having a set of defined performance objectives to achieve, is as much about the development and demonstration of team-working skills.

3.1.5 Universities entering more than one team

If a university enters more than one team, teams **must** operate **independently** and the UAS and associated deliverables must be entirely their own work. See also the note on Plagiarism below.

3.1.6 IMechE Membership

All team members/students **must** register for **free affiliate IMechE membership** upon entering a team. To register as an affiliate member, please follow the link. Please allow up to a month for your membership application to be processed.

It is not mandatory for the Academic Lead or Team Supervisor to register as an IMechE member to supervise a team. Free IMechE membership is available to students only.

If you experience any difficulties registering as an affiliate member, please contact uaschallenge@imeche.org.

3.2 Entry Conditions

3.2.1 Building on a previous year's entry

Whilst new designs are strongly encouraged, Teams may adapt and improve the design or construction from a previous year's entry. Where a design is adapted, the pre-existing work **must** be clearly identified in the Concept Paper.

Credit will not be given to the current year's team for previous year's work. In the event that previous year's work is not clearly identified it will be considered plagiarism, see below.

3.2.2 Plagiarism

We will be monitoring your work for plagiarism (copying from last year's work, from the internet, use of unattributed images, unattributed use of AI/LLMs etc.) with the loss of score for **any** instances detected. The judges' rulings on this will be final.

3.2.3 Industry Support

Some specialist industry support is allowed (see sponsorship 3.4), where specific skills and knowledge are required outside the scope of the students. The extent of such support **must** be declared in the Design & Development Specification.

3.3 Costs and Funding

3.3.1 Entry fee

An entry fee of £950 per team is payable upon submission of an entry form. Any deliverables due ahead of delivering the entry fee will not be scored. Teams will not be invited to the demonstration event if the fee is not delivered. This fee contributes towards the cost of putting on the Fly-off Event. It is non-refundable in the event that a team cannot participate in the Demonstration Event.

3.3.2 IMechE funding

The IMechE will **not** fund the costs of the UAS design and development, nor the team attendance at the Demonstration Event.

3.3.3 Demonstration Event cancellation

In the event that the live Demonstration Event is cancelled for reasons beyond the reasonable control of IMechE including, without limitation, any pandemic, epidemic and any legislation, regulation, ruling or omission (including failure to grant any necessary permission) of any relevant government, court, competent national authority, a partial refund of entry fees may be given to cover the costs incurred by the IMechE. Any refund is solely at the discretion of the IMechE. All reasonable efforts would be made to continue running the competition as a 'virtual' event and, as noted above, these rules cover that eventuality.

3.4 Sponsorship of Teams

Universities are encouraged to approach potential commercial sponsors, particularly aerospace companies at any time prior to or during the Challenge, for both financial support and technical advice. Note that where technical advice is received from sponsors, the judges will need to be sure that all of the development work has been undertaken by the students themselves. Such sponsorship shall be fully acknowledged in the Design & Development Specification.

3.5 Transport of aircraft to Fly-off Event

Teams are encouraged to investigate transport of their UAS to the fly-off event early. This can be a non-trivial planning aspect of the competition, especially for teams who will have to ship their aircraft in from outside of the UK. Special considerations may also be required for transporting or locally purchasing batteries.

3.6 Insurance and Regulation

3.6.1 UK Teams Public Liability Insurance

Teams **must** confirm that adequate public liability insurance is in place (at least £10M). This will cover all members of the team, and Teams should simply be able to obtain proof of cover from their university.

Public liability insurance covers the cost of legal action and compensation claims made against your team if a third party is injured or their property suffers damage as a result of your action.

All on site participants will be required to sign a liability waiver (which can be found on the competition website) to confirm that public liability insurance is in place. Teams will not be permitted to participate without this confirmation.

3.6.2 Non-UK Teams Public Liability Insurance

Non-UK teams' Public Liability Insurance requirements will be met by a BMFA membership. This must be obtained (details TBD) prior to the live event. This will cover their requirements for Public Liability Insurance.

All on site participants will be required to sign a liability waiver (which can be found on the competition website) to confirm that public liability insurance is in place. Teams will not be permitted to participate without this confirmation.

3.6.3 Team Pilot Personal Accident Insurance

In addition to the Public Liability Insurance, the Team Pilot is required to hold Personal Accident Insurance for flight risks covering their development test flying.

Note: The BMFA offers competitively priced insurance for members. Alternatively companies such as Flock https://flockcover.com/ may be able to offer suitable UAS insurance.

3.6.4 Medical Insurance (Overseas Teams)

Teams from outside the UK are also required to present evidence of medical insurance covering participation in the UAS Challenge fly-off event. This must be provided with the liability waiver at registration. Teams will not be permitted to participate without evidence of cover.

3.6.5 CAA Drone Regulations

As discussed at Section 4.6.1, teams must comply with the UK 'Drone and Model Aircraft Registration' regulations.

3.6.6 Ofcom Regulations

As discussed at Section 4.3.4, all transmitters must comply with UK's Communication' regulator.

3.7 Resources

3.7.1 UAS Challenge Mentoring Scheme

The Mentoring Programme pairs an Industry Partner with an UASC team on a random basis. The period of engagement in the programme is between three to nine months. The aim of the Mentoring Programme is to: provide teams with a point of contact for general queries regarding the plan, design, build, test and marketing of the UAS for the purpose of the Challenge; to help the team integrate with the concept of the Challenge and its guidelines and provide teams with general guidance, advice and a professional role model in terms of a career in engineering.

Due to the limited number of industry mentors, not all teams will be able to enter the scheme and those that are provided the opportunity are strongly recommended to engage with their mentors and make full use of the opportunities the Programme provides them.

To express interest in the mentoring scheme, please email uaschallenge@imeche.org. Once assigned an industry mentor, the team is expected to engage with the mentor on a regular basis. Failure to engage with the industry mentor on a regular basis for a duration of a month, will result in your team being removed from the mentoring scheme and replaced by a new team. For more information on the mentoring scheme, please refer here.

3.7.2 Additional resources

There are plenty of resources to help teams plan, design and build a competitive and successful UAS:

- The UAS Challenge Website https://imeche.org/events/challenges/uas-challenge gives further information;
- See Annex C for general guidance and tips on design and build of the UAS. Annex C.4 gives a link to presentation material on the Challenge website;
- The briefing webinar in November noted at Section 2.1 will also provide useful guidance;

- Make use of Industry sponsors as well as your Academic supervisor.
- Online Project Management software associated with design control and engineering projects is available free of charge from Mashoom. www.mashoom.co.uk
- Each team is allowed a one hour long virtual session with a member of the UAS Challenge event/committee to ask any advice/guidance – Please contact uaschallenge@imeche.org to arrange availability. Additional time may be permitted dependent on availability of Challenge team members.

4 Design and Operational Requirements

The UAS will consist of an air vehicle, transport and storage container, any launch equipment, and a ground control station (GCS). It shall be designed to perform the mission defined at Annex A whilst being compliant with the specification defined in this section.

A note on the language in this section: The term 'shall' denotes a mandatory requirement. The term 'should' denotes a highly desirable requirement. Where a paragraph is in *blue italics* and preceded by "*Note:*" this indicates a point of guidance or clarification rather than a requirement.

4.1 Air Vehicle Requirements

4.1.1 Air Vehicle Configuration

Any air vehicle configuration is permissible.

4.1.2 Air vehicle Mass & CG

Maximum Take Off Mass (MTOM) shall not exceed 10.0 kg, including the Aid Package, the scoring GPS Tracker and an RF locator.

Teams shall generate an estimate of their Centre of Gravity (CG) position as part of the Design and Development Specification (see Annex D.3).

The air vehicle fuselage shall be marked with the position of the empty CG. Empty in this case meaning in flyable condition with batteries but without payload. The marking, in the form shown below, shall be on both sides of the fuselage or the bottom of the wing where that is not possible, and with a minimum diameter of 12 mm.

4.1.3 Air Vehicle Materials & Environmental Impact

Lead weights shall **not** be used in any part of the airframe.

The teams should consider and attempt to minimize the environmental impact of their choice of materials in all aspects of the UAS. In the design process, consideration should be given to the use of non-hazardous and recyclable/recycled materials; low pollution; low energy usage; low noise.

4.1.4 Air vehicle fly-off envelope limitations

The air vehicle shall not exceed 40 kts true airspeed (KTAS) or 200 ft AGL at the fly-off event.

Note: These are artificial limits imposed due to safety considerations. It is expected that for autonomous flights this will be controlled by the aircraft's flight computer. During manual flying the competition pilot will judge airspeed and altitude.

Note: The airfield at the BMFA site is not at sea level and the site slopes.

4.1.5 Weather Limitations

The air vehicle shall be designed to operate in winds of up to 20 kts gusting to 25 kts, and light rain. The air vehicle should be capable of take-off and landing in crosswind components to the runway of 5 kts with gusts of 8 kts.

The air vehicle and onboard systems should be able to cope with standard UK weather conditions. This may include rain and/or wet ground conditions.

Note: it is always within the teams authority to not fly their aircraft if they deem the conditions unsuitable.

Note: handling the aircraft outside on the ground within the weather limits should also be considered by the teams.

4.1.6 Take-off and Landing

The air vehicle shall be designed to take-off from within a 10 m x 10 m box and landing within a 10 m x 20 m box. There are no obstacle clearance requirements. After landing, the air vehicle shall be capable of being flown again with a fresh battery but without repairs – if this is not the case, the landing portion of the flight will be penalised.

The air vehicle should be designed to operate from hard or grass runways.

Note: At the fly-off event, operation will be from a short grass runway surface.

Use of an auxiliary catapult launcher, or dolly is permitted, providing the design and operation is deemed safe and satisfactory by the Flight Safety Officer and Scrutineers.

Hand launching shall **not** be permitted.

4.1.7 Navigation System

Note: At the start of the demonstration, the organisers will provide the GPS co-ordinates of course waypoints, together with co-ordinates marking the outer boundary of the allowable flying area (the Geo-fence).

The air vehicle shall be capable of automatically navigating around the course via the GPS co-ordinates provided.

The air vehicle shall also be capable of storing the co-ordinates of the Geo-fence marking the boundary of the flying area and shall ensuring that the air vehicle does not breach the geo-fence..

The air vehicle navigation system shall automatically send a command signal to activate the Flight Termination System in the event that the air vehicle strays outside of the Geo-fence boundary during a mission flight.

Note: The waypoints that you will be provided are the locations of the course turns. It will be up to you to provide adequate waypoints for your aircraft to successfully navigate around those turns whilst remaining within the boundary, for the weather conditions experienced on the day.

Note: The mission stages are defined at A.3, testing different capabilities of the UAS which would be important for a humanitarian aid delivery system. The scoring criteria for the Mission is provided at Annex A.4.

4.1.8 Design Mission Range and Endurance

The air vehicle shall be designed to fly for 15 minutes with 20% battery capacity remaining.

Note: the course is not specified until the fly-off event. However, in previous years, a lap of the course was ~ 2.5km. You should aim to be able to achieve multiple laps

4.1.9 Propulsion Systems

Only electric motors shall be permitted for propulsion.

Note: Propellers, rotors, ducted fans or other mechanical means of converting power from the electric motors to thrust are allowable.

4.1.10 Land-away recovery

In the event that the air vehicle lands (controlled or otherwise) away from the runway, it shall make an audible and visual alert and at least 25% of the upper, lower and each side surface of the aircraft shall be bright colours to improve ease of air vehicle location and recovery.

Additionally, for each flight at the fly-off event, the air vehicle shall be fitted with an IMechE provided, independently powered, Radio Frequency (RF) locator.

Note: the specific locator has yet to be defined

4.2 Platform Energy Storage

4.2.1 Batteries

Only batteries shall be used for energy storage on the aircraft.

There are no restrictions on the electrical power system voltage or current draw.

The battery/batteries shall be:

- Lithium Polymer (LiPo);
- Positively secured to prevent movement in flight;
- Located such that it has some protection in the event of a crash; and
- easily accessible and removable without the use of tools.

Teams shall ensure that the maximum current draw possible from the air vehicle does not exceed the maximum safe continuous current that can be delivered by the battery/batteries.

Teams shall ensure that the design of their air vehicle allows the batteries to be removed without requiring tools, within 60 seconds. Additionally batteries used in the air shall include bright colours to facilitate their location in the event of a crash.

Any electrical power / battery architecture deemed high risk in the opinion of the scrutineers will be disqualified.

Overseas teams should also note the guidance on transport of hazardous materials at Annex C.3.

4.2.2 Platform Energy Safety Link

The air vehicle shall have a clearly labelled and accessible, externally removable link to isolate power to **the whole aircraft**. It shall be positioned away from all propellers so that there is minimum risk of injury when making safe the aircraft. A typical example is shown below.

Note: this is a requirement so that in the event your aircraft lands away from the runway and requires the recovery team to retrieve it, they can immediately cut off all power from the batteries to the aircraft.

4.2.3 Propulsion Energy Safety Link

The air vehicle shall have a clearly labelled and accessible, externally removable link to isolate power **to all motors**. It shall be positioned away from any propellers so that there is minimum risk of injury when making safe the aircraft.

Note: this is a requirement so that you may power on your aircraft, whilst minimising risk to yourselves, whilst you work on your aircraft prior to flight.

4.3 Control

4.3.1 Manual/autonomous control

The air vehicle shall be able to be flown manually or fully automatically from the initiation of the take-off to the full stop on final landing, including navigation around all waypoints and release of the Aid Package.

Note: Stability augmentation systems do not classify as 'autonomous' or 'automatic' control.

Note: Automatic take-off implies that the system, after it has been started, can be positioned at the runway threshold manually, then when the control is transferred to the UA, it executes the take-off without further human intervention. Auxiliary launch/landing equipment is permitted, so long as it all operates automatically.

It shall be possible to revert to manual control at any point in the flight & to trigger the Flight Termination System (see section 4.3.2) during automatic operation.

Note: The Flight Safety Officer (FSO) will command the operation with the master controller being held by the IMechE Safety Pilot throughout the flight, removing the requirement for a buddy box. The FSO will direct and the Safety Pilot will attempt to gain manual control of an errant UA, if it is safe to do so, or initiate the FTS if required.

The master controller shall be set up to operate in Mode 2 configuration, that is with yaw and throttle on the left hand stick, and roll / pitch on the right hand stick.

4.3.2 Flight Termination System

A FTS shall be incorporated as part of the design and is a mandatory requirement to achieve a Permit To Fly. The actions of the FTS shall safely land the air vehicle as soon as possible after initiation.

Note: In this instance a "safe landing" is simply one that does not injure anyone – it does not necessarily mean the aircraft will be undamaged!

For all aircraft, the throttle shall be set to 'engine off'.

For fixed wing aircraft the following commands shall be set:

- Pitch: full nose up
- Roll: full right
- Yaw: full right
- High lift devices (if fitted): maximum deflection
- Spoilers/speed brakes (if fitted): maximum deflection

Other actions could include deployment of a recovery parachute if fitted.

For hybrid VTOL aircraft, the aircraft shall **not** transition between hover and forward flight following any activation of FTS or Fail Safes.

The FTS **shall not** trigger a "return to home" action.

Note: As the demonstration element of the competition is held in a fully segregated area avoiding over-flight of personnel or buildings, the safest option in the event of a fault with the air vehicle is to cut propulsive power and descend immediately to ground. In this circumstance, the default setting of commercial autopilots to return to home base is not a safe option. As a consequence, the purpose of the FTS is to initiate automatically all relevant actions which transform the air vehicle into a low energy state should the connection between the GCS, air vehicle or RC Controller be lost or be subject to interference / degradation.

The Aid Package **shall not** be jettisoned in the event of the FTS being activated.

The FTS shall be automatically triggered:

- By breach of the Geo-fence.
- After 5 seconds of RC Signal loss. This is the connection directly between the RC controller and the air vehicle.
- After no longer than 10 seconds from lost Datalink.

The FTS shall also be triggered manually by the Flight Safety via the Master Controller (RC Controller) if the Flight Safety Officer deems that the UA's behaviour a threat to the maintenance of Air Safety.

If the Flight Controller has the capability, it is allowable that the Failsafe Action for Datalink loss is for the air vehicle to enter a loiter mode if it continues to follow the rest of the rules set within this document. This is allowed so that the Pilot is given a chance to manually recover the air vehicle. If this method is chosen, the GCS must provide an audible cue to indicate to the Pilot that this is happening. In this event, the remainder of the flight shall be completed manually and the Flight Controller is not allowed to regain control of the air vehicle for automatic flight modes.

Note: The Datalink is defined as the link between the GCS computer and UA, relaying the UA's telemetry / positional info and video feed etc. to the GCS.

Note: whilst the specified FTS is mandated for the Demonstration Event, teams may require different failure management controls while they are undertaking flight testing in their local environment. They should assess the safety requirements of their flight test area. It is the teams' responsibility to operate safely and within the law when conducting development flight testing.

4.3.3 Ground Control Station

The UAS shall include a GCS, which *could* comprise a tablet or other device plus the associated telemetry. It shall display and record the following information, which shall be visible to the Operators, Flight Safety Officer and Judges during the mission flight:

- Current air vehicle position on a map;
- Local Airspace, including the Geo-fence Flying Zone;
- Height AGL (QFE);
- Indicated Airspeed (kts); and
- Information on air vehicle Health.

Note: Data latency in the order of 2 seconds is acceptable.

In the absence of such live telemetry the Flight Safety Officer's decision on boundary breaches is final with respect to flight safety.

The ground control station datalink ID shall not be left at its default value when at the flight line in the fly-off. Teams will be allocated datalink channel IDs at the start of the fly-off event in order to reduce the chances of interference.

The air vehicle shall have a suitable port for a wired connection between the air vehicle and the ground control station. This is to ensure all air vehicles are able to be programmed without the need for RF transmission, in order to reduce the sources of interference.

For the purpose of scoring the air vehicle navigation performance, the GPS track downloaded from the Tracker (Section 4.4.3) will be used and the Judges' decision is final.

4.3.4 Radio Equipment

All radio equipment and datalinks shall comply with EU directives, and shall be licensed for use in the UK (Ofcom IR 2030 – UK Interface Requirements 2030 Licence Exempt Short Range Devices). See link:
https://www.ofcom.org.uk/__data/assets/pdf_file/0028/84970/ir-2030.pdf

- IR 2030/1/10 433 MHz ≤10 mW e.r.p (10% duty cycle limit)
- IR 2030/1/12 434 Mhz ≤10mW e.r.p (≤25 kHz channel spacing)
- IR 2030/1/14 868 MHz ≤25 mW e.r.p
- IR 2030/1/23 5.8 GHz ≤25 mW e.i.r.p
- IR 2030/7/1 2.4 GHz ≤100 mW e.i.r.p when frequency hopping modulation is used
- IR2030/1/19 869.40- 869.65 MHz (commonly referred to as 868 in product descriptions) ≤500 mW e.r.p. (10% duty cycle limit or see IR2030 for other options)

For resilience of operation Radio equipment, including data links, shall be capable of reliable operating ranges of **at least** 1 km.

Note: The Mission will not require the air vehicle to operate further than 500 m from the pilot.

Radio equipment providing control of the air vehicle and the Flight Termination System shall be 'Spread Spectrum' compliant on the 2.4 GHz band, to allow simultaneous testing of several UAS without interference. Evidence of compliance shall be presented in the Design Report and FRR submissions and be reviewed at the Scrutineering.

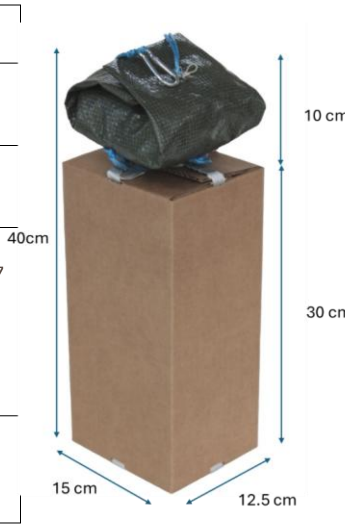
If an imagery downlink is incorporated, and if it is central to the safety of flight, control or for Flight Termination decisions, then it shall be suitably reliable and resilient to interference.

4.4 Payload Requirements

4.4.1 Payload - Aid Package Specification

The air vehicle shall deliver a payload of an AirDropBox (ADB) Micro UAV system (see http://www.airdropbox.co.uk/products/), as a representative payload volume for an Aid Package. These will be provided free of charge to teams upon registration. Key parameters are provided below.

Empty ADB Micro System Empty Mass	0.5 kg
Minimum payload (sand) mass for parachute activation	1.25 kg
Max Delivered payload (sand) volume	3.75 litres
External Aid Package Dimensions	15 cm x 12.5 cm x 30 cm The standard parachute adds 7 cm - 10 cm to the packed length. So it is recommended accommodate the whole payload that you provision: 15 cm x 12.5 cm x 40 cm
Approx minimum release height for the standard AirDropBox parachute	50 ft – 80 ft



The air vehicle shall deliver a payload of at least 1.25 kg of **sand**, this does **not include the empty weight of the ADB Micro System**.

The standard parachute requires a 1.25 kg payload to activate and is sized to give a 1.5 kg payload a descent speed of about 11 mph. A 5 kg payload may land at up to 30 mph. Teams are free to modify the parachute if required to change the descent speed, or release height. The objective is to ensure that the payload is delivered to the Drop Zone, and that it remains **intact**.

Note: care must be taken in the payload system design and deployment to ensure that the payload does not drift outside the Geofence, nor that the air vehicle has to be positioned outside the Geofence in order to compensate for payload drift.

The ADB Micro UAV System box shall **not** be modified. Nor shall any additional external protection be added to increase the packages robustness.

Standard **builders' sand** shall be used to provide the desired payload mass. The sand will be provided by the IMechE at the Demonstration event. This has a density of around 1.6 kg / litre depending on water content. Teams are free to fill the containers with as much sand as they require to perform the mission whilst remaining within their aircraft's design constraints. An ADB Micro UAV filled to capacity with sand will have a mass of about 6.5 kg.

Note: carriage of payloads greater than the minimum of 1.25kg will attract a higher score. Carriage of payloads less than the minimum will attract a reduced payload score.

4.4.2 Aid Package Carriage and Delivery

The air vehicle should be designed to facilitate rapid loading of the Aid Package into the air vehicle. Ideally without the use of tools. There are no restrictions on the carriage and release mechanism, except:

- The Aid Package shall be deployable from the air vehicle by automatic command.
- The Aid Package shall **not** be modified for attachment to the payload release mechanism within the aircraft. Any retention straps must be releasable without tools; and
- The Aid Package shall be deployed whilst the air vehicle is in flight. The air vehicle is **not** permitted to land to deploy the Aid Package.

Note: Care should be taken to ensure the reliability of payload release and safe separation from the aircraft.

4.4.3 GPS Tracker

In addition to the Aid Package, the air vehicle shall be designed to carry a GPS tracking data logger (the Tracker) in order to support the scoring of the competition.

The tracker shall be positioned on the upper surface of the aircraft but covered to protect it with a clear view of the sky above. It may be mounted internally or externally, but there must be a 140 degree field of view above the tracker around the full 360 degree azimuth which is unobscured by metallic or carbon fibre parts. A cover of fabric, plastic, foam or GRP will not affect the reception.

If teams cannot meet this specification they should contact the organisers to discuss the requirements further. The instrument should be secured to the aircraft by means of straps or held firmly in place in an enclosure, while permitting ready access to the two buttons and status LEDs.

The Organisers will provide the Tracker, described at Annex B, during the Demonstration event. Teams shall fit the Tracker to the air vehicle before the Scrutineering process and return it to the Organisers **immediately** following a flight, for post-flight evaluation of the 3D trajectory.

4.4.4 RF Locator

In addition to the Aid Package and the tracker, the air vehicle shall be designed to carry an RF locator. This device has not yet been defined. It shall be internally mounted – and in an RF transparent location (i.e. not under carbon fibre etc). It will weigh no more than 50g, be no-greater in size than 5cm x 5cm x 2.5 cm and will be self-powered. Further details will be provided as soon as they become available.

4.5 Storage & Re-Assembly Requirements

4.5.1 Storage Container

Teams shall design and make a Storage Container for **safely** transporting their UAS and associated equipment, including any launch device. This should be as small as practical to facilitate agile operations, but **shall not exceed external** dimensions of 1500 mm x 600 mm x 600 mm (this includes, handles, hinges, clasps etc.). No score will be awarded for COTS storage containers without modification or justification.

The container should allow for the air vehicle or its components to be secured in place. Innovation is encouraged, and the Storage Container may also be designed with additional functionality such as, to facilitate handling of the air vehicle during assembly and test.

Note: One of the tasks is to assemble and pre-flight the UAS out of the Storage Container within 6 minutes , thus ease of access and handling would be an advantage.

Note: if teams outside of the UK are presented with limitations imposed by their transport providers, please get in contact with the IMechE team as soon as possible so that we can come up with an accommodation ruling before your arrival at the fly-off event. As a general rule however, the overall volume of storage must not exceed that laid down above.

4.5.2 Assembly

Teams shall design their air vehicle for **routine** assembly when removing the air vehicle from storage container.

The design should allow for the routine assembly/disassembly of the air vehicle **without** the need for tools. The exception to this are propellers and rotors, which **shall** be fitted and torqued according to their specs.

Note: 'routine' in this instance means those actions that would be carried out in order to transfer the air vehicle to and from its container and to prep it for flight.

4.5.3 Connections

Major subassembly component connections (e.g. wing to fuselage) shall have secondary retention mechanisms (e.g. cotter pins, pip pins, locking wire, etc). These will be items of inspection in the scrutineering. If the scrutineers do not believe that suitably safe and robust connections are in place flying will not be permitted.

During assembly the team will likely have to reconnect various electrical and/or mechanical connections. Teams should consider how they design these connections to physically prevent incorrect configurations.

4.6 Regulatory, Safety, and Environmental Requirements

4.6.1 Compliance with UK Drone Regulations

This section contains useful information and links to stay compliant with UK drone regulations.

Note: International Teams should refer to any relevant flight restrictions in their given country. The information provided here serves only as a guide and may be outdated at the time of reading. It is essential that each team conducts their own review of the drone regulations that apply to their country.

Operator ID and Flyer ID – The legal requirements for flying in the United Kingdom Civil Aviation Authority (UK CAA) airspace.

- An individual from the team, or, a nominated individual from the University, **shall** obtain a UK CAA 'Operator ID' which will look like this 'GBR-OP-###########'. This will cost £10 (correct as of September 2022) and will last for one year. You MUST display this number in block capitals a minimum of 3mm high on the main body of the unmanned aircraft, and in a position that does not need tools to access. The Operator ID can be used on all of the unmanned aircraft you are responsible for, i.e. if you bring two airframes to the competition, you may use the same Operator ID on both.
- Any person that flies the unmanned aircraft (whether directly by remote control, or by automated computer control) **shall** obtain a UK CAA 'Flyer ID' which will look like this 'GBR-RP-###########' or 'FLY-######'. You **shall** complete a free online multiple-choice quiz to obtain the Flyer ID and it will then last up to 5 years.

Where you can fly – The legal requirements for the unmanned aircraft you are flying.

- If your unmanned aircraft is over 250g it will default into the UK CAA 'A3 Open Category, which means:
    - You must not fly within 50m horizontally of any uninvolved person (anyone you can brief and who has chosen to be near the unmanned aircraft, i.e. your team, can be considered involved).
    - There should be no uninvolved people in the area of the flight, i.e. fly somewhere remote away from parks and other outdoor spaces used by the public.
    - You must not fly within 150m horizontally of a residential (houses), commercial (shops, businesses), industrial (factories, warehouses, manufacturing) or recreational (parks, beaches) areas.
- You may fly under an Article 16 Authorisation if you join one of the approved organisations that hold one (BMFA, LMA, FPV UK). This will allow you to fly in recreational areas (parks, beaches), provided the area is suitable and you do a risk assessment.

Dropping of Articles – The legal requirements for dropping any item from your unmanned aircraft.

- By law, you MUST NOT permit any item to be dropped from your unmanned aircraft if you are flying in the UK CAA Open Categories.
- By law, you MUST NOT permit any item to be dropped from your unmanned aircraft if you are flying under a UK CAA PDRA01 Operational Authorisation (unless specifically permitted in writing in said authorisation).
- You MAY drop articles from your unmanned aircraft, provided they are not dropped in a manner that might endanger any person or property if you are flying under an Article 16 Authorisation.

Insurance – The recommendations and legal requirements.

- By law you only need insurance for an unmanned aircraft once its take-off weight (i.e. its flying weight) exceeds 20kg, or, if the purpose of the flight is commercial in nature.
- The IMechE strongly recommend that you hold a minimum of public liability insurance for your practice flights, for which the British Model Flying Association is recommended.

Fly-off competition – What you must have at the live event.

- Your unmanned aircraft **shall** have a UK CAA Operator ID displayed on it. (International teams can apply for a UK Operator ID only online)
- The IMechE supply a remote pilot for the fly-off event.

Resources – Where to get the information.

- UK CAA Operator ID and Flyer ID can be obtained here: https://register-drones.caa.co.uk
- UK CAA requirements for flying in the Open Category document CAP2012: https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=9954
- UK CAA guidance document for unmanned aircraft CAP722: https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=415
- British Model Flying Association: https://bmfa.org
- British Drone Flyers: https://britishdroneflyers.org (the British Drone Flyers is also the BMFA, same organisation, same members benefits, just a different name and membership period).

4.6.2 Pilot Roles and Competence

Subject to the 'Drone and Model Aircraft Registration' regulations noted at Section 4.6.1 above, the following guidelines discuss the required Pilot competency.

During the final competition flying event, the IMechE shall provide an experienced BMFA qualified Safety Pilot who shall be responsible for undertaking the manual flying assessment and attempting to recover the air vehicle or activate the FTS in the event of uncontrolled flight or departure from the Flying Zone. As a result, final competition flights will only be conducted by the Safety Pilot and using the Safety Pilot's Flyer ID.

The Team shall function as the Operator at the final competition flying event and shall be responsible for flight readiness, including correct programming of the UAS and pre-flight checks. As an IMechE pilot will be provided for competition flying, it is **not** mandatory for the team pilot to hold a BMFA qualification or Flyer ID at the event, **however the Team's Operator ID must be displayed on the outside of the air vehicle.**

4.6.3 Flight Termination System

The FTS forms a core part of the design safety requirements and is described at Section 4.3.2 above. You shall demonstrate the functionality of the FTS on the ground prior to being given permission to fly.

4.6.4 Other Design Safety Requirements

The design and construction of the UAS shall employ good design practice, with appropriate use of materials and components.

The design shall be supported by appropriate analysis to demonstrate satisfactory structural integrity, stability and control, flight and navigation performance, and reliability of safety critical systems.

4.6.5 Operational Safety Requirements

N.B. Only those students involved with the launch and recovery of the air vehicle shall be permitted onto the flight line. Any breach of this rule will result in a heavy penalty for the respective team.

Note: This will be further clarified at the demonstration event during the initial safety briefing – and will be loudly reinforced if flight line staff predict a possible breach.

The air vehicle shall remain within Visual Line of Sight (VLOS) from the Pilot, and remain below 200 ft AGL;

The air vehicle shall not be flown within 50 m of any person, vessel, vehicle or structure not under the control of the FSO. During take-off or landing however, the air vehicle shall not be flown within 30 m of any person, unless that person is under the control of the FSO;

The maximum airspeed of the air vehicle in level flight shall not exceed 40 KTAS;

During the entire flight the air vehicle shall remain in controlled flight and within the Geo-fence boundary of the Flying Zone;

In the event of an air vehicle appearing uncontrolled or at risk of departing from the Flying Zone, the Safety Pilot shall attempt to recover the air vehicle manually, or failing this shall activate the FTS. The Safety Pilot shall comply with directives from the FSO.

Any Personal Protective Equipment (PPE) needed by the team and/or Flight Line officials, for maintenance or operation shall be listed in the Flight Readiness Review.

All students involved with the launch and recovery of the air vehicle on the flight line must wear safety glasses. Open toe footwear will not be permitted in the pits or on the flightline.

4.7 Limits on use of COTS Items

The UAS airframe and physical control systems shall be designed from scratch, and **not** based upon commercially available kits or systems. This is a qualifying rule, meaning that an entrant based on a commercially available system will not be eligible for entry.

Commercial Off The Shelf (COTS) stock component parts shall be limited to motors, cameras, batteries, servos, sensors, autopilots and control boards such as the Pixhawk or Ardupilot platforms. If you are unsure if something counts as COTS or not, contact the IMechE.

Note: Teams are allowed to use the supplied software with COTS autopilots, although it may need modifying to meet the specific competition mission challenges and safety requirements – see above re: FTS and return to home.

The total cost of COTS components used in the air vehicle should not exceed £1,300. Anything above this figure needs to be justified. A Bill of Materials and costs shall be delivered as part of the design submission, and a production cost estimate will be expected at the Project Presentation.

Note: Cost efficient solutions will score more points.

Note: Teams may use COTS components which already exist at the University, but for which no receipts are available. An estimate of the price can be obtained by looking up part numbers or by manufacturer, and a screen shot of the price will suffice.

Teams shall also demonstrate that manufacture of the airframe and integration of the UAS has been predominantly undertaken by the students themselves, rather than being outsourced to a contractor or academic support staff.

5 Statement of Work

This section provides details of the activities and outputs in each stage. Teams are encouraged to plan these activities thoroughly and with plenty of time to spare. Annex C.2 gives a few tips to assist with program planning.

5.1 Challenge Stages

5.1.1 Concept

This stage comprises basic requirements capture and trade studies leading to the selection of the system concept and a plan for its development. This stage is fundamental in selecting the right concept for success at the competition. This concludes with the preparation of a Concept Paper.

5.1.2 Design and Development

Detailed design for manufacture supported by structural, aerodynamic, system and performance analysis. This stage shall include an assessment of how the requirements are to be verified through test, and importantly how the safety requirements are to be met. It may be helpful for some prototyping to be undertaken. This stage includes the Preliminary and Critical Design Reviews' Reports, together with the Design and Development Specification.

The simulation element of the competition will consist of an X-Plane model created to demonstrate the configuration and design aspects of the air vehicle; based on the evidence presented within the design and development documentation submitted. This stage concludes with the submission of the X-Plane model and Pilot's Handbook.

5.1.3 Manufacture and Test

This stage comprises construction of the UAS, though if some early prototyping has occurred to de-risk the design, may run concurrent to earlier stages. Demonstration through analysis, modelling and physical test to show that the design will meet the requirements and is sufficiently robust and reliable.

Physical test should include subsystem test, as well as flight testing of the complete UAS. It is suggested that the teams conducted several flight tests prior to the demonstration event. There will be no test flights permitted at the demonstration event.

*Note: For UK Teams this should be at a BMFA Club site (*https://bmfa.justgo.com/clubFinder.html*) or other suitable flying location as per CAA guidance (*https://register-drones.caa.co.uk/drone-code/where-you-can-fly*).*

Note: Non-UK Teams should follow their local regulations.

This stage concludes with the submission of the Flight Readiness Review (FRR) deliverable.

5.1.4 Demonstration

The flying demonstration event is held over three days and comprises a multi-stage process of qualification and demonstration, including:

- Scrutineering;
- Flying Quality Assessment;
- Mission Flight;
- Business Case Presentation.

Further details of the Demonstration Event are provided at Section 5.3.

5.2 Deliverable Items Description

As well as deliverables for the competition, the following are extremely useful events to hold/documents to generate for your team and give a flavour of standard industry processes. A more detailed description of deliverables is available at Annex D. If you believe that you will struggle to deliver any of these, or it is unclear what is expected – please contact the IMechE and we will endeavour to assist you.

5.2.1 Concept Paper

This initial report is a summary of the team's design concept. The requirements for this paper are specified at Annex D.1. This must be uploaded to Mashoom by the date specified in 4.3.

5.2.2 Preliminary Design Review (PDR)

Shortly after the commencement of your detailed design phase you should conduct, as a team, a review to assess: whether you are addressing all the mandatory requirements of the Challenge, that you will achieve your performance objectives, and that your schedule is achievable. Your Academic Lead or Team Supervisor should chair this review. A detailed record of the meeting including all the actions placed at the meeting on team members should be produced and uploaded to Mashoom.

5.2.3 Design and Development Specification

This is a detailed description of your UAS design and its development and is a significant part of the overall competition. The requirements for this report are specified at Annex D.3. This must be delivered by the date specified at 2.1.

5.2.4 Critical Design Review (CDR)

At the completion of your design phase and before you commence final manufacture of your UAS, you should hold a Critical Design Review following the same process as for the PDR. This is your opportunity to ensure that your UAS will be successful at undertaking the Challenge.

5.2.5 X-Plane Simulation

Teams are required to submit an X-Plane model of their UAS, which will be flown by IMechE pilots around a course modelled on that used for the live event. The requirements for the X-Plane model are specified in Annex D.6 Flight Readiness Review

5.2.6 Flight Readiness Review

The Flight Readiness Review (FRR) submission is a critical safety and operational review to confirm if your aircraft is ready to undertake demonstration flights to the customer. This is detailed at Annex D.5. If the judges consider there are non-conformances with the FRR, they may provide feedback to the team.

5.2.7 Media and Engagement

At the fly-off event, the teams shall bring evidence showing the team's media promotion of the Challenge and their engagement with schools as part of the STEM (Science, Technology, Engineering and Mathematics) Outreach Programme. This could be videos, posters, or other evidence they wish to present.

5.2.8 Deliverable Portfolio

Teams shall bring to the flying event a hard copy portfolio comprising their Concept Paper, PDR record, Design & Development Specification, CDR record, and FRR.

5.2.9 Design & Development Poster

Teams shall provide and display an A0 poster in the pits at the demonstration event, which summarises the Design, Development, Manufacturing and Testing achievements, the innovations in the design and the attention to safety and environmental issues.

5.2.10 Business Presentation

During the fly-off event, teams shall deliver a presentation covering their Business Plan and addressing Environmental issues arising.

The Business Plan should give a well-articulated understanding of their market, an outline revenue model and sales projections, and summarise how the UAS capabilities and cost projections align with the target market. It should include a cost breakdown of the demonstration vehicle and how this will be translated into the selling price of the production system, including support and operational costs.

Teams should explain how they are minimising the environmental impact of their design and operation.

Teams will have 10 minutes for their presentation, and there will then be up to 5 minutes of questioning from the judges.

5.3 Fly-off Event

Once arrived at the fly-off event teams shall **not** remove their aircraft or components from the fly-off event site until the close of the competition. Any teams found doing so will be penalised.

5.3.1 Scheduling

The Fly-off Event is provisionally scheduled from Monday 30th Jun – Thursday 3rd July 2024, referred to as Day 1 – Day 4.

Teams shall arrive at BMFA Buckminster site **no later than 14:30** on Day 1 in order to attend a **safety meeting at 15:00** - this meeting **will not be repeated** and is a requirement for competition activity. This mandatory detailed briefing will be given at the beginning of the Fly-off Event covering the logistics and timings for the event, rules and good conduct for safe operations, pre-flight briefings etc.

Teams should arrive with a fully serviceable UAS that is in good working condition.

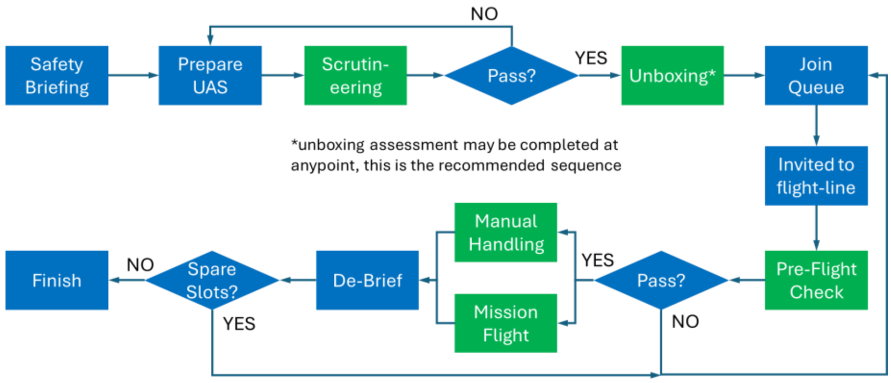
Flying, scrutineering and judging will start on Day 2. The Project Presentations will take place on Day 3 and Day 4.

There will be no test flying permitted at the event (see 5.1.3). A Mission flight is deemed to have started from the moment the FSO gives take-off clearance, even where the air vehicle then crashes prematurely. Any flying after the cut-off time on Day 4 will not attract any points.

Once they pass scrutineering, teams may join the flying queue. The schedule is necessarily tight and teams shall take responsibility for their readiness in order to keep a good tempo of scrutiny and flying. The flight line team may direct a team deemed not be ready, to go to the back of the flying queue. Any team (individual, group, or air vehicle) that crosses the flight line without permission will be sent to the back of the flight queue and may additionally be penalised points.

Team readiness for scrutineering and flying is imperative in ensuring an efficient schedule, and to maximise your chances of a successful flight. For example, paperwork for the scrutineers needs to be complete and submitted on time.

The sequence of events that each team will go through in the preparation and flight operations is depicted below. The Green boxes denote the tasks which are scored:



Note: The scheduling of scrutineering and flying is very tight over the event. The judges and FSO have ultimate discretion. They will try to ensure that everyone flies, and that no-one is disadvantaged, but this cannot be guaranteed.

5.3.2 Set up of Catapults

Launch catapults, where used, shall be set up initially during the Pre-Flight Preparation (Section A.2), and then may be left assembled so as not to disrupt flying tempo. They may be recovered back to the hangar at the end of the flying day.

5.3.3 Prepare UAS

Preparation shall include uploading all the waypoint and Geo-fence co-ordinates, thoroughly checking out the UAS to confirm that it is ready for Scrutineering, and ensuring that paperwork (e.g. Form 701s) are completed as far as possible.

5.3.4 Scrutineering

As soon as they are ready, the team shall register for scrutineering with the event Schedule Manager on a self-assessed readiness basis. The Schedule Manager may introduce slot times to ensure that all teams are scrutineered.

A panel of expert aircraft engineers will inspect the UAS to ensure:

- that it is safe and airworthy;
- that any Corrective Actions issued by the Judges are incorporated; and
- that any late modifications introduced are reviewed and acceptable.

The scrutineering panel will have reviewed the FRR submission (see Annex D.5), which is a key input to the Scrutineering process as it should contain evidence of satisfactory testing.

The assessment will include:

- Regulatory Compliance – Pass/Fail criteria;
- Airworthiness Inspection – Structural and Systems Integrity:
    - Verify that all components are adequately secured, fasteners are tight and are correctly locked;
    - Verify propeller structural and attachment integrity;
    - Check general integrity of the Aid Package and deployment system;

    - Visual inspection of all electronic wiring to assure adequate wire gauges have been used, wires and connectors are properly supported; including accessibility of LiPo Batteries (Refer 3.1.3).
- UA manufacturing assessment including:
    - Design and Build quality, including use of appropriate materials, systems integration and configuration control;
    - Attention to detail in assembly and aesthetics;
    - Crashworthiness and environmental proofing;
    - Sound and safe organisational, workshop and operating practices, such as configuration control, tool control, checklists and flight reference cards.

If a team fails scrutineering they will be given guidance on how to rectify the faults.

Efforts will be made to retain flexibility in the schedule to allow teams who fail scrutineering to repair, rectify, test and re-apply.

Teams **shall** ensure that all paperwork prepared during the challenge (such as the completed Form 701) is submitted to the organisers during the event, to be retained by the IMechE. The team may retain copies of paperwork.

5.3.5 Storage and Flight Readiness Demonstration

Those teams that have passed scrutineering will conduct a 6-minute timed task to unpack, assemble and check out the UAS, including the ground station for a safety controls check. The storage case itself will also be assessed for build quality, level of protection it affords the UAS and any interesting design features it may have.

The objective of this task is to demonstrate the team's ability to deploy the UAS at short notice for an urgent operation.

Note: this demonstration may be conducted at any point during the event. Teams should ensure they schedule it so that it does not delay the tempo of mission flying.

5.3.6 Pre-Flight Check

Following scrutineering, teams will proceed airside for controls functional and power checks. This will include:

- Control checks – Communications; Function and Sense:
    - Radio range check, motor off and motor on;
    - Verify all controls operate in the correct sense;
- FTS – Verify correct operation of the fail-safe flight termination systems;
- Verification of waypoints and geofence settings.

Assuming this is satisfactory up to four members of the team together with the UAS will then move to the Flight Line.

Note: this is the time that you should use in order to get your aircraft ready to fly (except attaching the propellers). It should be possible to walk your aircraft straight to the flight line for take-off from this point. You should also be monitoring the weather and have ensured that your waypoints are appropriate for the weather conditions.

5.3.7 Flight Line

At the Flight Line there will be a short flight safety brief by FSO. The team shall brief the FSO and safety pilot on the controls and operation of their air vehicle.

There should be no additional set up required from this point. If preparation time exceeds 5 minutes, or the team hits snags, the FSO may direct the team to withdraw and let another team fly. This is ultimately the FSOs judgement and their decision is final.

5.3.8 Manual Flying Assessment

The team shall conduct one manual handling assessment flight, flown by an IMechE designated pilot, which will contribute to the total Challenge score. This flight will consist of a single manual take-off, circuit and landing.

Note: The intent of this scored flight is for the teams to consider and design for good flying qualities, without relying on the flight controller to maintain control.

5.3.9 Mission Flight

When the safety pilot confirms that the team is ready to launch, the FSO will give their authority to launch, and this is when the mission time starts.

During a flight, if the air vehicle strays outside the Geo-fence marking the boundary of the flying area, the aircraft shall automatically activate the FTS. If the FSO believes that the aircraft has breached the geo-fence then they shall activate the FTS via the command link. This will result in the termination of the mission.

After the air vehicle has landed, the team shall pack up and clear the Flight Line in less than 5 minutes. They will then move back to the hangar.

Teams shall return the GPS Tracker to the Judges for evaluation **immediately** after the flight, or risk being penalised 10 points. This is necessary to avoid delays in the judging and to avoid wasted time chasing up teams for their tracker.

Note: Weather is a random element – some teams may get good weather over the three days, and others may have to fly in poorer weather. This is the luck of the draw. The earlier in the competition you are ready to fly, the greater your choice of when to fly, and chances of getting favourable conditions.

5.3.10 Safety of Operations

The Flight Safety Officer (FSO) shall have absolute discretion to refuse a team permission to fly, or to order the termination of a flight in progress.

Only teams issued with a 'Permit to Fly' through the Scrutineering process will be eligible to enter the Manual Flying Assessment and Mission Flight stages.

Teams shall be responsible for removal of all batteries from the site that they bring to the event, including safe disposal of any damaged batteries.

Note: the assessment of safety includes the team members' attitude to safety of operations, observing safe working practices in the pit lane, always adhering to FSO instructions, not transmitting when not approved.

5.3.11 Supplementary Rules for Demonstration Event

A set of Supplementary Rules may be issued to teams before the FRR, describing in more detail the running procedures for the Demonstration event. These supplementary rules will not impact any issues essential to the UAS design selection.

6 Adjudication and Scoring Criteria

6.1 Overall Scoring Breakdown

The competition will be assessed across the following elements: design and development (150 points), X-Plane Simulation (150 points), Pre-Mission assessments (100 points), the Flight Demonstration (500 points), and Business Case (50 points) scores.

	Activity	Score
Pre-Fly-off Event	**Design and Development**	**250**
	Concept Paper	50
	Preliminary Design Review (PDR)	25
	Design and Development Specification	120
	Critical Design Review (CDR)	25
	Flight Readiness Review	30
	X-Plane Simulation	**150**
	X-Plane Submission	125
	Pilot's Handbook	25
Fly-off Event	**Pre-Mission**	**150**
	Packaging and Storage	50
	Scrutineering	50
	Manual Flying Quality Assessment	50
	Flight Demonstration	**550**
	Automatic Take-off	25
	Payload Delivery (mass & distance)	200
	Return Navigation	100
	Energy Efficiency	100
	Automatic Landing	50
	Design implementation	25
	Conduct and Professionalism	50
	Business Case	**50**

A maximum of **1150** points is therefore available.

More detailed information on the scoring of the Design and Development is provided at Annex D.3, and of the Flight Demonstration at Annex A.4.

6.2 Appeal process

Teams will be given a period of 30 minutes after a provisional score has been posted to lodge an appeal. The team will have to lodge a 20 point bond with their appeal which will be deducted from their score if the appeal fails.

7 Prizes and Awards

Prize	Award Criteria	Notes
Grand Champion	Highest aggregate score from the Design & Development documents, X-Plane Simulation, and the Pre-Mission and Flight Demonstration. All elements of the Challenge, including the Business Presentation have to have been completed to be eligible.	Points as section 6.1
Runner Up	2nd highest aggregate score from the Design & Development, X-Plane Simulation and the Pre-Mission and Flight Demonstration. All elements of the Challenge, including the Business Presentation have to have been completed to be eligible.	Points as section 6.1
3rd Place	3rd highest aggregate score from the Design & Development, X-Plane Simulation and the Pre-Mission and Flight Demonstration. All elements of the Challenge, including the Business Presentation have to have been completed to be eligible.	Points as section 6.1
Innovation	The most innovative concept taken through to **flight demonstration.** This could include an innovative layout of propulsion and flying surfaces, aerodynamics, structures, use of materials, and manufacturing methods.	Assessed from the Design Reports, confirmed at the demonstration event.
Design	For the entrant with a well-structured design approach, the most elegant and well thought through design, as described through the Concept Paper and Design Review stages that fully meets all the requirements laid down in the rules and taken through to demonstration.	Evidence of the design trade-offs considered between systems, structures, aerodynamics etc. Elegant solutions to meeting the mission requirements.
Simulation	For the entrant with the highest overall score achieved for their X-Plane Simulation Model. This will include likeness to their proposed design, submitted documentation and pilot instructions.	Assessed from the X-Plane submission and design reports.
Scrutineering	The best presented UAS that is fully compliant with the competition rules and meets the technical, build quality and supportability objectives of the competition.	Judged by the scrutineers at the Demonstration event.
Safety	For the entrant developing the best combination of a well-articulated safety case, with evidence that safety has been considered throughout the design and development stages and demonstrating safe operation and team behaviour.	Judged from the Design Report and from the Flight Demonstration Event.

Environmental	For the air vehicle demonstrating the most environmentally sustainable design in materials, noise and energy usage.	Assessment of materials selection, and flight energy efficiency score.
Airworthiness	For the entrant demonstrating the best approach to airworthiness, through design, well-engineered features, use of sound engineering practice and attention to the aircraft's suitability for flight.	Judged by the scrutineers at the Demonstration event.
Operational Supportability	For the team who can most quickly and professionally go from a fully stowed to flight-ready UAS safely, whilst demonstrating the best team-working.	Judged by scrutineers during the pre-flight inspections.
Business Proposition	For the entrant with the most promising business and marketing case presented to a panel of sponsors, reflecting a well-articulated understanding of the market and good alignment of the UAS capabilities and cost projections with the target market.	Judged by a panel of the event sponsors at the Flight Demonstration event.
Most Promise	For the entrant which couldn't quite make it all work on the day, but where the team showed most ingenuity, teamwork, resilience in the face of adversity, and a promising design for next year's competition.	This could either be a team that failed to make it to the Flight Line, or one that did not reach its full promise during the flight trials/simulation.
Advancement Award	Highest scores for a university that has not previously taken part or has excelled compared to previous years' entries.	
Media and Engagement	For the team which engages most effectively with local media, schools, social media, and gets engaged with schools as part of the STEM Outreach Programme at the event, to promote participation and engagement with the Challenge.	This is assessed from the evidence of a teams Media & Engagement and STEM activities.

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Note: The UAS Challenge team have done their best to ensure that the rules provided above and in the annexes below are as clear as possible. However, they are certainly not perfect. The UAS Challenge is supported by a team who are all interested in seeing teams succeed and UAS fly at the demonstration event. The rules are not intended to catch people out - if you require any points of clarification, spot any errors, or think your team could do with some additional technical support, please do contact us.

Annex A Demonstration

A.1 Overview

The demonstration comprises several activities within the setting of a simulated mission. Your UAS will have to be removed from storage, safely prepared for flight and the carry out its mission before being safely recovered. You must have passed scrutineering before moving on to the demonstration activities.

Before your aircraft can fly you will need to remove it from it's storage container, assemble it and prepare it for flight. You will be timed while unloading your aircraft and your storage container will be assessed. You will have to demonstrate that you can safely and correctly assemble your aircraft within 6 minutes.

The flying demonstration comprises two tasks, a single manual flight to assess the handling qualities of the air vehicle, and up to 3 attempts at undertaking the autonomous aid payload delivery mission.

Note: The number of flying slots achievable during the event may limit the number of attempts. In the event that flying slots are limited, priority will be given to those teams who have flown fewer attempts.

In addition to the flying, points are awarded for Design Implementation, Conduct and Professionalism, Scrutineering and the Business Case.

A.2 Preparation

A.2.1 Storage and Unboxing

This task requires the UAS to have been scrutineered but otherwise can be undertaken at any time during the 3 flying days. Only one attempt at this task per team is allowed.

*Note: It is recommended to attempt this task as early as possible in the fly-off event. It is much harder to do this task if your aircraft is damaged whilst flying!*Starting with the UAS in its Storage Container, the team shall unpack the UAS, and prepare it for flight, including airframe assembly, inserting and connecting the battery and flight controls, loading an empty Aid Package, a check of control functions, and other pre-flight checks (waypoints and geofence do not need to be loaded). If a launch catapult is used, this shall be assembled in the launch configuration in parallel with the air vehicle preparation. This is a timed task, supervised by a Scrutineering Official. The task completes successfully when the Official is satisfied that the pre-flight checks have been completed thoroughly and safely. It is important therefore that the team members demonstrate the safety checks clearly to the Official.

Score maximum marks by completing the pre-flight preparation within 6 minutes.

If, after the unboxing task has been completed an air vehicle is seen to receive further preparatory actions, for example, fitting of bracing wires, the team will score 0 for their unboxing.

A.2.2 Booking a flight line spot

You do not need to have completed the unboxing activity prior to your first flight, but you do need to have passed scrutineering. Once you have done so you may book your aircraft into the flight queue. Your aircraft should remain at your station in the tent until called forwards to the waiting area adjacent to the flight line. This typically only holds 2 air vehicles. At this point you should make sure that you have already loaded the waypoints and geo-fence into your aircraft.

A.2.3 Transfer to the Flight Line

When your team progresses to the front of the queue you will be called forward by a member of the flight line team. This will be to a position just inside the flight line where you will demonstrate that your air vehicle's controls operate in the correct sense. You will demonstrate the various means of activating the FTS. Once this is completed you may fit your propellers/rotors as appropriate. With the exception of propulsion removable links, your aircraft should be ready in all respects to fly. This is **not** a scored or timed task.

A.2.4 Final Check-out

The team will then be called forward to the launch point, where you will receive a brief from the FSO and shall provide them with a brief on the handling and control aspects of your UAS. You will show them how to activate the FTS and any mode selection switches on the master controller. You shall show them that your waypoints and geo-fence are programmed into the GCS. At the FSO's instruction, you shall place your air vehicle into the take-off box (and onto any launch mechanism that you may have) and insert the propulsion removable link. This should take no more than 2 – 3 minutes, and there is **a maximum time limit of 5 minutes** for this task.

Note: the above 3 items are all required for the aircraft to fly, regardless of whether or not you are attempting a manual handling or automatic flight.

A.3 Flying Tasks

Note: before carrying out any flying tasks be aware of the weather conditions and its effects on your air vehicle's performance.

Note: There will be no manually flown navigation attempts

A.3.1 Manual Handling Assessment.

The air vehicle's handling will be assessed by an IMechE designated pilot. This consists of a manual take-off, circuit and landing. The pilot will provide the judges with a verbal report on the handling of your air vehicle. This is a scored task.

Note: once you have completed your manual handling assessment you will need to book in to the flight queue again for an automatic flight

A.3.2 Mission Task: Payload Delivery

The mission is to automatically deliver the maximum possible mass of payload to a pre-defined location following a pre-planned route and then returning to the launch point, demonstrating its potential endurance by navigating as many waypoints as possible within 15 minutes of the start time and with at least 20% battery capacity remaining.

Figure A3 depicts the general layout of the airfield with example Waypoints (WP) and the Payload Release Point (PRP). The actual position of WPs and the PRP will be provided to teams at the start of the Demonstration Event.

Note: There are penalties for exceeding the maximum mission time of 15 minutes (see Scoring at Annex A.4.3).

A.3.2.1 Task: Take off

When the FSO is satisfied that the team is ready, they will give clearance to take-off, and the mission time will start. The team will launch the air vehicle which shall perform an automatic take-off, climb out in a controlled manner and head towards the first WP. If a manual take off is requested the IMechE pilot will take-off, achieve a safe height and then attempt to pass over to automatic control for the navigation task.

A.3.2.2 Task: Navigation and Payload Delivery

The air vehicle shall navigate to the Payload Release Point (PRP) via several Waypoints (WP) located on the airfield.

The air vehicle shall fly **around** the waypoints in a specified direction and in numerical order. This must be undertaken automatically to gain navigation points. Points will not be gained if the corner is cut when flying around a WP and it is not permissible to shorten the course by leaving out certain WPs. 1 or 2 circuits may be made before payload release, with more points being gained by making the second circuit.

The air vehicle shall automatically release the payload as close to the PRP as possible. Points are awarded for:

- successful release of the Payload
- initiating the payload release close to the PRP coordinates;

Payloads that are damaged on impact, releasing some of the sand, will not score as many points.

Note: the navigation task is scored using the tracking data from the GPS units provided by the IMechE, and not by the flight computers positioning information.

A.3.3 Task: Return Navigation

Continuing without landing after the previous task, the air vehicle shall fly for the longest distance possible around the course of WPs, without breaching the overall mission time of 15 minutes and completing with a minimum of 20% battery capacity remaining.

A.3.4 Task: Precision landing

The air vehicle shall position for an approach and precision touchdown within the 10 m x 20 m landing box. Manual landings, landings which start or stop outside of the box and any landing which damages the aircraft will receive reduced points.

A.3.5 Finish Mission

The core mission is complete and the clock stopped when the air vehicle has come to a halt, with its motor stopped. A judge shall record the overall mission time. The team should ensure that their remaining battery capacity is recorded. The team should return back through the flight line to the tent. The team should return the GPS tracker.

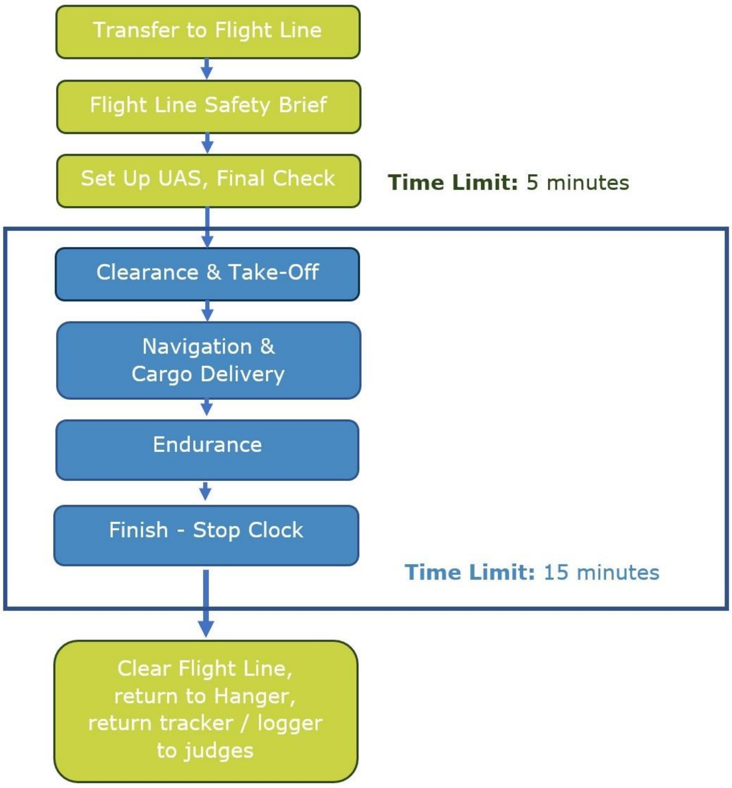

Figure A1: Mission Tasks

A.4 Scoring

The scoring is presented below for the Mission. Teams should study this carefully when selecting the air vehicle concept and defining the performance characteristics at the start of the design process.

A.4.1 Route distances

The organisers will provide details of the routes at the start of the demonstration event; as guidance for the teams, the course represents roughly a 2.5 km circuit.

All distances quoted are the straight-line distances between Waypoints, and do not account for positioning manoeuvres or turn radii when going around the Waypoints.

A.4.2 Scoring of Repeated Mission attempts

If there is time in the flying programme, teams may be allowed up to three attempts at the mission.

The score which is used in the final judging will be the highest scoring attempt.

A.4.3 Mission Scoring

Task	Scoring	
Storage and Flight Readiness		50
Packaging and Storage	Maximum 30 points. Scored based on size, novel features, security & protection of components.	
Unboxing	Score 20 points for time ≤ 6 minutes Time to assemble and ready UAS for flight, starting with the UAS packaged in the closed Storage container. Includes the installation of batteries, an empty payload and performing all control function and other pre-flight checks to the satisfaction of the Scrutineering Official. Propellers **must not** be fitted. Includes the assembly and check of a launch catapult if used.	
Manual Flying Quality Assessment		50
Automatic Take-off		25
Short take-off	25 points, automatic take-off within box. 5 points, manual take-off or exceeds the 10m box.	
Payload Drop		200
Automatic Payload Mass and Distance	Maximum 150 points Mass of payload (kg) x number of waypoints flown with payload x 1.75 points. A payload mass below 1.25 kg will only attract 1 point per waypoint (i.e. a maximum of 20 points).	
Accuracy	25 points if the payload release is initiated within 10 m of the PRP coordinates.	
Safety	25 points if the payload lands undamaged.	
Automatic Landing		50
Precision touchdown	50 points, air vehicle touches down and comes to a full stop within the box. 25 points, air vehicle comes to a full stop outside of the box. 10 points, manual landing or a landing which damaged the air vehicle.	
Energy Efficiency		100
Energy Efficiency	Maximum 100 points Calculated from the payload mass distance and the return navigation distance against the battery remaining capacity at end of flight	
Return Navigation		100
Score	5 points for each WP after payload has been dropped, up to a maximum score of 100 points.	
Penalties		
Max speed	Zero points for the mission if the maximum speed limit of 40 kts is exceeded.	
Mission Time	Zero points for the mission if exceeding the 15 minute time limit	
Flight line incursion	Depending on severity, points may be deducted from teams who cross the flight line without permission.	
Safety	Depending on severity, points may be deducted from teams whose conduct is deemed to pose a safety risk.	

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A.5 General Points

A.5.1 Navigation

Each team will be provided with a map of the airfield, showing the Geo-fence boundary within which the air vehicle must remain at all times, together with any other no-fly zones. The map will provide GPS co-ordinates for the Geo-fence vertices, the Waypoints (WPs) and the humanitarian Aid Package delivery point.

Note: the coordinates you receive mark the position of the turns only. Teams should provide their air vehicle with as many waypoints as possible to enable it to safely and efficiently navigate around the turns.

Figure A3 shows an example of the flying area and how WPs may be positioned around the airfield flying area; **Note that this is illustrative only**, and details of the actual Geo-fence boundary to the flying area and WP locations will be provided to the teams at the start of the demonstration event.

The mission route will define the WP order. The air vehicle should aim to fly **around** each WP leaving the WP correctly, and the accuracy of the navigation will be evaluated by analysis of the GPS data logger after the flight.

A.5.2 Timings

With many teams flying, it is essential for the smooth running of the event that teams are punctual with their timing, and do not over-run the allocated slot time.

To keep up the flying tempo, there will be at least two teams at the Flight Line at any one time, so that if one team has to withdraw because of technical problems, another team is immediately ready to fly.

If at the Flight Line a team cannot get the UAS ready within the 5 minute allowance, the FSO will direct the team to retire and request another mission slot time, which may be granted at the discretion of the organisers. Note however that the team may be put to the back of the queue.

A.6 BMFA Airfield Site Plan

Figure A3 below shows the general layout of BMFA Airfield, and an illustration of how the flying area and Waypoints might typically be configured. The **actual** disposition of Waypoints and the Geo-fence flying area boundary will be provided to teams at the start of the flying demonstration event.

Address: BMFA Airfield Buckminster, Sewstern, Grantham, Lincolnshire, NG33 5RW

Note: The runway at BMFA Buckminster is short mown grass.

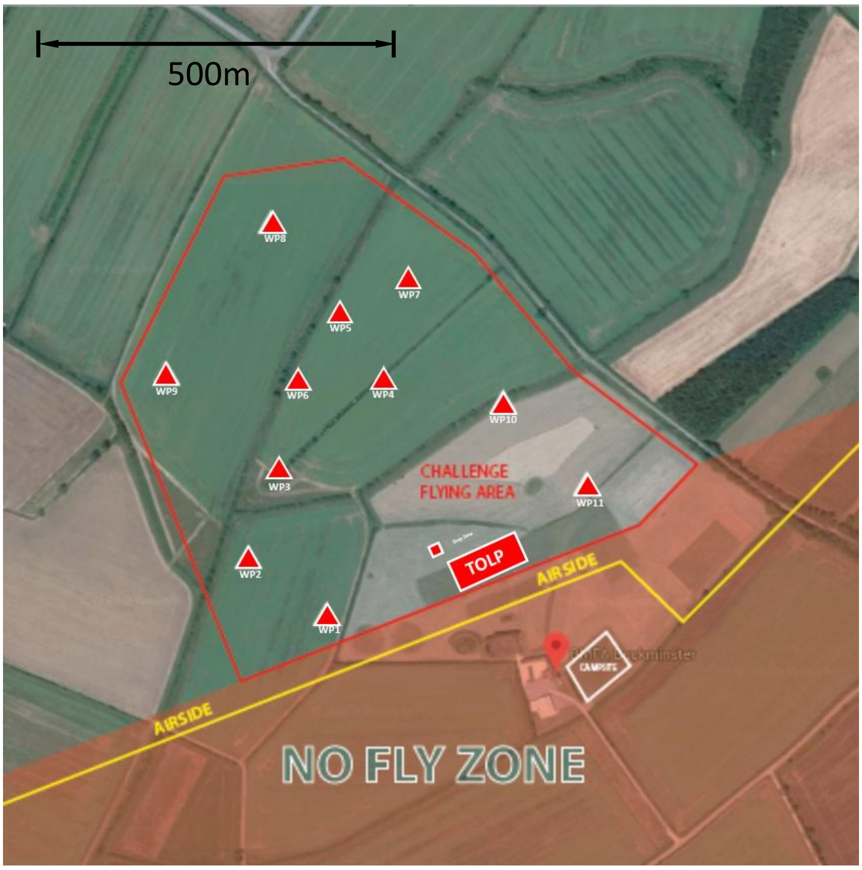


Figure A3: BMFA Airfield showing example Waypoints and Drop Zone

Annex B GPS Tracker Information and Operation

The FR300 FlywithCE GPS Tracker is to be provided by the Royal Institute of Navigation (RIN) to provide a historical track of competitors in the IMechE UAS Challenge. Because of its accuracy, small size and light weight it is ideal for providing historical navigation data in Unmanned Aerial Systems. The tracker will provide position (Lat & Long), Altitude, Date and Time. In addition it creates a log of estimated accuracy and satellite status throughout the flight.

Operation on Day of Competition

Operation is very simple: there is an on/off switch on the side; and a blue LED lights…; after a few minutes, when it is ready for use, the blue LED blinks. The trackers will be collected on landing and the data downloaded immediately. The data is presented both in tabular format and a superimposed track on a suitable map (Memory Map aviation chart or OS map). Downloaded data can be made available to competitors at the end of the competition.

Before each competition flight teams will be handed a tracker by RIN staff. It is their responsibility to:

- Attach the tracker securely to the aircraft; and
- Once the tracker is attached, check that the LEDs on the tracker indicate it is logging. If it does not appear to be logging, teams should notify a member of RIN staff but **should not attempt to operate the tracker unless instructed to do so.**

Tracker description

A description of the device operation is given here for information only, and a diagram of the tracker with dimensions, mass, and status LED descriptions is provided below.

- **Power on:** Temporarily press the power button to switch on. On power-up the Bluetooth and GPS status LED will glow to confirm it is in GPS mode and the system will commence acquisition. The power LED should glow Green showing a full charge.
- **Tracking/Log function:** Press and hold the track button for 1.5 secs, green light will go out to show new track starting.
- **Switch-off:** Do not switch the tracker off, the RIN staff will keep it running until download.

Key Characteristics	
Length:	78 mm
Width:	28 mm
Depth:	18 mm
Mass:	32 g

Annex C General Guidance for Teams

This section offers a few **hints and tips** to help teams achieve a successful and competitive entry. This is in part based on feedback from previous competitions.

C.0 Communicate

When in doubt, contact us.

C.1 Concept Selection

The air vehicle should be designed to carry the maximum mass of Aid Package to score highly.

Only electric motors are permitted for propulsion.

The assessment panel will be looking for teams to explain their rationale in making their system design decisions and trade-offs. Recording decisions and actions in meetings will make this easier when looking back for evidence of this.

C.2 Program Planning

One of the most important activities that teams should do is plan the development of the UAS. Make sure that all key dates are noted and included in the plan, this can help with producing a work breakdown required to achieve certain goals by set milestones.

Make time allowances for things to go wrong – it's highly likely that the aircraft will crash on initial test flights, so troubleshooting and rebuilding will be key activities! Designing for ease of manufacture will also make this less painful.

It's vital that teams test subsystems as early as possible. It's easier to test subsystems before final integration as this narrows down the scope of potential problems that need fixing and helps as subsystems can often be put together quickly and their effectiveness verified separately to the rest of the system.

Teams are advised to bring spare parts of key components. Don't rely on it all being OK on the day – it rarely is! The more innovative the solution, the more testing it will require, but the pay-off could be greatest.

C.3 Shipping – Overseas Teams

Overseas teams should carefully check the airline regulations for transport of hazardous materials such as batteries and make suitable arrangements for shipping or local purchase in the UK.

Overseas teams should also check with airlines that they are able to transport payload of the size and weight required.

C.4 Construction Quality

Guidance on good practice to help teams with converting their designs into viable, flying air systems are held on the IMechE UAS Challenge webpage, including:

- UAS Challenge Good Practice Guidelines, giving how to approach the engineering design and build process through to the fly-off event;
- UAS Challenge Good Practice Build Guide, giving top tips on how to build your UAS.

Go to: https://www.imeche.org/events/challenges/uas-challenge/team-resources/challenge-document-library

The aircraft should be suitably robust in order to endure transportation to the competition site as well as flying multiple missions. Handling loads will probably far exceed any flight loads. As such, ensure that the aircraft is constructed with this in mind, ensure that the system is packaged safely during transport and ensure that the aircraft can withstand several take-offs, flights and landings!

Do ensure that mechanical systems such as pushrods, control linkages, propellers are properly locked, for example with locknuts or wire locking, and bolts/pins inserted from above (gravity aided), to avoid them failing during flight.

Ensure wiring is retained securely, so as not to interfere with flight controls or fasteners.

For any connection that needs to be made during assembly (mechanical or electrical) try to design out the possibility of incorrect connections being made – e.g. use unique connectors for adjacent components.

Ensure that control linkages operate with minimal lateral load / moments.

Get your UAS inspected during build by an experienced aeromodeller to help with construction details and best practise.

C.5 Radio Equipment

Note the mandatory requirement for 2.4GHz band, Spread Spectrum compliant systems, and range of 1 km. A good quality receiver is key to ensuring reliable reception at longer ranges.

A range check shall be carried out as part of your system testing prior to the Demonstration Event, and you are reminded allow for the possibility that the RF environment at the Demonstration Event may be more hostile than at your home field.

C.6 Demonstration Event Preparation

Be organised and do be prepared for breakages. Do bring a workbench so that you can safely do maintenance and repairs. Bring plenty of tools and spare parts for your UAS. Bring appropriate PPE for safe working including safety glasses. Ensure that batteries can be changed easily – bring spare batteries.

There will be limited time in the schedule allowed for testing, so plan to use your time wisely.

It is your responsibility to dispose of your rubbish; bring a suitable bag to handle damaged batteries etc. There is no facility provided for this on site.

Note there is no electrical power or Wi-Fi available on the Flight Line.

C.7 Use of Launch Catapults

If using a launch catapult, note that assembly of the catapult needs to be demonstrated during the timed UAS assembly. After setting up the catapult for the first demonstration mission, it can be left assembled to avoid delays to the flying programme.

C.8 Route planning around Waypoints

These will be provided to the teams on the first day of the fly-off event in Buckminster. The air vehicle is required to fly **around** each Waypoint (WP), **in order**, **in a specified direction**, i.e. either leaving the WP to the right or the left. This information will be provided in a table at the start of the event. 'Cutting a corner' when rounding a WP will not score any points. Section A.6 gives an example of a possible layout.

The flightpath programming should be carefully considered to ensure that the WP is passed on the correct side with a bit of margin to allow for navigational error. The course plotted should ensure that turn radii are not excessively tight, taking into account the flight speed of the air vehicle and limiting the bank angle to around 30 degrees. It should also ensure that the flight path is safely inside the Geo-fence, again with a good margin to allow for drift in the prevailing weather conditions or navigational errors.

C.9 The Route to a Permit to Fly

For background reading on the wider regulations applicable to UAS, teams are encouraged to consult the CAA Guidance for UAS design and operation, CAP-722, which is downloadable for free from the CAA website. The BMFA and the Large Model Association also have some helpful guidance and operating practices. See also the Air Navigation Order 2020.

C.10 Marquee Activities

The marquee where all of the teams' air vehicle will be prepped is a busy place. Don't be afraid to have a look around at what else is happening and talk to your neighbours.

Space to work is tight, keep your bench tidy. This will make for a safer working environment, it will make it easier to locate tools and spares, it will give you more space to work in, it will make you look more professional, it may make the difference between you being able to get something ready in time or not.

Annex D Deliverable Item Requirements

D.0 Deliverable Items

For all teams, the documents comprise a Concept Paper, a Preliminary Design Review (PDR) record, a Design & Development Specification a Critical Design Review (CDR) record and a Flight Readiness Review (FRR). In addition, an X-Plane Simulation Model along with a Pilot's Handbook is also required.

This Annex covers the **mandatory** requirements and guidance on the structure and content of the deliverable documents. Documents must be submitted as a .pdf. The judges will be seeking evidence that you have understood the Engineering Challenges summarised in Section 2.2. It is important that each deliverable is submitted on time and 10 points will be deducted for each day late. In the case of the Flight Readiness Review, late delivery might also prevent you from flying at the Demonstration Event.

Each deliverable attracts a score that contributes to the overall competition score. These scores will remain provisional until the judges are satisfied that the UAS flown at the Demonstration event is as described in the deliverables.

All deliverables should be written on paper size A4. The only exception being the A0 poster for display at Buckminster.

You will need to bring a hard copy portfolio of all your documents to the Demonstration Event for inspection by the judges, scrutineers and Flight Safety Officer. These should be presented in a single folder.

Each submitted document must have a cover page with the following information:

- Image of your proposed vehicle – this should be the prominent feature of the cover page, and should be a perspective view (i.e. not a plan or side view).
- Team number
- University name
- Team name
- List of team members, their courses and year
- Name(s) of supervisor
- Signature of person compiling the document (normally team leader)
- Signature of person authorising its issue (normally academic lead). Ideally an additional signature that your mentor has checked the submission.
- Sponsor logos (if applicable)

All files uploaded to Mashoom must have your team number and university in the file name in the form: # University Team Document (e.g. 17 Surrey Dodo – Concept Paper).

D.1 Concept Paper

(50 points)

The Concept Paper is a short description of your chosen concept to address the requirements of the UAS Challenge. It takes the form of a report of no more than 3 pages of text, 1 page of drawings/sketches and a 1-page graphical project plan.

You should use the 3 pages to describe the aircraft configuration, the propulsion and control systems, and your package carriage and release system and the basis for their selection. You should state any elements that have been inherited from a previous year's entry.

You should also highlight any aspect of you concept or design process that you think is novel.

Your drawings or sketches should show the major features of the design and be clearly labelled.

Your project plan, which should take the form of a simplified Gantt or similar chart, must show the major steps in your design and development process, the deliverables to the IMechE and the dates when you will be undertaking your Preliminary and Critical Design Reviews. You should ensure that you have left plenty of time for testing and any design iterations that may be required when formulating your plan.

This must be uploaded to Mashoom by the date specified in 2.1

Guidance on how the Concept Paper Submission will be assessed

The assessment panel will be looking for a number of factors including:

- Clear articulation of your concept and the reason behind its selection
- A clear project plan with key milestones and delivery dates
- Overall quality of the report

D.2 Preliminary Design Review (PDR)

(25 points)

The purpose of a PDR is for the whole team to take an early review of your design to confirm that it will address all the mandatory requirements set out in these rules, that it will meet your performance requirements and that you remain on schedule against your project plan. This should be held no more than 1 month after you have started your detailed design. You should hold this review on the date set out in the project plan delivered in your Concept Paper even if you are behind schedule, as it will help you establish what is required to get you back on track. The review should be chaired by an independent person, ideally your academic supervisor or a Chartered Engineer. An important output of a successful review is a set of clear actions to correct any design or schedule shortfalls with a date and named person within the team for the completion of each action placed.

You will need to take detailed minutes of the meeting and clearly record all actions placed. These must be uploaded to Mashoom within 1 week of the meeting.

D.3 Design & Development Specification

(120 points)

This is a detailed description of your design and its development of **no more than 22 pages**, including diagrams, tables and charts. This report **shall** follow the structure described below as the individual sections will be allocated to expert judges for review. Each section **shall** be started on a new page. This report must show that you have understood and are compliant with all the requirements of the competition and that your design will be safe to fly.

Cover Page (not included in the page count)

- As for Concept Paper

Brief summary description of the design (1 A4 page maximum)

(10 points)

- A text description of proposed design.
- List and reason for all significant changes since the Concept Paper
- List any contributions from sponsors
- Weight of payload to be carried in the mission

Project Management (2 A4 pages maximum)

(10 points)

- A review of progress against your project plan with any necessary amendments and with further detail for the remaining steps in the programme. It shall show lead times and dependencies that will have to be managed;
- A table summarising the project (resourcing, skills, procurement, manufacturing, etc.) risks and their mitigation.

Requirement Review (2 A4 page maximum)

(10 points)

- A table with a configured list of **all** key requirements and **how they are being met** (e.g.):

ID	**Requirement**	**Response**
4.1.2	All up mass <= 10 kg and CG clearly marked.	A detailed weight budget has been produced with a 10% contingency allowance. The CG has been calculated and will be marked on both sides of the fuselage.
4.3.4	Compliant with EU directives, and licensed for use in the UK. Reliable operating range of 1 km. Control of the air vehicle and the FTS is 'Spread Spectrum' compliant on the 2.4 GHz band. Control and FTS transmissions are 2.4GHz	≤100mW spread spectrum conforming to IR2030 and CE marked. 433MHz telemetry limited to 10mW
4.3.2	Acceptable FTS design which lands the air vehicle as soon as possible	Configured in the Pixhawk with motor power cut and controls set.

Design Description (11 A4 pages maximum)

(40 points)

- A Functional Description, and the rationale for selection, of each of the proposed systems, including Airframe, Propulsion, Flight Controls, Navigation & Mission Control, Sensors, Autonomy / Automatic Operation, Payload Carriage and Delivery system, and Flight Termination System, highlighting any novel features;
- Aerodynamic, structural and performance calculations supporting the sizing, stability and control calculations, including your CG calculations, that supports the design configuration. Indicate any uncertainties that still need addressing;
- A detailed weight breakdown;
- A diagram showing the system architecture and data flow for the navigation and mission control, flight control, vision sensor and the design for automatic operation;
- UAS overall layout & description with a dimensioned three-view scale drawing including the position of the CG of the UA;

Safety (2 A4 page maximum)

(20 points)

- Describe your overall approach to safety and how you will establish the airworthiness of the system.
- Record your main safety risks, presented as a table of hazards and how they will be mitigated, together with your assessment of 'severity' and 'probability' for each hazard, considering the examples provided below.

Severity	Examples
Marginal	Irreparable damage or loss of the UAS.
Minor	Minor injury to a participant. Damage to public property.
Major	Single major injury to a participant. Single injury to a member of the public.
Catastrophic	Multiple injuries. Death of any party.

Probability	Example
Frequent	Likely to occur frequently during UAS Challenge.
Occasional	May occur occasionally during UAS Challenge.
Remote	Remote possibility of occurring during UAS Challenge.
Improbable	Highly unlikely to occur during UAS Challenge.

Manufacturing and support description (2 A4 pages maximum)

(10 points)

- Describe the proposed manufacturing process and construction techniques to be used, including any safety and environmental issues and how they will be addressed. Any special equipment should be listed. Final assembly should be undertaken in-house and any outsourcing of major subsystems must be justified.
- Describe the Storage Container for transporting the UAS.
- Describe the support equipment, handling and storage fixtures necessary for the development flight trials and prototype customer demonstration at BMFA.
- Highlight any innovative aspects.

Qualification Test Plan (1 A4 page maximum)

(10 points)

- Using a table format, summarise your test plan indicating how each performance and safety requirement will be verified (e.g.):

ID	Objective	Method	Success criteria	Test results and date
QTP 1	MTOW of 10.0kg	Weighing scales – aircraft fully loaded and with dummy weighted tracker	≤10.0kg	Awaiting manufacture – expected *DD/MM*

Cost Breakdown (1 A4 page maximum)

(10 points)

- A detailed table listing all the bought out items, including their actual or estimated costs. This must include any costs incurred through outsourcing any manufacturing.
- A total cost and a separate sub-total cost for the COTS items, as defined in 4.7.

This must be uploaded to Mashoom by the date specified in 2.1

Guidance on how the Design Report will be assessed

The judges will be looking for a number of factors including:

- Demonstration of a sound systems engineering approach to meeting the design requirements;
- A structured design process adopted by the team, and how the derived performance requirements are developed for each of the sub-systems such as wing (or rotor), airframe, propulsion, control, navigation, payload handling etc.;
- Extent of innovation;
- Adherence to the rules;
- Depth and extent of underpinning engineering analysis;
- Design and planning to meet safety and airworthiness requirements;
- Evidence of sound project management, planning, budgeting;
- Overall quality of the submission.

D.4 Critical Design Review (CDR)

(25 points)

The purpose of this review is for the whole team to take a critical review of your design to confirm that it is ready to be manufactured, that it is addressing all the mandatory requirements set out in these rules, that it is meeting all your performance requirements and that you remain on schedule against your project plan. This review is held at the end of your design phase and before you start major component manufacture and system testing. This review should be held on the date set out in the project plan delivered in your Concept Paper even if you are behind schedule as it will help you to establish what is required to get you back on track. The review should be chaired by an independent person, ideally your academic supervisor or a Chartered Engineer. An important output of a successful review is a set of clear actions to correct any design or schedule shortfalls with a date and named person within the team for the completion of each action placed.

You will need to take detailed minutes of the meeting and clearly record all actions placed. These must be uploaded to Mashoom within 1 week of the meeting.

The team may wish to undertake further intermediate reviews.

D.5 Flight Readiness Review Submission

(50 points)

The Manufacture and Test stage culminates with the Flight Readiness Review in which you review whether your aircraft is ready to undertake flight testing. This is a critical safety and operational reviewand should be chaired by an independent person, ideally your academic supervisor or a Chartered Engineer. You will need to take detailed minutes of the meeting and clearly record all actions placed..

In addition you must fully complete the IMechE's Form 701 supported with:

- A full statement and justification of any changes introduced since the Design & Development Specification with any impact on the safety or performance of the vehicle;
- A pre-flight check list;
- A report about how any Corrective Actions required by the judges from the Design & Development Specification have been fully addressed;
- Confirmation that the team Pilot has experience of operating the UAS during development testing;
- A signed declaration by a suitably qualified Chartered Engineer and Member (or Fellow) of a Professional Engineering Institution, that in their opinion:
    - The UAS appears compliant with the requirements noted in Annex B;
    - The design and build quality is satisfactory;
    - Safety and Airworthiness aspects have been addressed satisfactorily, with appropriate fail safe mechanisms and a risk register completed;
    - The system has been tested, both by modelling and demonstration to evaluate the performance and reliability;
    - The team members preparing and operating the UAS are suitably competent to ensure safe operations.

The FRR meeting minutes and the Form 701, with its supporting documents specified above, must be submitted to Mashoom on the date specified in 2.1

Failure to submit your complete FRR on time may result in exclusion from the Demonstration Event.

Typically, you would have completed at least 10 flights exploring elements of your flight and mission envelope and at least 2 full mission test flights. This is your confirmation that you are Flight Line ready and can safely proceed to the Flight Demonstration event in July, where your vehicle will be scrutineered and be issued with a 'Permit to Test' by the Flight Safety Officer.

Guidance on how the FRR Submission will be assessed

A panel of judges and scrutineer representatives who will review the FRR submission and assess whether the team has reached the maturity necessary to enter the flight demonstration phase of the competition.

The assessment panel will be looking for evidence on the extent and rigour of testing to demonstrate the performance and safety features of the UAS.

D.6 X-Plane Model

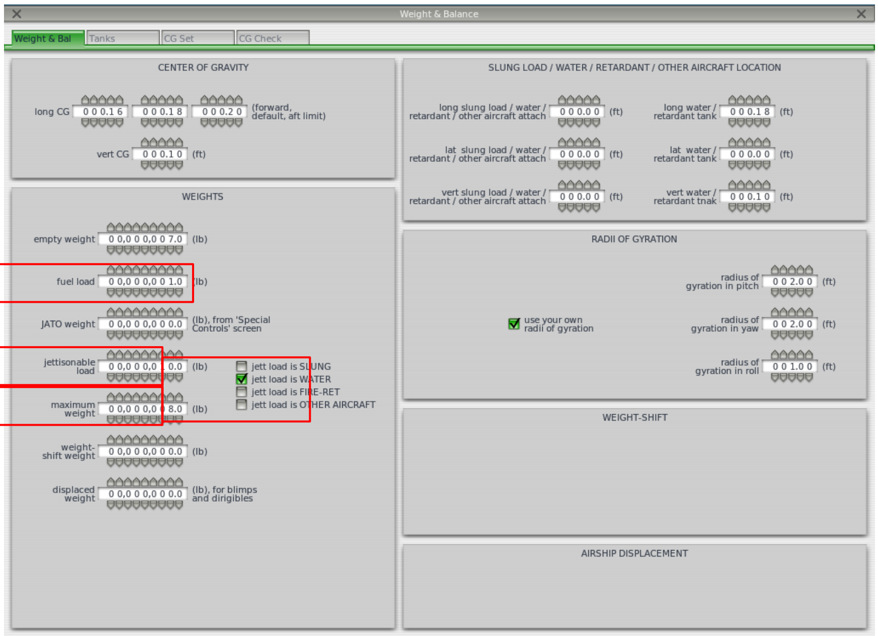
(150 points)

This section provides additional guidance for X-Plane Plane Maker Submission. Prior to submission of the Plane Maker aircraft, all teams must ensure if they plan to carry a payload, that the following parameters are selected within Plane Maker:

Within the **Weight and Balance section**;

1. Jettisonable Load – Should be the maximum payload your team will carry during the challenge. This will be set to max by the pilots flying your aircraft, so please ensure your aircraft can fly with this weight. Its location on the aircraft should also be set to reflect the real aircraft.

2. Jett load is WATER – This must be set to water and not any other form of payload, otherwise we will be unable to simulate the payload drop.
3. Maximum Weight – This is the maximum take-off weight of the aircraft.



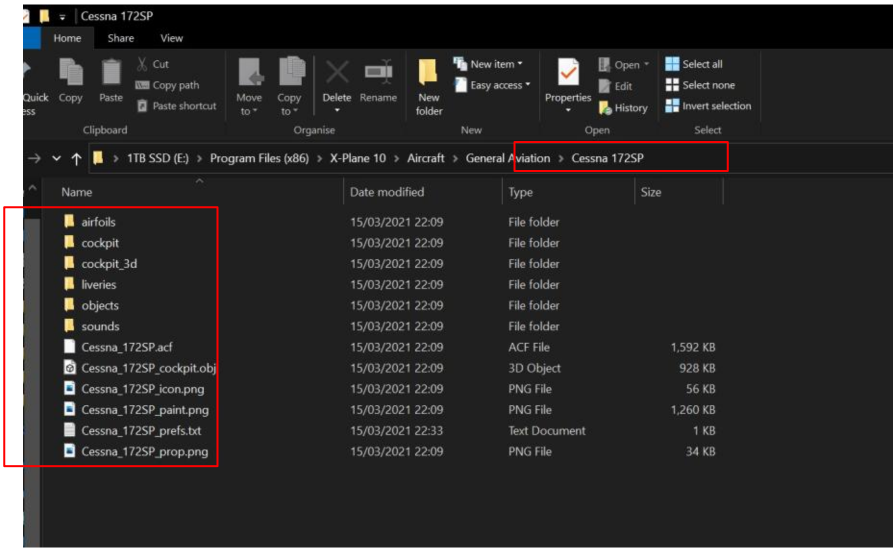
Guidance on using X-Plane plane maker should be sort from the following manuals;

- Plane Maker Version 11.5

Version should correspond to the version of X-Plane Simulator being used. The above is the only version that the UAS Challenge will accept for aircraft submissions.

Upon completion of your aircraft within Plane Maker it is essential that the aircraft is saved in the correct format. The following screenshot demonstrates an example file structure you would see for an aircraft containing such information as airfoils and textures, as well as the main body of the aircraft (.acf);

1. Examples of Sub-folders that will be seen within the main file structure – not all teams will have all folders, it is dependent on the level of data you have added into your model.
2. Main file structure – The final folder seen within the structure as shown below, should contain all the relevant subfolders and have the .acf file present. This is the folder that should be zipped and compressed (name will be dependent on what you have called your aircraft).



Take Note – It is essential that you do not rename any of the folders or files within the structure shown in the diagram above (label 1). The .acf file name will depend on what name you have given your aircraft, but this name should be consistent through all files as seen above.

The folder should be zipped as a compressed file under the following naming format and submitted through Mashoom;

UAS_UNIVERSITYNAME_TEAMNAME

It **is highly recommended** that each team practises saving the aircraft through this process and opening it within a **fresh install of X-Plane** for a trial flight – If you encounter any issues, it is likely we will as well.

All Teams will submit a Pilot's handbook along with the X-Plane submission tiled **UAS_UNIVERSITYNAME_TEAMNAME_PILOT_HANDBOOK_DOC.** This shall be a maximum of 6 A4 pages and should detail the following;

- Any changes have been made to your aircraft design due to the limitations imposed by X-Plane.

- Key information for the pilot to fly the aircraft manually for example.

- Centre of Gravity
- Whether your aircraft has brakes and how to release them.
- Payload you want to complete the mission with.
- Speed at which the aircraft should be flown.
- Key handling characteristics and whether any special controls.
- Flaps, speed brakes etc
- Any additional controls to start/fly the aircraft

This must be uploaded to Mashoom by the date specified in 2.1