UAS Challenge 2022

Competition Rules

UAS Challenge 2022

Mission and Competition Rules

Issue 1, September 2021

Contents

Glossary and Abbreviations

AGL	Above Ground Level
BMFA	British Model Flying Association
BRS	Ballistic Recovery Systems
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CDR	Critical Design Review
CG	Centre of Gravity
COTS	Commercial Off The Shelf
EU	European Union
FMC	Flight Management Computer
FRR	Flight Readiness Review
FSO	Flight Safety Officer
FTS	Flight Termination System
FW	Fixed Wing
GCS	Ground Control Station
GPS	Global Positioning System
KIAS	Knots: Indicated Air Speed
MTOM	Maximum Take-Off Mass
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
QFE	Q-Code Field Elevation - Altimeter zeroed at runway height
RIN	Royal Institute of Navigation
RW	Rotary Wing
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
VFR	Visual Flight Rules
VLOS	Visual Line of Sight
WP	Waypoint

1 Introduction

1.1 Challenge Overview

The IMechE Unmanned 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. With a Maximum Take-off Mass (MTOM) of 10.0 kg and operating within Visual Line of Sight (VLOS), the Unmanned Aircraft (UA) will be designed to undertake a representative humanitarian aid mission.

The system will be required to operate automatically, performing a series of tasks such as area search, navigating waypoints, accurately dropping the Aid Package and returning to base via a defined route.

The Challenge will be held annually over the duration of an academic year, with the competition commencing in November, and the flight demonstration being held in the following summer. This period will be structured into design, development and demonstration stages, with a business presentation, as well as the flying demonstration contributing to the scoring.

With the Covid-19 pandemic disrupting the 2020 and 2021 events, these rules have been updated to allow participants to engage either live or virtually.

1.2 Objectives of the Event

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

i. Provide an opportunity for students to learn practical aerospace engineering skills for industry;
ii. Provide a challenge to students in innovative airframe design and the systems engineering of a complex system, requiring them to follow an industry-recognised engineering development lifecycle (design, development and demonstration) against a demanding mission requirement;
iii. Provide an opportunity for students to develop and demonstrate team working, leadership and commercial skills as well as technical competence;
iv. Enhance employment opportunities in the sector;
v. Stimulate interest in the civil UAS field; and
vi. Foster inter-university collaboration in the UAS technology area, and to provide a forum for interdisciplinary research.

1.3 Real World Scenario

A natural disaster has occurred, with a large stretch of remote coastal area devastated by an earthquake and tsunami. Several thousand people living in coastal communities are cut off; their houses destroyed, and with night-time temperatures dropping below freezing, they urgently need supply drops of humanitarian aid of food, shelter and first aid supplies. Time is critical, and a UAS supply mission is launched from the Rescue Centre some distance away from the affected area.

The UAS operates automatically, transiting rapidly via pre-planned waypoints to the devastated area, and delivering the aid safely and accurately to the local people. During the mission it searches in defined areas for other potential aid recipients and relays the location co-ordinates back to base so that another aid drop or rescue mission can be organised. It returns to base via a different route to ensure de-confliction with other Rescue UAS operating in the area. It 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.

1.4 Structure of this document

Section 2 presents the overview of the Challenge, setting out what is involved for participating teams, the schedule of key activities, eligibility and funding;

Section 3 presents the requirement specification for the UAS, with sufficient information for teams to design and develop the system;

Section 4 provides the 'Statement of Work' for the Challenge, outlining what is required in each of the stages, including the design review deliverables;

Section 5 summarises the Scoring for both the Design and Demonstration elements.

Section 6 summarises the Prize categories which will be awarded. These are designed to recognise merit and achievement in a range of areas reflecting the key competition objectives;

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 is a useful tabular summary of the design and operational requirements.

Annex C gives technical details of the GPS tracker to be fitted to the UA, so that teams can make allowance in the design for installation of this item;

Annex D provides some general guidance to help the teams develop a practical and competitive UAS;

Annex E gives the requirements for completion of the deliverables.

1.5 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.

1.6 STEM outreach to Local Schools

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.

2 Competition Overview

2.1 Context

The Challenge is structured to replicate a real world aircraft system development programme, with a phased 9 month design and development process 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, yet aiming to keep the workload manageable for student teams.

2.2 Generic Mission Tasks

The Challenge is to design, build and demonstrate a small fully automatic UAS to fly a mission modelled on the real life humanitarian aid scenario described in Section 1.3. The Challenge will vary from year to year, but typically seek to test a number of characteristics, such as:

- Innovative concepts;
- Accuracy of Aid Package delivery to pre-determined points on the ground;
- Maximum mass of Aid Package that can be safely transported in the time;
- Time to complete the Aid Package delivery mission;
- Navigation accuracy via waypoint co-ordinates provided on the day;
- Search object recognition, detecting, recognising and geo-locating objects;
- Automatic operations from take-off to landing;
- Safety culture, demonstrating safe design, manufacture and flight operations;
- Minimum environmental impact, notably noise levels and overall efficiency;
- Maximum Aid Package / empty weight ratio.

The representative mission is presented at Annex A.

2.3 Challenge Schedule

The Challenge will formally be launched at the start of the academic year in October. Key dates and activities are presented at Section 4.3. Broadly the Design phase completes by mid April, and the Demonstration event is held in July.

Adherence to deadlines is a prerequisite for entry into the next stage, and **penalties will be applied if deliverables are not submitted on time** (see Annex E).

There will be a Welcome Workshop webinar in November to help teams with guidance on the factors for success, with example case studies from past competitions. It should help teams with their planning and technical decisions. More information will be posted on the IMechE webpage in early October.

2.4 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 which minimises energy consumption, and attention to minimising use of hazardous materials.

The prize categories (see Section 6) recognise merit in meeting these engineering challenges.

2.5 Eligibility and Team Structure

2.5.1 Team Composition

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

2.5.2 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*** is a final year undergraduate or postgraduate student and is one of the team. 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 final event, the Team Leader must be the main point of contact for the duration of the event and is responsible to:

  - communicate any issues with the aircraft to IMechE volunteers
  - attend regular meetings with competition organisers
  - ensure the team adheres to event schedule and turn up for scrutineering, business case presentation and fly-off on time

2.5.3 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.

2.5.4 Limits on Team Size at Demonstration Event

Please note that team attendance at the Demonstration Event is currently limited to **no more than 10 members per team**, plus your Academic Lead **or** Team Supervisor. This is because of the expected number of teams and the logistics constraints at the BMFA Buckminster site.

Note: The IMechE may or may not allow additional team members at the final event (to be confirmed in January).

2.5.5 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.

Note: As stated at 2.5.1 above, final year undergraduate and/or postgraduate students must constitute at least 70% of the joint team.

2.5.6 Universities entering more than one team

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

2.5.7 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 shall be clearly identified in the Concept Report.

2.5.8 Plagiarism

We will be monitoring your work for plagiarism (copying from last year's work, from the internet, use of unattributed images, etc.) with the loss of score for any instances detected.

2.5.9 Industry Support

Some specialist industry support is allowed, where specific skills and knowledge are required outside the scope of the students. The extent of such support **must** be declared in the Design Report and / or Review Report submissions.

2.6 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 Review submissions.

Teams may apply for IMechE's grant/award funding towards participating in the Challenge via the Group Project Award. See: https://www.imeche.org/careers-education/scholarships-and-awards/group-project-award

To be eligible for a grant you must:

- Be a member of the Institution;
- Provide three references to support your application;
- Limit the team size to a maximum of 8 team members.

This award is purely made on the merit of the application and a guarantee of success cannot be provided.

2.7 Covid-19 Restrictions

With the continuing uncertainty around Covid restrictions on overseas travel, these rules allow for entrants to participate either live or virtually.

2.8 Costs and Funding

2.8.1 Entry fee

An entry fee of £850 per team is payable upon submission of an entry form. This fee contributes towards the cost of putting on the Demonstration Event. It is non-refundable in the event that a team cannot participate in the Demonstration Event.

2.8.2 IMechE funding

Apart from teams who are successful in securing the above Group Project Award grant funding, the IMechE will **not** fund the costs of the UAS design and development, nor the team attendance at the Demonstration Event.

2.8.3 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.

2.9 Insurance and Regulation

2.9.1 Public Liability Insurance

Teams are required to 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.

2.9.2 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 both development test flying and the demonstration event.

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.

2.9.3 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.

2.9.4 CAA Drone Regulations

As discussed at Section 3.3.1, teams must comply with the UK 'Drone and Model Aircraft Registration' regulations.

2.10 Resources

2.10.1 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.

2.10.2 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 D for general guidance and tips on design and build of the UAS. Annex D.4 gives a link to presentation material on the Challenge website;
- The briefing webinar in November noted at Section 2.3 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

3 Design and Operational Requirements

The UAS shall be designed to perform the mission defined at Annex A whilst being compliant with the specification defined 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 design requirement.

3.1 UAS Design Requirements

3.1.1 Airframe Configuration and Mass

Fixed Wing, Rotary Wing or other air vehicle configurations are permissible. The MTOM shall not exceed 10.0 kg, including the Aid Package and the GPS Tracker (Annex C).

The UA shall be designed for rapid assembly / disassembly to fit into the Storage Container (see Section 3.1.13 below).

3.1.2 Propulsion Systems

Electric motors only shall be permitted for propulsion.

3.1.3 Electrical Power System

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

The UA shall an externally removable link to isolate power to all the motors. A typical example is shown.

3.1.4 Aid Package Specification

The Aid Package delivered by the UA shall comprise the AirDropBox Micro system (see http://www.airdropbox.co.uk/products/) These will be provided free of charge to teams upon registration. Key parameters are provided below.

Empty ADB Micro System Mass	0.5 kg
Delivered cargo (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 length and is about 17 cm x 17 cm in width / height.
Approx minimum release height for the standard AirDropBox parachute	50 ft – 80 ft

Standard **builders' sand** shall be used to provide the cargo mass. This has a density of around 1.6 kg / litre. 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 filled to capacity with sand will have a mass of about 6.5 kg.

The standard parachute is sized to give a 1.5 kg cargo a descent speed of about 11 mph. A 5 kg cargo may land at up to 30 mph. Teams are free to modify the parachute if required to deploy from a lower altitude or to change the descent speed. The objective is to ensure that the cargo is delivered with precision onto the Drop Zone, and also to ensure that it remains intact.

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

ADB Micro System

3.1.5 Aid Package Carriage and Delivery

The UA should be designed to facilitate rapid loading of the Aid Package into the UA.

The Aid Package shall be deployable from the UA by automatic command.

The Aid Package shall be deployed whilst the UA is in flight, from a minimum height of 50 ft AGL. The UA is **not** permitted to land to deploy the Aid Package.

Each Aid Package bundle shall have a speed retarding system to limit its speed of impact at the ground. This is a safety consideration in the real world scenario. The standard AirDropBox Micro comes with a parachute, though it is permissible to modify this.

The Aid Package must remain intact and undamaged during and after impact with the ground.

The Aid Package shall **not** itself be modified to enhance its resilience to ground impact, for example by reinforcement with duct tape, nor is it permitted to wrap it in protective packaging.

Each Aid Package shall have the team number **clearly** marked for judges to identify when recording the distance from the centre of the Drop Zone.

3.1.6 Autonomy

Your UA must fly fully automatically from the initiation of the take-off to the full stop on final landing, including navigation around all waypoints, release of Aid Package, and location of the Ground Marker.

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 human intervention. Auxiliary launch/landing equipment is permitted, so long as it all operates automatically. Hand, catapult or dolly launch is also permitted.

3.1.7 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)

Radio equipment, including data links, shall be capable of reliable operating ranges of more than 500 m.

Radio equipment providing control of the UA 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.

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.

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 Flight Termination System (FTS) if required.

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.

3.1.8 Camera / Imaging System

The UA should carry a camera system and image recognition capability to undertake the Ground Marker search and location exercise set out in the Optional Task, see Annex A.3.3.

The ground marker position shall be interpreted on the UA and relayed automatically to the base station during the flight.

3.1.9 Flight Termination System

A Flight Termination System (FTS) shall be incorporated as part of the design and is a mandatory requirement to achieve a Permit To Fly.

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.

The actions of the FTS must aim to safely land the UA as soon as possible after initiation. For Fixed Wing aircraft, the throttle shall be set to 'engine off' and the control surfaces set to initiate a rapid spiral descent.

For Rotorcraft (helicopter or multi-rotor) throttle shall be set to idle that will result in a gentle but guaranteed descent straight downwards. For hybrid aircraft the aircraft shall not transition (between fixed wing-rotary and rotary-fixed wing) following activation of FTS.

Other actions could include deployment of a recovery parachute.

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 UA 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 UA into a low energy state should the data links between the Ground Control Station (GCS) and UA 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 initiated after 5 seconds lost Uplink. The Uplink is defined as the data link which provides control inputs to the UA from the GCS (manually or autonomously), including manual initiation of the FTS.

The FTS shall be automatically initiated promptly and no longer than 10 seconds after lost Downlink. It shall also be initiated by breach of the Geo-fence.

Note: The Downlink is defined as the data link which relays the UA's telemetry / positional info and video feed to the GCS.

The FTS shall be capable of manual selection via the Master Controller, should the Flight Safety Officer deem the UA's behaviour a threat to the maintenance of Air Safety.

A 'Return to Home' function is not acceptable as an FTS for the reasons explained above.

3.1.10 **Navigation System**

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 UA shall automatically navigate around the course via the GPS co-ordinates provided. It shall also be capable of storing the co-ordinates of the Geo-fence marking the boundary of the flying area.

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

3.1.11 **Location Finder**

In the event of the UA making an un-commanded departure and landing outside of the designated Landing Area, the UA shall make an audible and visual alert to improve ease of UA location.

3.1.12 Ground Control Station

The UAS shall include a Ground Control Station (GCS), which could comprise a tablet 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 UA position on a map;
- Local Airspace, including the Geo-fence Flying Zone;
- Height AGL (QFE);
- Indicated Airspeed (kts);
- Information on UA Health.

3.1.13 Storage and Handling

Teams shall design and make a Storage Container for transporting their UA. 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.

Innovation is encouraged, and the Storage Container may also be designed to facilitate handling of the UA during assembly and test.

Note: One of the tasks is to assemble and pre-flight the UAS out of the Storage Container in the quickest possible time, thus ease of access and handling would be an advantage.

3.1.14 GPS Tracker

The Organisers shall provide a GPS tracking data logger (the Tracker), described at Annex C. The design of the UA shall ensure that the Tracker can be easily fitted and removed.

Teams shall fit the Tracker to the UA before the Scrutineering process, and return it to the Organisers immediately following a flight, for post-flight evaluation of the 3D trajectory.

3.1.15 Limits on use of COTS Items

The UAS airframe and 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 consideration.

A guideline maximum value of COTS components used in the UA itself is £1,000. A Bill of Materials and costs will be required as part of the design submission, and a production cost estimate will be expected at the Project Presentation. Cost efficient solutions will score more points.

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.

Note: Permitted Commercial Off The Shelf (COTS) stock component parts are limited to motors, cameras, batteries, servos, sensors, autopilots and control boards such as the Pixhawk or Ardupilot platforms. Teams are allowed to use the supplied software *with COTS autopilots, although it may need modifying to meet the specific mission challenges.*

3.2 Operational Requirements

3.2.1 Mission

The mission is defined at Annex A, 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.

3.2.2 Take-off and Landing

The UA shall be designed to take off and land from within a 10 m x 10 m box. Landing includes touchdown and roll-out, with the UA required to stop within the box.

The UA should be capable of operating from both short grass and hard runway surfaces.

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

3.2.3 Design Mission Range and Endurance

For the purpose of sizing the battery load, the design team should consider the requirements for the Mission. The total Mission time is limited to 15 minutes.

The Mission shall **not** require the UA to operate further than 500 m from the pilot.

For resilience of operation, the radio equipment including data links, shall be capable of reliable operating ranges beyond 500 m.

3.2.4 Weather Limitations

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

Note: The UA should be reasonably weatherproof, with tidy wiring and the electronics reasonably well sealed from the environment.

3.2.5 Real time telemetry

See Section 3.1.12 for details of the Ground Control Station, which shall display real time flight information to the Operators, Flight Safety Officer and Judges during the mission flight. This allows confirmation of UAS location with respect to the flying area and Geo-fence boundary.

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.

For the purpose of scoring the UA navigation performance, the GPS track downloaded from the Tracker (Section 3.1.14) will be used and the Judges' decision is final.

3.3 Safety and Environmental Requirements

3.3.1 Compliance with UK CAA Drone Regulations

The 'Drone and Model Aircraft Registration' regulations came into force in the UK from 30th November 2019. As a result under the Air Navigation Orders specified in CAP393, Article 94, teams must register an Operator and a Remote Pilot in order to fly UA in the UK (it is possible for one person to be both the Operator and the Remote Pilot).

The registration requirements are currently as follows:

Part 1: Operator

- The University or a designated individual nominated by the University will need to register with as a drone 'Operator'.
- The Operator will be assigned an Operator ID which must be displayed on the relevant UA.
- Minimum age of an Operator is 18.
- Operator registration fee is £9.
- Operator registration period 1 year.

Part 2: The Remote Pilot

- Any person that wishes to operate UA over 250g up to a maximum of 20kg in the UK must pass an online theory test on 'flying safely and legally' in order to obtain a Flyer ID.
- Flyer registration fee is free.
- Flyer registration period is 3 years.

Teams should visit the CAA website covering the registration for flying drones and model aircraft - https://register-drones.caa.co.uk/.

If test flying in the UK before the competition fly-off event (including during the FRR video), then the Team must ensure they use a registered Remote Pilot, who shall share responsibility for the UAS with the Team's Operator.

Note: International Teams should refer to any relevant flight restrictions in their given country.

3.3.2 Pilot Roles and Competence

Subject to the 'Drone and Model Aircraft Registration' regulations noted at Section 3.3.1 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 attempting to recover the UA 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 must 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. Given that the flight is conducted fully automatically, 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 UA.**

The Team Pilot shall have flown the UAS before (including during the FRR video).

3.3.3 Flight Termination System

The FTS forms a core part of the design safety requirements and is described at Section 3.1.9 above.

3.3.4 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.

Batteries used in the UA shall contain bright colours to facilitate their location in the event of a crash;

At least 25% of the upper, lower and each side surface of the aircraft shall be a bright colour to facilitate visibility in the air, and to aid retrieval of the aircraft in the event of a crash;

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

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

3.3.5 Operational Safety Requirements

The UA shall remain within Visual Line of Sight (VLOS) and no greater than 500m horizontally from the Pilot, and remain below 400 ft AGL;

The UA 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 UA shall not be flown within 30 m of any person, unless that person is under the control of the FSO[1];

The maximum airspeed of the UA in level flight shall not exceed 60 KIAS;

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

In the event of a UA appearing uncontrolled or at risk of departing from the Flying Zone, the Safety Pilot shall attempt to recover the UA 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.

3.3.6 Environmental Impact

Teams are encouraged to determine the overall efficiency of the UA, by measuring the energy usage during the testing prior to the Demonstration Event.

In the design process, consideration should be given to environmental impact, including the use of non-hazardous and recyclable materials; low pollution; low energy usage; low noise.

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[1] Air Navigation Order, Articles 94 and 95

4 Statement of Work

This section provides details of the activities and outputs in each stage.

4.1 Challenge Stages

4.1.1 Overview

Figure 1 below depicts the stages of the Challenge, and the key deliverables for the Live Event. Note also Figure 2 in Section 4.3 shows the deliverables and process for both the Live and Virtual Events.

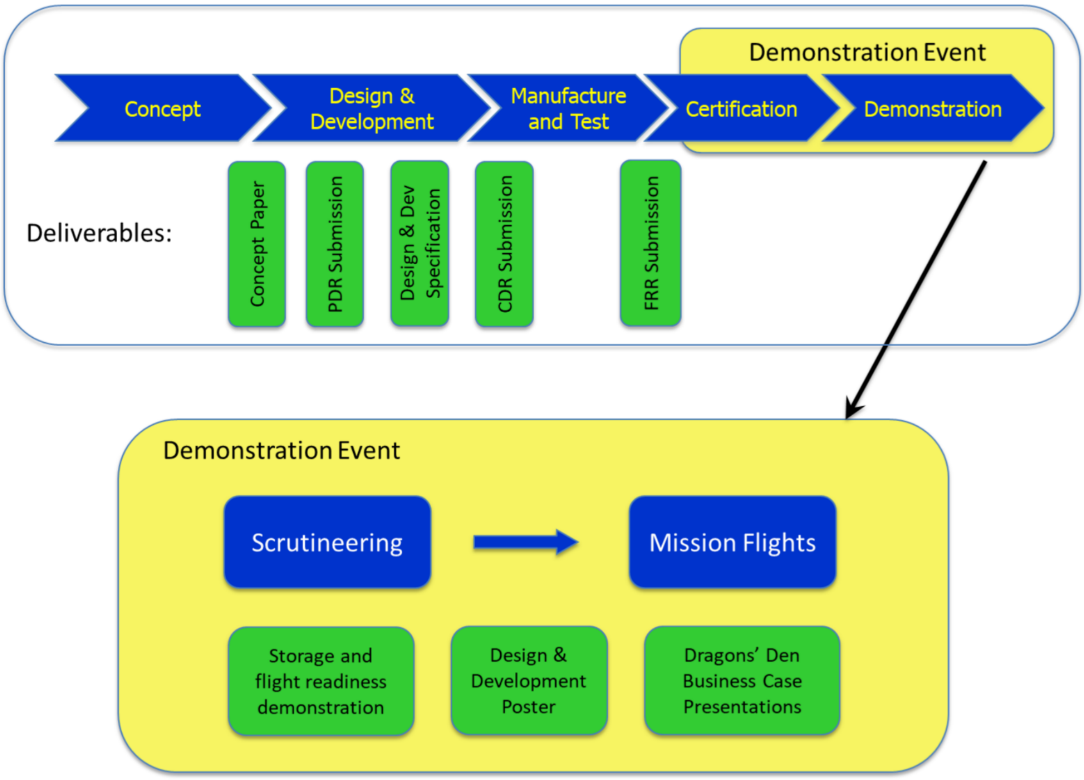


Figure 1: UAS Challenge Stages and Deliverables – Live Event

4.1.2 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 to be delivered with the Application to join the Challenge.

4.1.3 Design and Development

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

4.1.4 Manufacture and Test

This stage comprises construction of the UAS, and possibly manufacture of prototypes during the earlier design stages to de-risk the design. Demonstration through analysis, modelling and physical test 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. This stage concludes with the submission of the Flight Readiness Review (FRR) deliverable.

4.1.5 Demonstration

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

- Scrutineering;
- Mission Flight;
- Dragons' Den Presentation.

Further details of the Demonstration Event are provided at Section 4.4.

4.2 Deliverable Items Description

4.2.1 Concept Paper

This initial report is a summary of the team's design concept and is delivered together with the team's application to enter the competition. The requirements for this paper are specified at Annex E.2.

4.2.2 Preliminary Design Review

This is a report of your initial review of your UAS design submitted on a form provided by the IMechE. You will have set the date for this review in your Concept Paper but it must be delivered by the date specified at 4.3 Deliverable Items Schedule. The requirements for this report are specified at Annex E.3.

4.2.3 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 E.4. This must be delivered by the date specified at 4.3 Deliverable Items Schedule.

4.2.4 Critical Design Review

This is a report of your final review at the completion of your design. It is submitted on a form provided by the IMechE. You will have set the date for this review in your Concept Paper but it must be delivered by the date specified at 4.3 Deliverable Items Schedule. The requirements for this report are specified at Annex E.5.

4.2.5 Flight Readiness Review (Live Event)

The Flight Readiness Review (FRR) submission is a critical safety and operational review to confirm whether or not your aircraft is ready to undertake demonstration flights to the customer. This is detailed at Annex E.6. If the judges consider there are non-conformances with the FRR, they may provide feedback to the team via a Skype or conference call.

4.2.6 Design & Development Poster (Live Event)

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.

4.2.7 Dragons' Den Presentation (Live Event)

During the Demonstration event, teams will be required to deliver a presentation covering their Business Plan, STEM engagement 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 also demonstrate how effectively they have promoted the competition and their design locally with schools, the media and on social media.

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

Teams will have 15 minutes for their presentation, and there will then be up to 5 minutes of questioning from the judges.

4.2.8 X-Plane Model (Virtual Event)

For the Virtual Event, 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 by the live event teams. The requirements for the X-Plane model are specified in Annex E.7.

4.2.9 Dragons' Den Video and Sponsors' interviews (Virtual Event)

For the Virtual Event, teams are required to submit a video of maximum length 15 minutes in place of the above Dragons' Den Presentation, and covering the same material. Virtual teams may then be required to attend an on-line interview, with representatives of the industry sponsors.

4.3 Deliverable Items Schedule

The deliverables will depend upon whether entrants opt either for the live or virtual event. This decision can be taken after the start of the competition, during the design phase. The flow chart and table below depict the process and the schedule of deliverables for the live and virtual events.

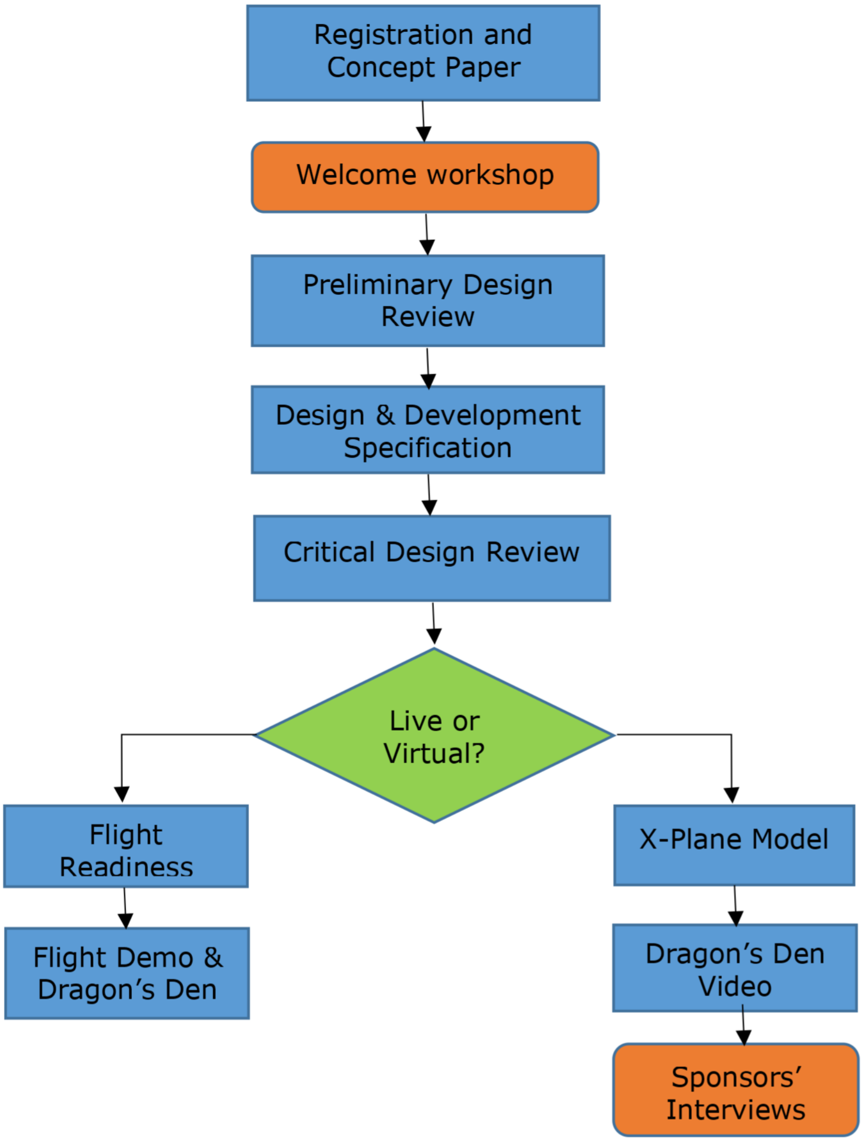


Figure 2: Live / virtual event process and deliverables

The schedule of deliverable items and activities is as follows:

Deliverable	Live Event	Virtual Event	Reference
Concept Paper Submission	14 Nov 2021	14 Nov 2021	Annex E.2
Preliminary Design Review Submission	Set by team (before 30 Jan 2022)	Set by team (before 30 Jan 2022)	Annex E.3
Design & Development Specification Submission	13 Mar 2022	13 Mar 202	Annex E.4
Critical Design Review Submission	Set by team (before 17 Apr 2022)	Set by team (before 17 Apr 2022)	Annex E.5
Flight Readiness Review Submission	19 June 2022	Not Applicable	Annex E.6
X-Plane Model	Not Applicable	6 Jun 2022	Annex E.7
Design & Development A0 Poster	06 July 2022	19 June 2022	Section 4.2.5
Dragons' Den Video	Not Applicable	19 June 2022	Section 4.2.6
Dragons' Den Presentation	07 July 2022	Not Applicable	Section 4.2.6

Note: dates may be subject to change.

4.4 Demonstration Event

4.4.1 Scheduling

The Demonstration Event is provisionally scheduled from Wed 6th July – Friday 8th July 2022. Teams must arrive at BMFA Buckminster site **no later than 12:00pm** on Wed 6th July.

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

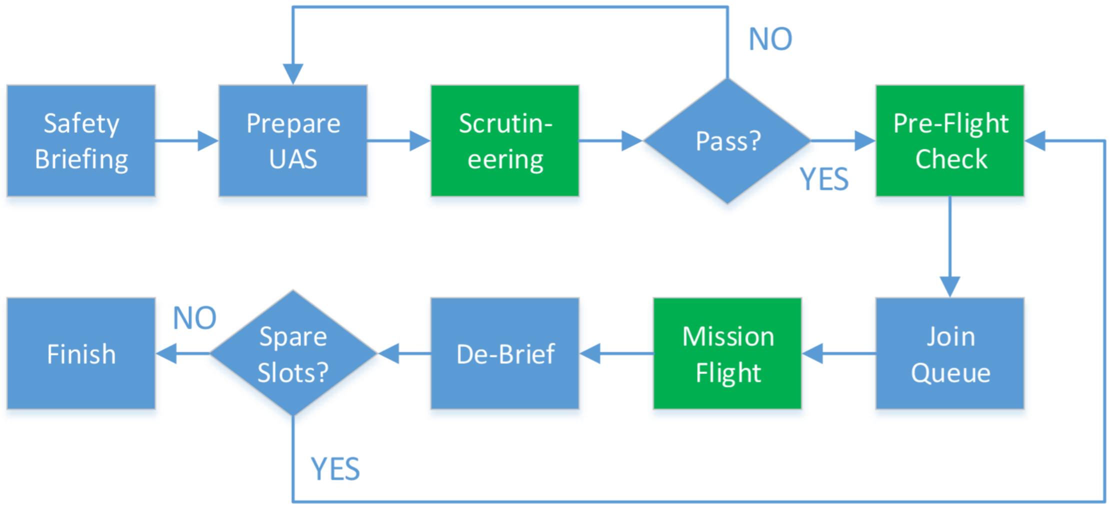
A mandatory detailed briefing will be given at the beginning of the Demonstration Event covering the logistics and timings for the event, rules and good conduct for safe operations, pre-flight briefings etc.

Day 1, will be set aside for scrutineering and to conduct shake-down test flights for overseas teams.

The remainder of scrutineering, all the competition flying and the Project Presentations will take place on Days 2 and 3. All flying on Days 2 and 3 will count as Mission flights and scored as such; there is no test flying on these days. A Mission flight is deemed to have started from the moment the FSO gives take-off clearance, even where the UA then crashes prematurely; Any flying after the cut-off time on Day 3 will not attract any points.

Once they pass scrutineering they may join the queue for the flight mission. The schedule is necessarily tight and teams must take responsibility for their readiness in order to keep a good tempo of scrutiny and flying.

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.

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

4.4.2 Set up of Catapults

Launch catapults should be set up initially during the Pre-Flight Preparation (Section A.2.1), 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.

4.4.3 Prepare UAS

Annex A describes the Mission, illustrated with example waypoint data. The exact Mission waypoint and package delivery co-ordinates will be briefed to each team at the start of the event.

Preparation should 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.

4.4.4 Scrutineering

As soon as they are ready, the team should 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 during the Thursday.

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 E.6), which is a key input to the Scrutineering process as it should contain evidence of satisfactory testing.

Starting with the UA stowed in its Storage Case, the assessment will include:

- Unpacking and assembly of the UA;

- 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;
- Storage Case – assessment for build quality, level of protection it affords the UAS, and any interesting design features.
- 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 **must** 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.

4.4.5 Storage and Flight Readiness Demonstration

Those teams that have passed scrutineering will conduct a timed task (target time 3 minutes, and no longer than 10 minutes) to unpack, assemble and check out the UAS, including the ground station for a safety controls check. 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.

4.4.6 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;

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

4.4.7 Demonstration Flight

At the Flight Line there will be a short brief by FSO. The team will then have a maximum of 5 minutes to ready the UAS. When the safety pilot confirms that the team is ready to launch, the FSO will give his authority to launch and this is when the mission time starts.

If the preparation time exceeds the 5 minutes, or the team hits snags, the FSO will direct the team to withdraw and let another team fly.

Note: the UA shall be able to do all tasks within the Mission – cargo drop, navigation, endurance, and area search – without having to be reconfigured in any way.

During a flight, if the UA strays outside the Geo-fence marking the boundary of the flying area, the FSO shall activate the FTS via the command link, if it has not already been activated automatically. This will result in the termination of the mission.

After the UA 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 must 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 two days, and others may have to fly in poorer weather. This is the luck of the draw.

4.4.8 **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 Demonstration Flight stage;

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, adhering to FSO instructions at all times, not transmitting when not approved.

4.4.9 **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.

5 Adjudication and Scoring Criteria

5.1 Overall Scoring Breakdown

The Design and Development elements will be scored identically for Live and Virtual, with a common set of prizes. The Flight Demonstration elements will have separate scoring for Live and Virtual, with separate prizes.

The competition will be assessed across three design and development elements, scoring 1/3 of the total points, and the Flight Demonstration scoring 2/3 of the available points:

	Live	Virtual
Design and Development	**200**	**200**
Preliminary Design Review	20	20
Design and Development Specification	160	160
Critical Design Review	20	20
Flight Demonstration	**400**	**400**
Packaging and Storage	50	N/A
Cargo Delivery (mass & distance)	120	150
Climb and Glide	40	100
Navigation	40	N/A
Endurance	60	100
Area Search	50	N/A
Precision Landing	40	50

A maximum of **600** points is therefore available.

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

5.2 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.

6 Prizes and Awards

Prizes are awarded either in Live (L) or Virtual (V) categories. Three prizes, for Airworthiness, Operational Supportability and Scrutineering, are only awarded for the Live competition.

Prize	Cat	Award Criteria	Notes
Grand Champion	L V	Highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
Runner Up	L V	2nd highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
3rd Place	L V	3rd highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
Innovation	L V	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 and for the Live event, from the FRR video, confirmed at the demonstration event.
Design	L V	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.
Scrutineering	L	The best presented UAS that is fully compliant with the competition rules and meets the technical, build quality and supportability objectives of the competition.	Live event only. Judged by the scrutineers at the Demonstration event.
Safety	L V	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 (for the live event) from the Demonstration Event.
Environmental	L V	For the UA demonstrating the most environmentally sustainable design in materials, noise and energy usage.	Assessment of materials selection, and flight efficiency from the Climb and Glide.
Airworthiness	L	For the entrant demonstrating the best approach to airworthiness, through the design and well engineered safety features.	Live event only. Judged by the scrutineers at the Demonstration event.

Operational Supportability	L	For the team who can safely assemble and prepare their UAS for flight in the shortest time 'out of the box', and who do so with great team-working.	Live event only. Judged by scrutineers during the pre-flight inspections.
Business Proposition	L V	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 Project Presentation event.
Most Promise	L V	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 (Live), or one that did not reach its full promise during the flight trials (Live or Virtual).
Highest placed new entrant	L V	Highest mission scores for a university that has not previously taken part.	
Media and Engagement	L V	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 at the Project Presentation and the STEM activities during the event.

Annex A Mission

A.1 Mission Overview

The mission is a single flight comprising a mandatory 'core' set of tasks, and two optional tasks, as depicted in the Flow Diagram at Figure A1. Completing both core and optional tasks successfully will score more points overall, but will require more design and development work.

The core task is to deliver a mass of cargo to pre-defined locations, as well as a glide task to evaluate aerodynamic efficiency, and a precision landing.

Optional tasks include an endurance trial around a circuit, and an area search for a hidden Ground Marker. Figure A2 depicts the Ground Marker characteristics.

Figure A3 depicts the general layout of the airfield with example Waypoints (WP) and the Drop Zone (DZ). The actual position of WPs and the DZ 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.2 Preparation

A.2.1 Core Task 1: Storage and Flight Readiness

This task requires the UAS to be ready for flight, whether or not it has passed scrutineering. It may be completed at the flight line area just before the mission flight, though to avoid delays at the flight line it can also be done at any point during the Event.

Starting with the UAS stowed in its Storage Container, the team shall unpack the UAS, and prepare it for flight, including airframe assembly, connecting the battery and flight controls, loading the Aid Package, check of the pre-programmed mission, check of control functions, and other pre-flight checks. If a launch catapult is used, this shall be assembled in the launch configuration in parallel with the UA preparation. This shall be 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 for the quickest time to complete the pre-flight preparation.

A.2.2 Transfer to the Flight Line

The team and UAS shall move to the Flight Line take-off area. The FSO shall give the team a short safety briefing, noting any local issues of wind or weather, safety hazards etc. This is **not** a scored or timed task.

A.2.3 Final Check-out

The team shall prepare the UAS for take-off, including loading the UA on the catapult as required. This should take no more than 2 – 3 minutes, and there is **a maximum time limit of 5 minutes** for this task.

A.3.4 Core Task 5: Climb and Glide

This is a test of aerodynamic performance efficiency, with a power-off glide between two WPs, positioned to provide a broadly cross-wind track.

Continuing from the previous task, the UA shall perform a climb to 350 ft above the first WP. The propulsion shall be cut, and the UA commanded to glide to the second WP.

Power shall automatically be re-applied either if the UA descends below 40 ft AGL or when it reaches the second WP.

The glide performance will be assessed from a post-flight GPS analysis of the track distance and height difference during the power off flight.

A.3.5 Core Task 6: Precision landing

Once the power is re-applied at the end of the Climb and Glide task, the UA shall position for an approach and precision landing within the 10 m landing box.

A.3.6 Finish Mission

The core mission is complete and the clock stopped when the UA has come to a halt, with its motor stopped. A judge shall record the overall mission time.

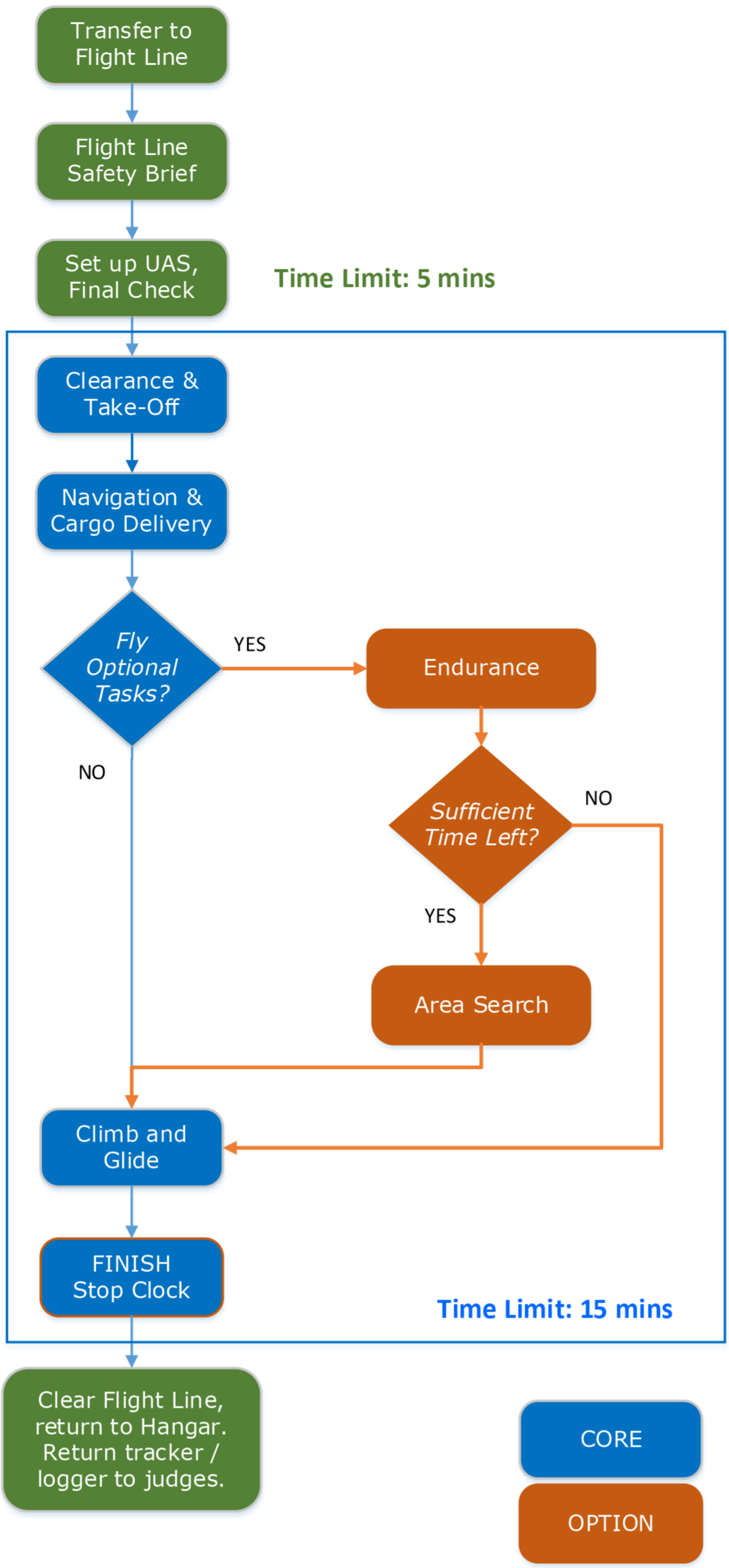


Figure A1: Mission Tasks

A.4 Scoring

The scoring is presented below for the Mission. Teams should study this carefully when selecting the UA 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 from the Launch Point to the Drop Zone at the start of the demonstration event; as guidance for the teams, the distance from take-off to the drop zone is roughly 5 km, consisting of two laps around a 2.5 km circuit.

The pre-defined route around waypoints from the Drop Zone back to the Launch Point is expected to be less than 0.5 km. 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. **All** flying on Days 2 and 3 will count as Mission flights.

The score which is used in the final judging will be the average of the best two attempts. If only one attempt is made, the judging will use the score from that single attempt.

Example 1: If Team A scores 120 points on Attempt #1, and doesn't have a second or third attempt, the judging will use that score of 120 points.

Example 2: If Team A scores 140 points on Attempt #1, and only 60 points on Attempt #2, the judging will use the average (140 + 60) / 2 = 100 points.

Example 3: If Team A score 50 points on Attempt #1, 130 points on Attempt #2 and 140 points on Attempt #3, the judging will use (130 + 140) / 2 = 135 points.

A.4.3 **Core Mission Scoring**

Task	**Scoring**
Storage and Flight Readiness	50
Packaging and Storage	Storage container is well designed, compact and offers innovative features. The dis-assembled UAS is packaged tidily within the container, including Ground Controller unit. Components are well protected and secure. Score maximum 15 points.
Pre-flight assembly and check	Time to assemble and ready UAS for flight, starting with the UAS packaged in the closed Storage container. Includes the installation of batteries, loading pre-programmed route, initialising GPS, and performing all control function and other pre-flight checks to the satisfaction of the Scrutineering Official. Includes the assembly and check of a launch catapult if used. Score 15 points for time ≤ 3 minutes (180 s). Score 0 points for time ≥ 10 minutes. Score = 21.43 – (0.036 x T), rounded to nearest integer, where 'T' is in seconds. *Example: Assembly and check-out takes 6:30 min:sec (390 s). Score: 7 points.*
Flight readiness penalty	Teams should have their UAS through scrutineering and ready to fly at the start of the first flying day. Score 20 points if queued on the flightline before 09:00 on the first flying day. Lose the above 20 point bonus if the final check-out (A.2.3) is delayed significantly causing the team to withdraw and sort out snags. Penalty of -50 points for failure to be at the flightline before 11:00 on the first flying day.
Cargo Drop	120
Short take-off	Deduct 20 penalty points if the UA fails to take-off within the 10 m box.
Cargo Mass and Distance	Mass of cargo delivered to the Drop Zone (kg) x the straight distance of the Route (km) x 3 points. *Example: 4.8 kg delivered via 5.0 km route – total points 3 x (4.8 x 5.0) = 72 points.*
Accuracy	Score $\frac{M(50-D)}{5}$ points for accuracy, where M is the cargo mass, and D is the distance in metres between the final resting point of the cargo and the centre of the Ground Marker. Cargos landing more than 50 metres from the Ground Marker score zero. Average the score over the number of drops. *Example: 4.3 kg cargo lands 12 m from DZ; 4.5 kg cargo lands 16 m from DZ. Score (4.3 x 38)/5 + (4.5 x 34)/5 = 31.6 / 2 drops = 32 points*
Missed Route	If the UA misses one or more WPs by a substantial margin, materially reducing the actual distance flown, the Judges may elect to reduce the measured distance in the above calculation.
Hung Cargo	If the UA successfully navigates to the DZ but a 'hang-up' occurs and the cargo fails to release, or is released far away from the DZ (> 100 metres), that scores zero, as no cargo has been delivered.

Task	**Scoring**
Damaged Cargo	Deduct 5 penalty points per kg of cargo which is significantly damaged or split open upon deployment. *Example: 4.7 kg of cargo splits open on landing: Deduct 5 x 4.7 = -23 points.*
Climb and Glide	40
Score	Score 5 x Glide Ratio. *Example: Measured track distance of 560 m descending 91 m (from 400 ft to 100 ft AGL), gives glide ratio of 6.2:1. Score 5 x 6.2 = 31 points.*
Navigation	40
Score	4 points for each WP successfully navigated up to a maximum of 40 points. Example: Route may comprise Launch - WP1 – 2 – 3 – 4 – 5 – DZ – WP9 – Land. Total 7 WPs including the DZ. Score 28 points.
Missed WPs	Score zero for each missed WP. This is where the UA 'cuts the corner', failing to turn around the correct side of the WP.
Mission Duration	-
Overall Mission Time	Incur penalty for exceeding the overall mission time limit. Score -3 points for every five seconds over the limit, and round up. *Example: actual overall mission duration recorded as 15:30 min:sec. Penalty incurred of -18 points.*
Precision landing	40
Precision landing	Score 40 points if the UA successfully lands and stops within the 10 m box. Deduct 20 penalty points if the UA comes to a stop more than 20 m away from the nearest edge of the landing box. Deduct 40 penalty points if the UA is more than 50 m from the landing box.
Automatic Operation	-
Penalty for non-automatic operation	Reduce score for the whole mission by 50% if any parts of the flight operation are performed manually, including take-off, landing, navigation and cargo delivery.

A.4.4 **Optional Mission Scoring**

Task	Scoring
Endurance	60
Score	Score 3 points per kilometre flown up to a maximum 60 points for a distance of 20 km or more. *Example: Distance flown = 16.3 km. Score = 16.3 x 3 = 49 points.*
Missed WPs	Penalty of 8 points deducted for each WP missed. This is where the UA 'cuts the corner', failing to turn around the correct side of the WP. Maximum penalty of 40 points.
Max speed limit	Score zero points if maximum speed limit of 60 kts is exceeded at any point.

Task	Scoring
Area Search	50
Score	Maximum score 50 points for locating the hidden Ground Marker, and automatically and correctly reporting the GPS location.
Accuracy	Accuracy of reported GPS location shall be within 10 metres of the measured position. Deduct 6 points for location reporting between 10 – 30 metres accuracy. Beyond 30 metres scores zero.
Automatic Reporting	Score zero where the GPS co-ordinates have to be manually interpreted from the on-board video or still picture.

A.5 General Points

A.5.1 Take-off

Take-off shall be conducted within the designated take-off and landing box, into wind as far as practicable. After take-off the system shall maintain steady controlled flight at any suitable height[2], typically around 40 - 100 ft.

The mission time starts when the Flight Safety Officer gives clearance for take-off.

A.5.2 Navigation

Each team will be provided with a map of the airfield, showing the Geo-fence boundary within which the UA 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.

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 UA should aim to fly **around** each WP leaving the WP correctly to left or right of track as specified, and the accuracy of the navigation will be evaluated by analysis of the GPS data logger after the flight.

The Flight Termination System shall be automatically initiated upon a breach of the Geo-fence.

The UAS shall navigate around the course automatically, manual control is not permitted.

A.5.3 Operating height

All operating heights between 20 ft - 400 ft are valid within the allowable flying zone. The UA must drop the Aid Package from a **minimum of 50 ft** height above ground, and cannot land to place the Aid Package (in the case of RW UAS).

During transit phases between the landing area to the Drop Zone, the UA shall maintain a safe height above ground.

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[2] Note heights are quoted in feet Above Ground Level (AGL).

A.5.4 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 Ground Marker Description

The ground marker shown in Figure A2 is a 2 m x 2 m white square.

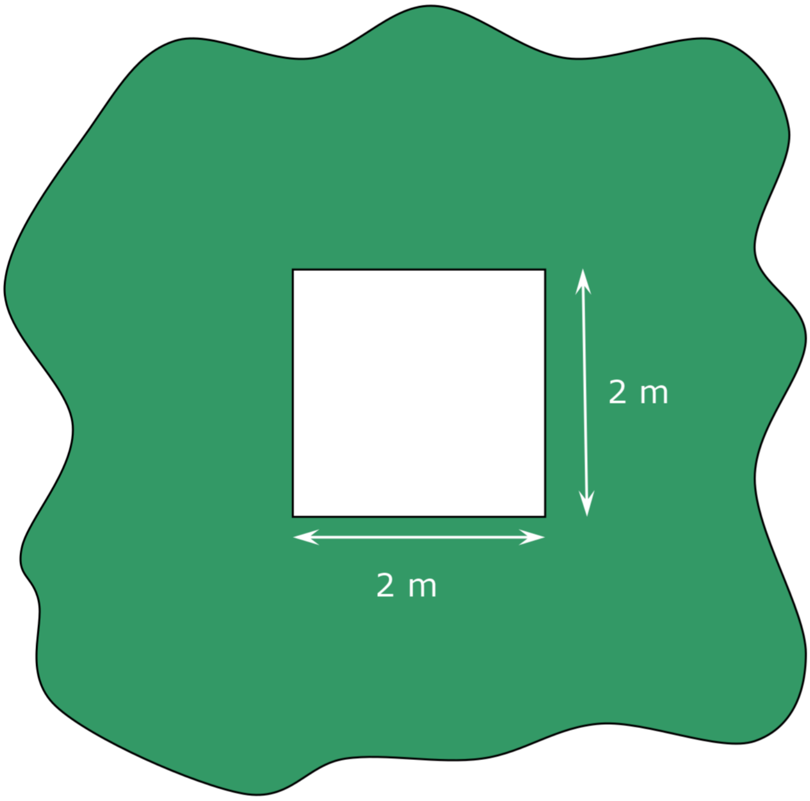


Figure A2: Ground Marker Dimensions

A.7 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.

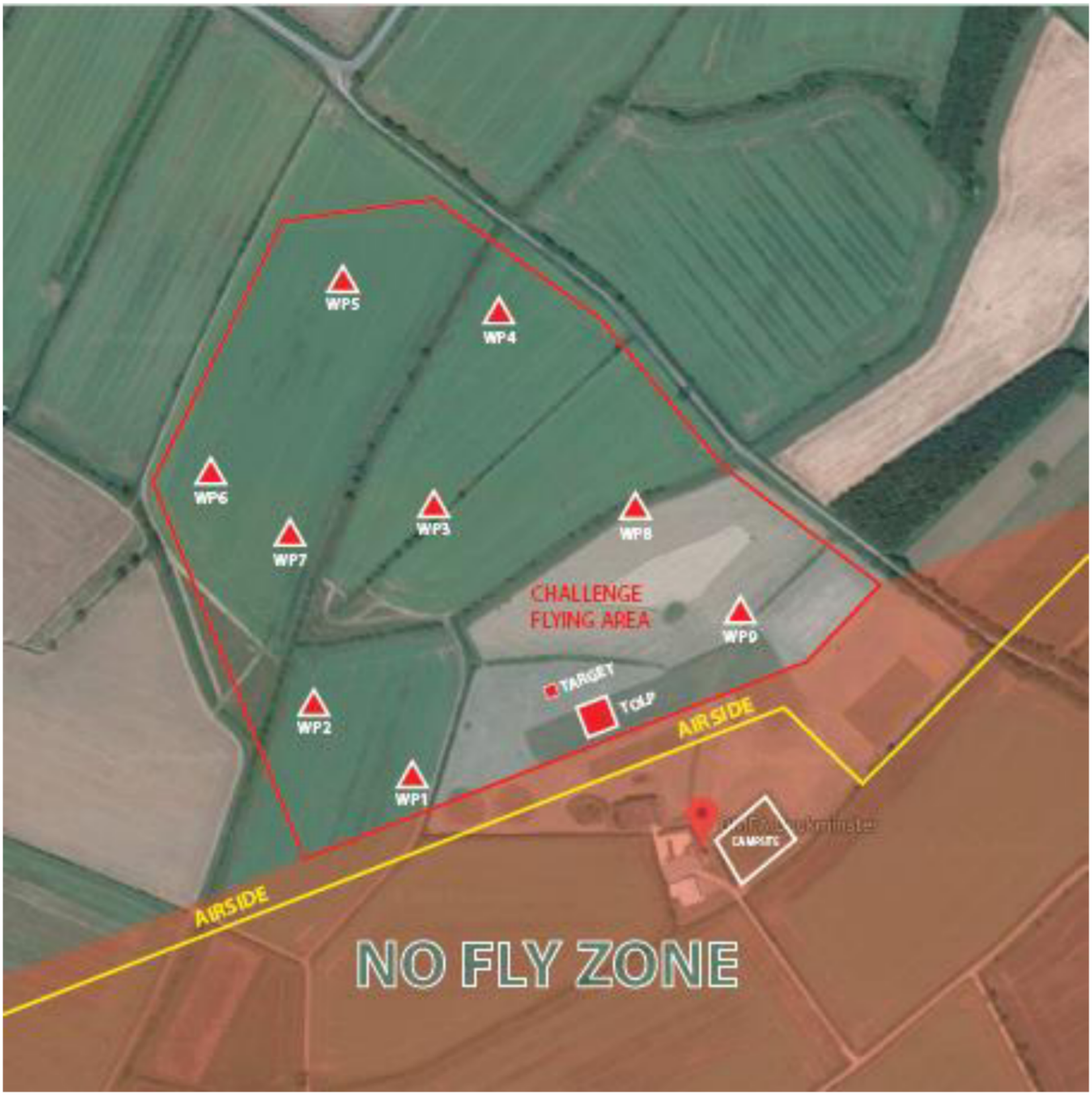


Figure A3: BMFA Airfield showing example Waypoints and Drop Zone

Annex B Competition Requirements Summary

To provide a helpful checklist for both teams and judges, the tables below summarise those requirements which form part of the scoring and assessment. Click on the paragraph references to hyperlink to the relevant section.

B.1 Entry and Eligibility Requirements

Ref	Requirement
2.5.1 Team Composition	Undergraduate / taught postgraduate team.
2.5.2 Team Supervisors	Suitably qualified Academic Lead or Team Supervisor appointed; He/she has approved deliverable documents.
2.5.3 IMechE Membership	Team members registered for IMechE affiliate membership.
2.5.4 Limits on Team Size at Demonstration Event	Max 10 team members at the demonstration event.
2.5.7 Building on a previous year's entry	Entries are not simply a development of a previous years' entry.
2.5.9 Industry Support	Extent of industry support is declared.
2.9.1 Public Liability Insurance	Written confirmation that Public Liability insurance is in place.
2.9.2 Team Pilot Personal Accident Insurance	Written confirmation that the team pilot has Personal Accident Insurance.
2.9.3 Medical Insurance (Overseas Teams)	Written confirmation for overseas teams of medical insurance to cover team members at the demonstration event.

B.2 Design Requirements

Ref	Requirement
3.1.1 Airframe Configuration and Mass	All up mass <= 10kg.
3.1.2 Propulsion Systems	Electric motors only.
3.1.3 Electrical Power System	Externally removable link incorporated.
3.1.4 Aid Package Specification	AirDropBox Micro. Sand used for cargo.
3.1.5 Aid Package Carriage and Delivery	Delivery system incorporates speed retarding device. Aid Package deployed from a minimum height of 50 ft AGL. The Aid Package is **not** reinforced or protectively wrapped. Aid Package has team number clearly marked.
3.1.6 Autonomy	Designed for fully autonomous operation.
3.1.7 Radio Equipment	Compliant with EU directives, and licensed for use in the UK. Reliable operating range of 1 km. Control of the UA and the FTS is 'Spread Spectrum' compliant on the 2.4 GHz band.
3.1.8 Camera / Imaging System	The ground marker position shall be interpreted on the UA and relayed automatically to the base station during the flight.
3.1.9 Flight Termination System	Acceptable FTS design which transforms the UA into a low energy state should the data links between the GCS and UA be lost, and lands the UA as soon as possible after initiation.

3.1.10 Navigation System	The UA shall automatically navigate around the course. Nav System shall be capable of storing the co-ordinates of the Geo-fence flying area. Nav system shall automatically activate the FTS when the Geo-fence is breached.
3.1.11 Location Finder	UA shall make an audible and visual alert to improve ease of UA location if it lands outside the designated landing area.
3.1.12 Ground Control Station	GCS shall display and record UA situational awareness information.
3.1.13 Storage and Handling	Storage and handling box shall not exceed external dimensions 1500 mm x 600 mm x 600 mm.
3.1.14 GPS Tracker	The design of the UA shall ensure that the Tracker can be easily fitted and removed.
3.1.15 Limits on use of COTS Items	Airframe and control systems shall be designed from scratch. A Bill of Materials and costs provided as part of the design submission. Teams shall demonstrate that manufacture of the airframe and integration of the UAS has been predominantly undertaken by the students themselves.

B.3 Operation Requirements

Ref	Requirement
3.2.1 Mission	Guidance only
3.2.2 Take-off and Landing	UA capable of take off and land from within a 10 m x 10 m box. UA capable of operating from both short grass and hard runway surfaces.
3.2.3 Design Mission Range and Endurance	The UA shall carry all the equipment needed for both core and optional tasks, without re-configuration.
3.2.4 Weather Limitations	UA designed to operate in winds of up to 20 kts gusting to 25 kts, and light rain, and crosswind components of 5 kts with gusts of 8 kts.
3.2.5 Real time telemetry	Guidance only.

B.4 Safety and Environmental Requirements

Ref	Requirement
3.3.1 Compliance with UK CAA Drone Regulations	Teams must register an Operator and a Remote Pilot in order to fly UA in the UK.
3.3.2 Pilot Roles and *Competence*	The Team's Operator ID must be displayed on the UA. The Team Pilot shall have flown the UAS before the demonstration event (including for the FRR video).
3.3.3 Flight Termination System	Guidance only.
3.3.4 Other Design Safety Requirements	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. Batteries used in the UA shall contain bright colours to facilitate their location in the event of a crash. At least 25% of the upper, lower and each side surface of the aircraft shall be a bright colour to facilitate visibility in the air, and to aid retrieval of the aircraft in the event of a crash.

3.3.5	Operational Safety Requirements	The UA shall remain within Visual Line of Sight (VLOS) and no greater than 500m horizontally from the Pilot, and remain below 400 ft AGL; The UA shall not be flown within 50 m of any person, vessel, vehicle or structure not under the control of the FSO. This is reduced to 30 m during take-off and landing. The maximum airspeed of the UA in level flight shall not exceed 60 KIAS; During the entire flight the UA shall remain in controlled flight and within the Geo-fence boundary of the Flying Zone; Any Personal Protective Equipment (PPE) needed by the team shall be listed in the FRR.
3.3.6	Environmental Impact	Consideration given to environmental impact, including the use of non-hazardous and recyclable materials; low pollution; low energy usage; low noise.

Annex C GPS Tracker Installation and Operation

The Wintec WBT-201 "G-Rays 2" 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.

Instrument position

The tracker shall be positioned on the upper surface of the aircraft 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. In the case of rotary platforms, avoid placing the tracker under the sweep of the rotor(s). If teams cannot meet this specification they should contact the organisers to discuss the requirements further.

Instrument fixation

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. It is suggested that a polystyrene "jacket" would provide an ideal method of locating the tracker firmly within the structure. Dimensions are provided overleaf.

Operation on Day of Competition

When first switched on in a new position the tracker may take up to 30 minutes to create an up to date almanac. The RIN staff will run the trackers on site for a suitable time before they are issued. The lock-on time for competitors will be between 4 and 32 seconds, thereafter the tracker will operate quite independently. As the information contained within the tracker could be a deciding feature of the competition the RIN staff will be available to assist in priming the trackers throughout. 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 live 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.

i. **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.

ii. **Tracking/Log function:** Press and hold the track button for 1.5 secs, green light will go out to show new track starting.
iii. **Switch-off:** Do not switch the tracker off, the RIN staff will keep it running until download.

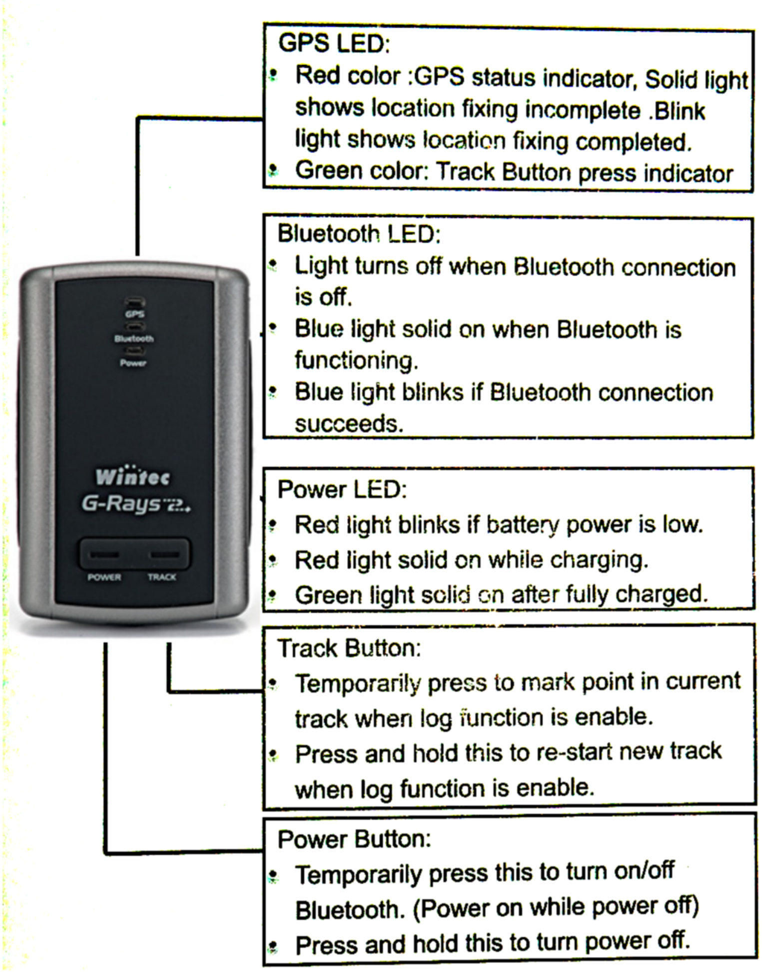
The tracker runs on a continuous data loop lasting in the region of 6 hours. The plan for the Challenge is that the RIN staff will hand over a live tracker leaving the competitors to position it on the vehicle and double-check the status LEDs. Teams should not attempt to operate the trackers unless instructed to do so.

Key Characteristics

Length:
59 mm

Width:
38 mm

Depth:



Annex D 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.

D.1 Concept Selection

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

Rotary Wing (RW) UAS and Fixed Wing (FW) UAS each have their advantages and drawbacks. The RW UA can hover above the Drop Zone to drop the Aid Package and thus may offer accuracy advantages, but may not be so competitive in speed or endurance, and may have reduced Aid Package capacity compared to the FW UA. It may also not be able to perform the Climb and Glide task. On the other hand the RW UA can fly more direct routes between waypoints as it can change direction very rapidly.

In previous UAS Challenge competitions, both FW and RW UAS have scored well. As the detail format of the mission has changed each year, the configuration of former winners is not necessarily a helpful guide.

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.

D.2 Programme Planning

Make allowance for things to go wrong – the aircraft will crash on the test flight and need to be rebuilt. Test subsystems early and in parallel. Provision spare parts. Don't rely on it all being OK on the day – it never is! The more innovative the solution, the more testing it will require but the pay-off will be greatest.

D.3 Shipping of Hazardous Materials – 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.

D.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 web-page, 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

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.

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.

D.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.

D.6 Aid Package Specification and Deployment

Remember that wind speed and direction must be allowed for when calculating the Aid Package release point.

D.7 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. Ensure that batteries can be changed easily.

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.

D.8 Use of Launch Catapults

If using a launch catapult, note that assembly of the catapult needs to be demonstrated during the timed UAS assembly to count towards T1. After setting up the catapult for the first demonstration mission, it can be left assembled to avoid delays to the flying programme.

D.9 Route planning around Waypoints

Note that the UA is required to fly **around** each Waypoint (WP) 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 incur penalty points.

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 UA 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 or navigational errors.

D.10 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, 5th Edition March 2019, Articles 94 and 95.

Annex E Deliverable Item Requirements

E.1 Deliverable Documents

For all teams the documents comprise a Concept Paper, delivered at the same time as your entry application to the UAS Challenge, a Preliminary Design Report (PDR), a Design & Development Specification, and a Critical Design Review (CDR). In addition, for those following the live route a Flight Readiness Review is required and for those on the virtual route an X-Plane Model.

This Annex covers the mandated 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 2.4. 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. In the case of the live event, these scores will remain provisional until the judges are satisfied that the UAS flown at the Demonstration event is as described in the deliverables.

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

- Team number
- University name
- Team name
- List of team members, their courses and year
- Name(s) of supervisor
- Sketch or image of your aircraft
- 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.

E.2 Concept Paper

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.

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 and the dates when you will be undertaking your Preliminary and Critical Design Reviews. Your Design Review forms must be submitted on the dates specified in your project plan. The PDR must be before 30th January 2022 and the CDR before 17th April 2022. You should ensure that you have left plenty of time for testing and any design iterations that may be required when formulating your plan.

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
- A clear project plan with key milestones and delivery dates
- Overall quality of the report.

E.3 Preliminary Design Review (PDR) — 20 points

The purpose of this review is for the whole team to take a preliminary 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 review must 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 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 time bound actions with a named person within the team for its completion to correct any design or schedule shortfalls.

You will need to take detailed minutes of the meeting but the judges only wish to see a simple IMechE proforma completed to confirm that the meeting has taken place on schedule (the form must be uploaded to Mashoom within 2 days of the meeting taking place), with a very brief summary of the discussions and the details of the actions placed.

Team number & name	
Chairman + position	
Team members present	
Review date	
Review purpose	
Review items covered and main issues arising (this should include: Requirements, Weight budget, Cost budget, Test plan, Safety, Risks, Schedule	
Changes since your Concept Paper	
Main issues arising and actions to be taken	
Chairman + Team Leader signatures	

E.4 Design & Development Specification **160 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 must be started on a new page. This report shall establish 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)

- A text description of proposed design.
- List and reason for all significant changes since the Concept Paper
- List any contributions from sponsors
- Weight of cargo to be carried in the core element of the mission and the optional tasks planned to be undertaken

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 should 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 the key Requirements, including regulatory requirements, and mission objectives and how they are being met (e.g.):

ID	Requirement	Verification
3.1.1	All up mass <= 10 kg	Detailed weight budget has been produced with 10% contingency.
3.1.7	Compliant with EU directives, and licensed for use in the UK. Reliable operating range of 1 km. Control of the UA 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
3.1.9	Acceptable FTS design which transforms the UA into a low energy state should the data links between the GCS and UA be lost, and lands the UA as soon as possible after initiation.	Configured in the Pixhawk with motor power cut within 1s and controls set for spiral dive.

Design Description (11 A4 pages maximum) (60 points)

- A Functional Description, and the rationale for selection of each of the proposed systems, including Airframe, Propulsion, Flight Controls, Navigation & Mission Control, Sensors, Image Processing, Autonomy / Automatic Operation, Cargo Carriage and Delivery system, and Flight Termination System, highlighting any novel features;
- Aerodynamic, structural and performance calculations supporting the sizing, stability and control 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 three-view scale drawing;
- A dimensioned 3-view diagram;
- A detailed systems architecture diagram

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)(20 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 support equipment, handling and storage fixtures necessary to 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.

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 3.1.15.

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, cargo 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.

E.5 Critical Design Review (CDR) (20 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 must 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 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 time bound actions with a named person within the team for its completion to correct any design or schedule shortfalls.

You will need to take detailed minutes of the meeting but the judges only wish to see a simple IMechE proforma completed to confirm that the meeting has taken place on schedule (the form must be uploaded to Mashoom within 2 days of the meeting taking place), with a very brief summary of the discussions and the details of the actions placed.

Team number & name	
Chairman + position	
Team members present	
Review date	
Review purpose	
Review items covered and main issues arising (this should include: Requirements, Weight budget, Cost budget, Testing undertaken and planned, Manufacturing plan, Safety, Risks, Schedule, FRR plans.	
Changes since your Design & Development Specification report	
Main issues arising and actions to be taken	
Chairman + Team Leader signatures	

The team may wish to undertake further intermediate reviews but these do not need to be submitted to the IMechE.

E.6 Flight Readiness Review Submission (Live teams only)

The Manufacture and Test stage culminates with the Flight Readiness Review in which you review whether your aircraft is ready to undertake demonstration flights to the customer. This is a critical safety and operational review and **must** be passed before the mission flights at the final event can be undertaken. 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. **Failure to submit your complete FRR on time may result in exclusion from the Demonstration Event.**

- A 10 minute video showing evidence of the development testing undertaken, including a continuous flying sequence showing at least a fully autonomous take-off, controlled flight, including any transition, and landing. Any payload release demonstration must comply with national regulations (for the UK, see Annex G). For the purposes of the FRR a ground release demonstration will be adequate;

- 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 and/or the CDR 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.
- A completed Form 701

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.

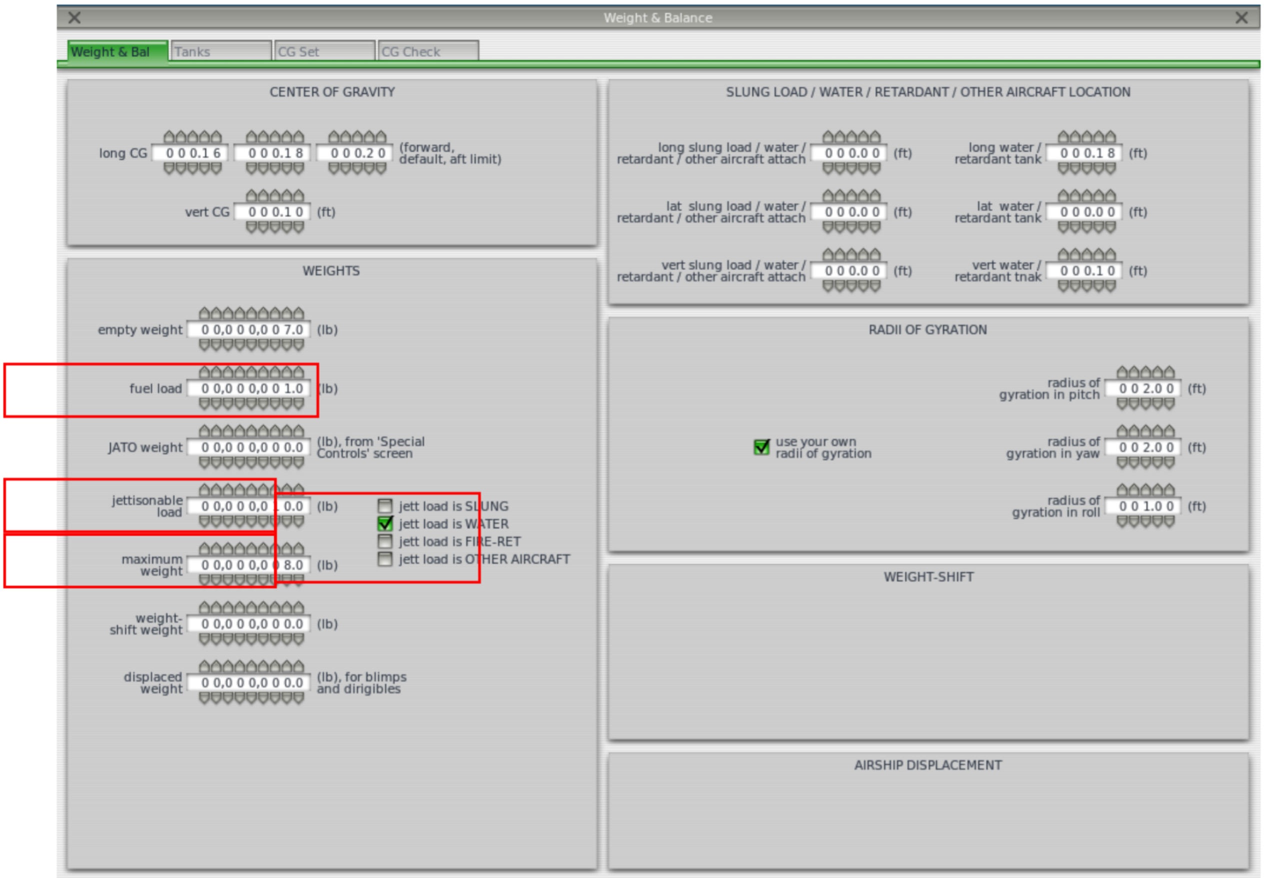
The assessment panel will be looking for evidence in the FRR Video about the extent and rigour of testing to demonstrate the performance and safety features of the UAS.

E.7 X-Plane Model (Virtual teams only) (400 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.
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.
4. Fuel Load – This will only need a value if a consumable fuel is used for the primary flight.



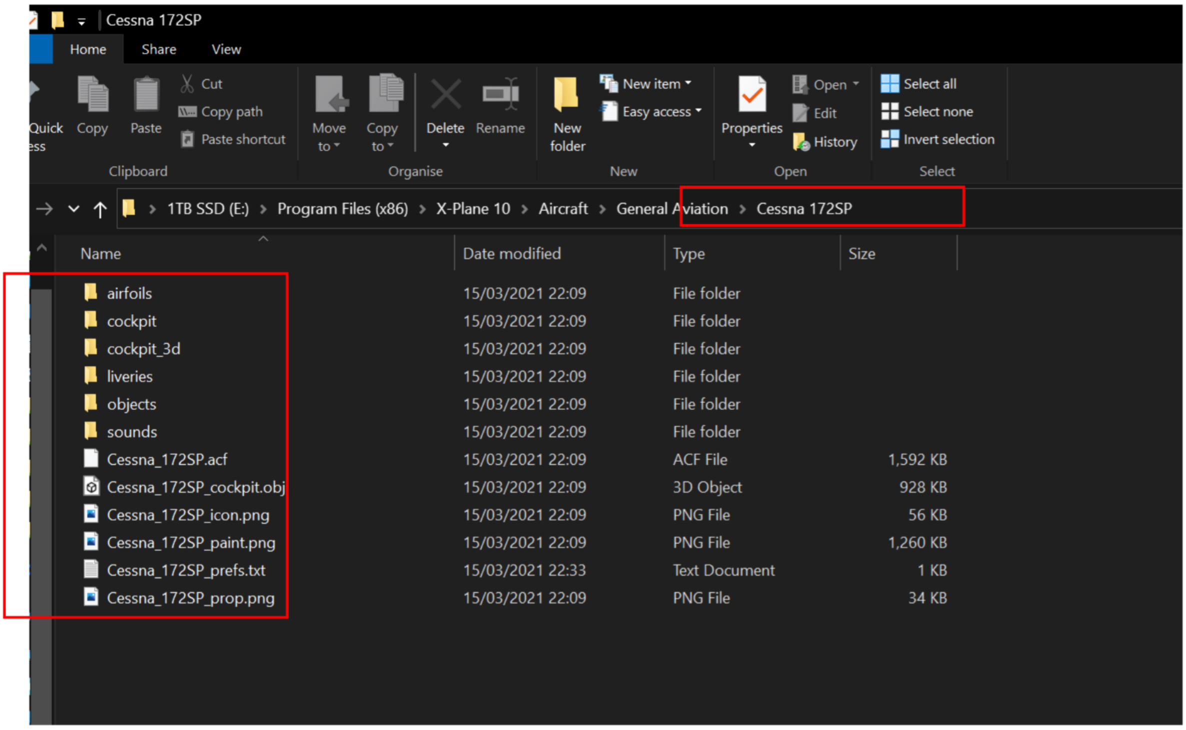
Guidance on using X-Plane plane maker should be sort from the following manuals;

- Plane Maker Version 11.5
- Plane Maker Version 10.5

Version should correspond to the version of X-Plane Simulator being used. The above are the only two versions 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.

If any changes have been made to your aircraft design due to the limitations imposed by X-Plane these should be explained within a word document included with your X-Plane submission titled **UAS_UNIVERSITYNAME_TEAMNAME_VIRTUAL_GUIDANCE_DOC.** This document should also contain key information for the pilot to fly the aircraft manually for example.

- 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