Institution of MECHANICAL ENGINEERS

UAS Challenge 2021

Competition Rules

UAS Challenge 2021

Mission and Competition Rules

Issue 10.2, August 2020

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
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
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

Competition Rules - Revision status

Issue 2, Aug 2014: Issued to Teams at the start of the 2015 competition.

Issue 3, Jan 2015: incorporates responses to feedback and questions.

Issue 4, Mar 2015: update to the example demonstration course and airfield map.

Issue 5, August 2015: Extensively revised to incorporate feedback.

Issue 6, September 2016: Revisions to mission, providing wider range of challenges and more flying, closer alignment of prizes with the scoring, and streamlining of the design documentation required from teams.

Issue 7, September 2017: Minor revisions to Missions 1 and 2, deletion of Mission 3. Design report submissions revised to reduce the workload on teams. Autonomous operation now mandated. Refinement of prizes. Details of Llanbedr airfield included.

Issue 8, September 2018: Mission challenges revised into a single multi-faceted mission. Scoring simplified. Restriction on electric system voltage to 4S to limit individual motor power. Clarifications and guidance on the conduct of the demonstration event. Clarification on automatic reporting of the ground marker alphanumeric, and deletion of the reporting 'time' element to reduce burden on judges. Aid Package specification changed from flour bag to First Aid Kit and Water. A short Preliminary Design Review (PDR) has been re-introduced.

Issue 8.1, December 2018: Update to Sections 3.1.6, 3.1.7, 3.3.1, 3.3.3, 3.3.4, Appendices C.4, D.4, clarifying that automatic operation is mandated, thus teams are not permitted to operate the UA manually, and therefore do not need a BMFA-A Pilot Qualification. Clarification on roles of Safety Pilot and Team Pilot. Requirement for buddy box deleted. PDR submission deadline moved back to 3 Feb 2019 (Sections 2.3, 4.3).

Issue 9, August 2019: Change to mission and cargo, encouraging new designs. Introduction of Packaging box and modular assembly challenge. Measure of fuel / power consumption and efficiency introduced, with Power Logger. Recognition of regulatory changes – drone registration. Concept paper now used to set a minimum competition entry standard, to help ensure teams will all be successful.

Issue 9.1, November 2019: Update on page 30, A.2.5, page 35 A.4.4 and page 43 Annex C Power Logger (highlighted in yellow). Update on A.7 Site Map as the event is relocating from Llanbedr to the BMFA National Flight Centre in Lincolnshire. CAA Drone Regulations have now been issued with 2.8.4, 3.3.1 and 3.3.2 updated.

Issue 10, March 2020: Changes introduced for 2021 competition include increase in maximum mass to 10kg; Cargo changed to AirDropBox Micro system; streamlining of document deliverables to reduce workload on teams and to reflect a more agile (rather than waterfall) approach to development; clarification of eligibility and team structure; inclusion of Annex B Requirements summary to assist the Judging and assessment of compliance.

Issue 10.1, May 2020: Amendments to lift restriction on 1st / 2nd year students. Change of rule to allow adaptation of previous designs. Note on use of anti-plagiarism software by the judges. Clarification on FTS requirement. Revision of the Power Logger architecture. Change to minimum radio and data link operating range. Revision of scoring to increase weighting for optional tasks.

Issue 10.2, Aug 2020: Revisions to allow for either live or virtual demonstration event in 2021.

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 2020, and the flight demonstration being held in June 2021. 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 event, these rules have been updated to allow for either a live or virtual demonstration event in 2021.

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 gives the technical details of the Power Logger to be fitted to the UA, recording the energy usage for UAs using electric propulsion;

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

Annex F gives the requirements for completion of the document deliverables, the Concept Paper, Design Report, Review Reports and Flight Readiness Review.

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 in June 2021, 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 for the 2021 competition is presented at Annex A.

2.3 Challenge Schedule

The Challenge will formally be launched at the start of the academic year in October, with the rules being available from the preceding March. Key dates and activities are as follows:

Activity	**Date**	
	Live Event	**Virtual Event**
Closing deadline for entry / concept paper to IMechE	15 Nov 2020	15 Nov 2020
Welcome Webinar / Seminar for all registered teams	w/c 16 Nov 2020	w/c 16 Nov 2020
Design Review #1 Submission	Set by team	Set by team
Complete Detail Design and Design Report Submission	15 Mar 2021	15 Mar 2021
Design Review #2 Submission	Set by team	Set by team

Activity	Date	
	Live Event	Virtual Event
Manufacturing, Support & Test Report + 3D Model Submission	Not Applicable	3 May 2021
Complete Manufacture & Test; FRR and Video Submission	21 May 2021	Not Applicable
FRR feedback (as required to address non-compliance)	28 May 2021	Not Applicable
Dragons' Den Video & A0 Poster Submission	Not Applicable	7 June 2021
Team Interviews	Not Applicable	14 – 16 June 2021
Flight Demonstrations, Dragons' Den & A0 poster	16 - 19 June 2021	Not Applicable
Sponsor Q&A Panel	19 June 2021	17 June 2021
Award Ceremony	19 June 2021	18 June 2021

Note that dates may be subject to change.

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 F).

The briefing webinar in November will 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 on the Welcome Webinar & Seminar 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 2021).

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 Design 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

The UAS Challenge organising committee will consider the possibility of running virtual and live demonstration events in parallel, if a significant number of teams cannot attend the live event due to continued restrictions arising from Covid-19. The circumstances will be assessed and a decision will be made and communicated to teams by March 2021.

These rules provide for a virtual (as well as the live) event in case that becomes necessary.

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 'Drone and Model Aircraft Registration' regulations which came into force in the UK from 30th November 2019.

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 0 for general guidance and tips on design and build of the UAS. Annex E.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, the GPS Tracker (Annex C) and Power Logger (Annex D).

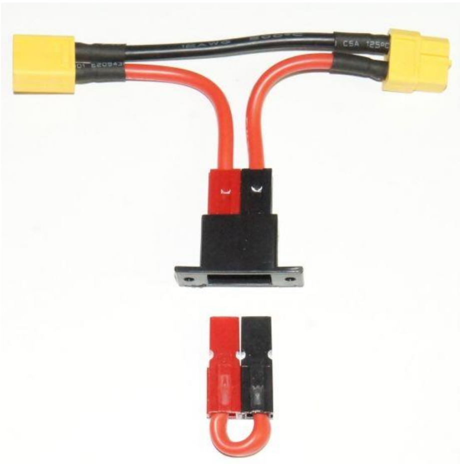
The UA shall be designed for rapid assembly / disassembly to fit into the Storage Container (see Section 3.1.13 below).

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, except that the design shall be compatible with any electrical load limitations imposed by the Power Logger (see Annex D). Batteries should have an operating voltage of 80 V or less, with a peak current of 100 A or less and a continuous current draw of 60 A or less in operation. If the total system draw exceeds these limits, then multiple power loggers may be used, or where the system can be divided into multiple identical parts it is acceptable to monitor one of these parts in order to estimate the energy usage of the complete system. For example, a log of the power drawn by one electric motors could be recorded, which would be multiplied up by the number of motors.



It is not necessary to measure the power drawn by the avionic systems; the intention is to measure the efficiency of the propulsive and lift-generating systems.

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
Cargo Volume	3.75 litres
Cargo Dimensions	15 cm x 12.5 cm x 20 cm

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.

ADB Micro System

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.

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 identification of the four Ground Markers.

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, location and identification exercise set out in the Optional Mission, see Annex A.3.

The ground marker alphanumeric and 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.

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 and Power Logger**

The Organisers shall provide both a GPS tracking data logger (the Tracker), described at Annex C, and an Electrical Power Logger, described at Annex D.

The design of the UA shall ensure that the Tracker and Power Logger can be easily fitted and removed.

Teams shall fit the Tracker and Power Logger to the UA before the Scrutineering process, and return them to the Organisers immediately following a flight, for post-flight evaluation of both the 3D trajectory, and the electrical power consumed.

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 30 m x 30 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, and reloading fresh batteries is **not** permitted between the core and optional tasks.

It is **not** permitted to re-configure the UA between core and optional tasks, for example swapping a payload delivery mechanism for a camera. The UA must carry all the equipment necessary to carry out both its planned core and optional tasks.

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 E.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;

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[1] Air Navigation Order, Articles 94 and 95

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.

The Organisers will measure the total energy consumed during the mission flight, using the Power Logger (see Annex D).

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.

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:

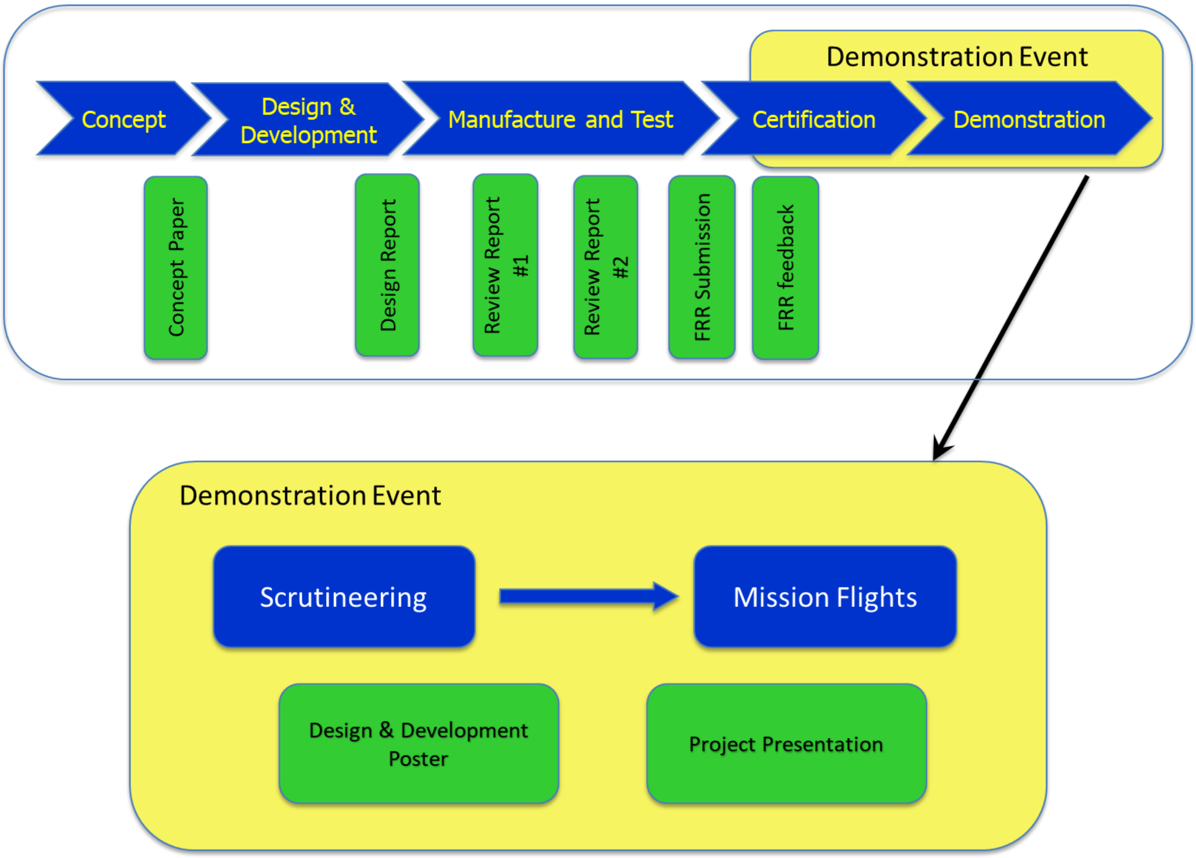


Figure 1: UAS Challenge Stages and Deliverables

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 Design Report. As the design matures formal reviews should be undertaken and submitted in two Review Reports.

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;
- Project 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 F.2.

4.2.2 Design Report

This is a detailed report of the proposed design of the UAS. The requirements for this report are specified at Annex F.3.

4.2.3 Review Reports

During the Design and Development process formal reviews should be undertaken to confirm that the requirements continue to be met and that progress is running to plan. A proforma report of these reviews, specified in Annex F.4 have to be submitted.

4.2.4 Flight Readiness Review

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 F.5. If the judges consider there are non-conformances with the FRR, they may provide feedback to the team via a Skype or conference call.

4.2.5 Design & Development Poster

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

4.2.6 Project Presentation

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.

For the Virtual Event, teams are required to submit a video of maximum length 15 minutes in place of the Project Presentation for the Live Event, and covering the same material.

4.3 Deliverable Items Schedule

The deliverables will depend upon whether or not is possible to hold a live demonstration event. The flow chart and table below depict the process and the schedule of deliverables for the live and virtual events.

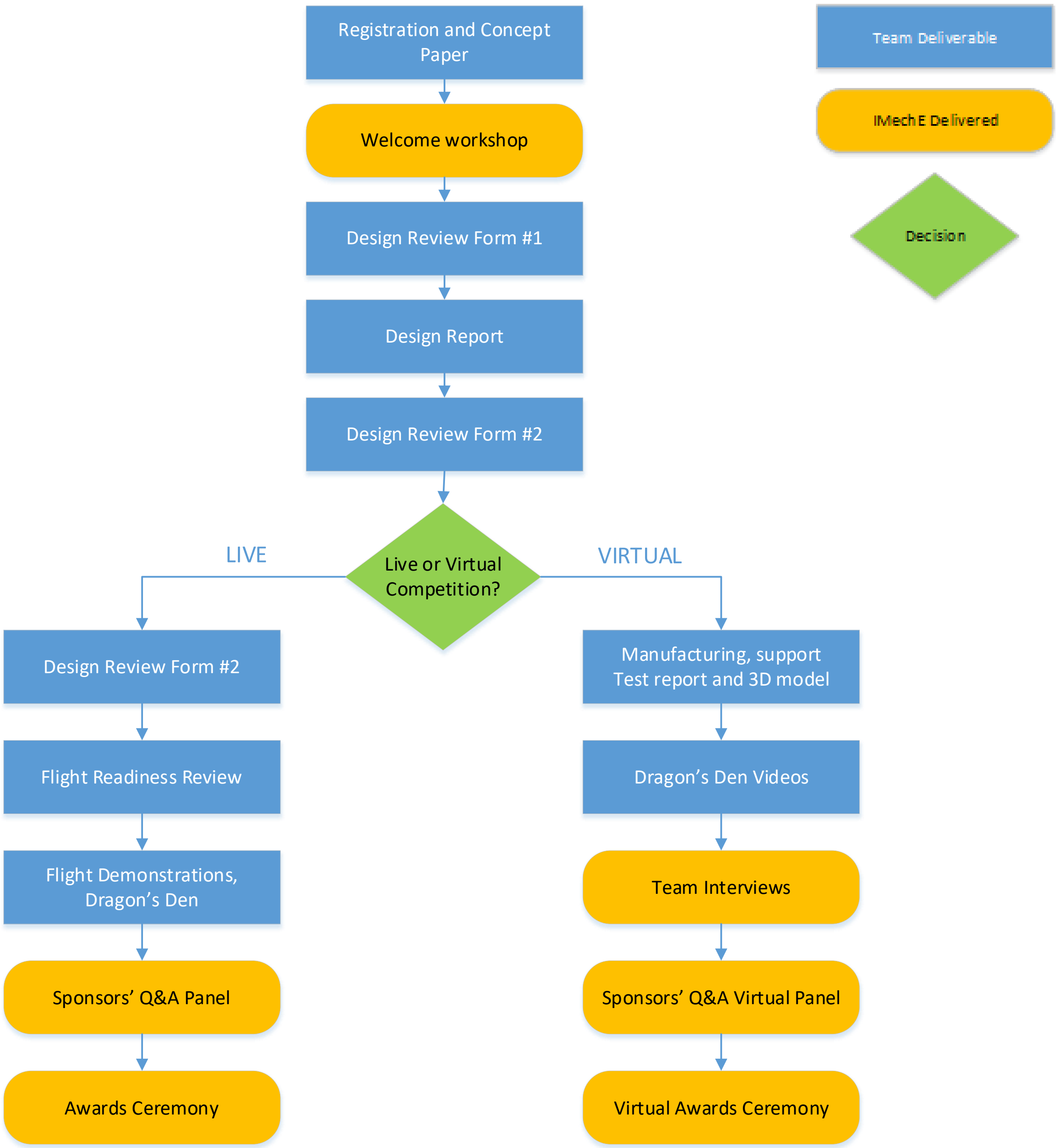


Figure 2: Live / virtual event process and deliverables

The schedule of deliverable items and activities is as follows:

Deliverable	Live Event	Virtual Event	Reference
Concept Paper Submission	15 Nov 2020	15 Nov 2020	Annex F.2
Design Review #1 Submission	Set by team	Set by team	Annex F.4
Design Report Submission	15 Mar 2021	15 Mar 2021	Annex F.3
Design Review #2 Submission	Set by team	Set by team	Annex F.4
Manufacturing, Support & Test Report + 3D model	Not Applicable	3 May 2021	Annex F.6
Flight Readiness Review Submission	21 May 2021	Not Applicable	Annex F.5
Design & Development A0 Poster	16 June 2021	7 June 2021	Section 4.2.5
Dragons' Den Video	Not Applicable	7 June 2021	Section 4.2.6
Project Presentation	16 June 2021	Not Applicable	Section 4.2.6

4.4 Demonstration Event

4.4.1 Scheduling

Teams arrive at BMFA site on Wednesday 16th June 2021, before 3:00pm.

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

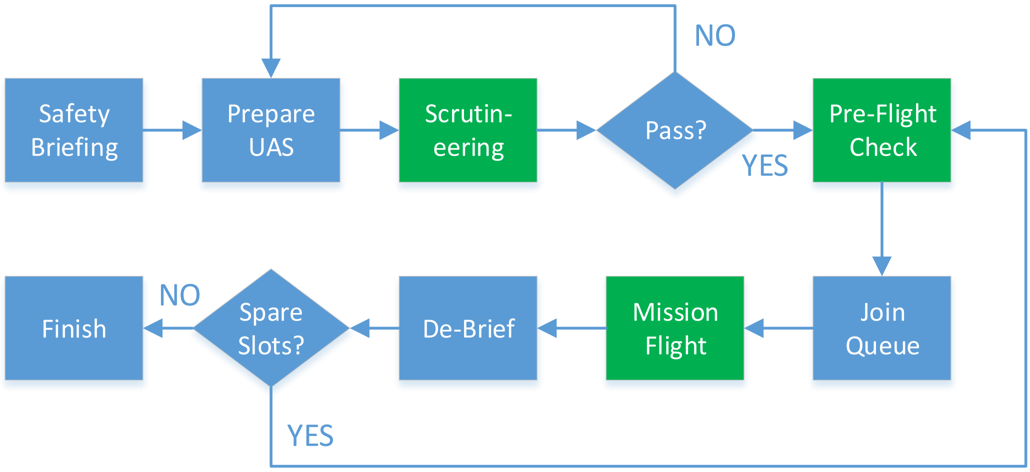
A mandatory detailed briefing will be given at the beginning of the Demonstration Event covering the logistics and timings for the event, rules and good conduct for safe operations, pre-flight briefings etc.

Day 1, Thursday 17th June will be set aside for scrutineering and to conduct shake-down test flights. Test flight priority will be given to overseas teams.

The remainder of scrutineering, all the competition flying and the Project Presentations will take place on Days 2 and 3, Friday 18th and Saturday 19th June. 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 2 day 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.2 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 made following the Design Report submission are incorporated, and that any late modifications introduced are reviewed and acceptable.

The scrutineering panel will have reviewed the FRR submission (see Annex F.5), 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 Pre-Flight Check

Those teams that have passed scrutineering will be allocated a demonstration flight time when they will proceed to the pre-flight check area with the UA in its Storage Container. They 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.

Should the time taken by a team for this task become extended, they may be asked to re-join the queue to let another team do the Pre-flight Check. This is to ensure the Flying Programme is kept running at tempo.

From there they will then 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.

4.4.6 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, speed trial, ground marker ID 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 and the Power Logger 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 trackers.

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.

4.4.7 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.

4.4.8 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 competition will be assessed across four 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**	**170**
Design Report	140	140
Review Report #1	15	15
Review Report #2	15	15
Flight Readiness Review	30	N/A
Flight Demonstration	**400**	**130**
Packaging and Storage	40	N/A
Cargo Delivery (mass & distance)	100	N/A
Climb and Glide	40	N/A
Navigation	40	N/A
Efficiency	40	N/A
Speed Trial	40	N/A
Ground Marker ID	50	N/A
Area Search	50	N/A
Manufacturing, Support and Test Report	N/A	90
3D Printed Scale Model	N/A	40

A maximum of **600** points is therefore available (Live) or **300** points (Virtual).

More detailed information on the scoring of the Design and Development is provided at Annex F, 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

There are a number of categories for which prizes will be awarded:

Prize	Award Criteria	Notes
Grand Champion	Highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
Runner Up	2nd highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
3rd Place	3rd highest aggregate score from the Design & Development and the Flight Demonstration	200 points Design & Development, 400 points Flight Demonstration
Innovation	The most innovative concept taken through to flight demonstration. This could include an innovative layout of propulsion and flying surfaces, aerodynamics, structures, use of materials, and manufacturing methods.	Assessed from the Design Report and the FRR video, confirmed at the demonstration event.
Design	For the entrant with a well-structured design approach, the most elegant and well thought through design, as described through the Concept Paper and Design Report 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 *	The best presented UAS that is fully compliant with the competition rules and meets the technical, build quality and supportability objectives of the competition.	Judged by the scrutineers at the Demonstration event.
Safety	For the entrant developing the best combination of a well-articulated safety case, with evidence that safety has been considered throughout the design and development stages, and demonstrating safe operation and team behaviour.	Judged from the Design Report and the Demonstration Event.
Environmental	For the UA demonstrating the most environmentally sustainable design in materials, noise and energy usage.	Assessment of materials, noise and flight efficiency, including best combined score in Flight Performance Efficiency plus the Climb and Glide.
Airworthiness *	For the entrant demonstrating the best approach to airworthiness, through the design and well engineered safety features.	Judged by the scrutineers at the Demonstration event.

Operational Supportability *	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.	Judged by scrutineers during the pre-flight inspections.
Business Proposition	For the entrant with the most promising business and marketing case presented to a panel of sponsors during the flight demonstration event, 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 *	For the entrant which couldn't quite make it all work on the day, but where the team showed most ingenuity, teamwork, resilience in the face of adversity, and a promising design for next year's competition.	This could either be a team that failed to make it to the Flight Line or one that did not reach its full promise during the flight trials.
Highest placed new entrant	Highest mission scores for a university that has not previously taken part.	
Media and Engagement	For the team which engages most effectively with local media, schools, social media, and gets engaged with schools as part of the STEM Outreach Programme at the event, to promote participation and engagement with the Challenge.	This is assessed at the Project Presentation and the STEM activities during the event.

* denotes those prizes which are **not** awarded in the case of a Virtual Event. Note also that for the Virtual Event the Grand Champion, Runner Up and Third Place prizes are awarded on the basis of the five virtual deliverables.

Annex A Mission

A.1 Mission Overview

The mission comprises a mandatory 'core' challenge, and some optional challenges. The optional challenges cannot be undertaken without completing the core challenge. The missions are depicted in the Flow Diagram at Figure A1.

A.1.1 Core Challenge

The mission scenario is an Unmanned Aircraft (UA) picking up humanitarian aid from a forward supply base and delivering as much aid as possible to a defined remote Drop Zone (DZ), via defined Waypoints (WP), within a specified mission time limit.

There are three routes from the base station to the DZ, a short, medium and long distance route. A longer route scores a greater number of points per mass of cargo delivered. Teams will need to plan their tactics carefully, and be familiar with the performance of their UA.

A 'climb and glide' test of the aerodynamic efficiency is part of the core challenge.

The UAS shall be stored and transported in a box or container, and assembled simply and quickly to be ready for deployment at short notice. The total time to deploy the system, from opening the container to being ready for take-off, shall form part of the challenge.

A power logger will be fitted to the UA and the overall energy consumed will form part of the scoring, with lower energy consumption scoring more highly.

The challenge aims to test the structural efficiency, flight performance, navigation, modularity, and load carrying capacity of the UAS designs.

A.1.2 Optional Challenges

In addition to the core task delivering a mass of cargo to pre-defined locations, additional optional tasks are set for teams with the resources and skills to build these capabilities into their UAS. These include a speed task around a circuit, identification of Ground Markers en-route, and an area search for a hidden Ground Marker.

At the start of the competition, each team will need to decide whether they have the necessary time, skills and resources to design for some or all of the optional tasks, in addition to the core task. Completing all the tasks successfully will score more points overall, but will require more design and development work.

A.2 Core Mission

This comprises the pre-flight preparation, cargo delivery task, and the climb and glide task.

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.

A.2.1 Task 1: Pre-Flight Preparation

This task follows satisfactory Scrutineering, and is carried out at the Pre-Flight Inspection area, just before going airside.

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 (T1) to complete the pre-flight preparation.

A.2.2 Transfer to the Flight Line

Following the pre-flight preparation, 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.2.4 Task 2: Cargo Delivery

A.2.4.1 Task 2a: Take off

When the FSO is satisfied that the team is ready, he/she will give clearance to take-off, and the mission time will start. The team will launch the UA which shall perform an automatic take-off, climb out in a controlled manner and head towards the first WP.

A.2.4.2 Task 2b: Navigation and Cargo Delivery

The UA shall navigate to the Drop Zone (DZ) via several Waypoints (WP) located on the airfield.

The UA shall fly **around** the waypoints in a specified direction, i.e. either leaving the WP to the right or the left. 'Cutting the corner' when flying around a WP will incur penalty points.

The UA shall automatically release the cargo as close to the DZ as possible. Points are awarded for:

- successful release of the Cargo
- the distance between the cargo (at rest) and the centre of the DZ;

Cargos that are damaged on impact, releasing some of the sand, will attract penalties.

A.2.4.3 Task 2c: Return to Launch Point

Following deployment of the Cargo, the UA shall return to the Launch Point by the most direct route possible. With due consideration to the prevailing wind, the UA shall position for an approach and fly overhead the launch point at approximately 20 ft agl.

A.2.5 Task 3: Climb and Glide

This is a test of flight efficiency, followed by a power-off precision landing.

A.2.5.1 Task 3a: Climb and Glide

Continuing from the previous task, the UA having overflown the launch point, shall perform a climb to 350 ft above the take-off point, describing a climbing circle, so that it is positioned into wind overhead the take-off area at the top of the climb. It shall fly straight and level briefly, and then the propulsion shall be cut, and the UA commanded to glide at its best glide speed, again performing one or more circuits, to return to the landing point.

The glide performance will be assessed from a post-flight GPS analysis of the track distance and glide speed, and the descent rate.

A.2.5.2 Task 3b: Precision power-off landing

Continuing its glide descent, **without application of motor power** the UA shall approach and land within the 30 m landing box.

A.2.6 Finish Core 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 mission time, T2.

Note: There are penalties for exceeding the maximum T2 time of 10 minutes (see Scoring at A.4.4.

A.3 Optional Mission Tasks

The optional tasks comprise a Speed Trial, Waypoint Marker ID, and an Area Search. For teams electing to attempt one or more optional tasks, the overall mission time will pause at the end of the core mission task, and continue when the FSO has allowed the team to launch for the Optional tasks.

Teams may elect to do either or both optional tasks, but subject to an overall mission time, including the Core Mission, of **15 minutes**.

Note: As an example, if the Core mission task had been completed in 9:30 min:sec, then the team would have 5:30 min:sec remaining to complete one or more optional tasks.

Teams may fly the optional missions in whichever order they choose.

It is **not** necessary to land between completing the Speed Trial and starting the Area Search. The UA may proceed from one directly to the other.

It is **not** permitted to load fresh batteries between the core and optional tasks.

A.3.1 Task 4: Speed Trial & Marker ID

A.3.1.1 Speed Trial

This shall be a timed speed trial around a closed course of Waypoints, of approximately 3km in distance. The UA shall take off, and the time shall start from crossing the first WP, to the time re-crossing the same WP. A shorter time scores more points.

Penalties shall apply for any WPs that are missed. **No** cargo should be carried or dropped during this task.

The maximum average speed shall not exceed 60 kts. This is a regulatory constraint, and penalties including the possibility of disqualification shall apply for exceeding this limit.

A.3.1.2 Ground Marker Identification

Somewhere on the lines joining the Speed Trial Waypoints, are placed four Ground Markers, as defined at A.6. These are coloured squares with an Alphanumeric character. During the Speed Trial, the UA shall automatically identify all four Ground Markers, and for each report the GPS co-ordinates, colour of the inner square, and the Alphanumeric character. This data shall be interpreted on the UA and relayed automatically to the base station during the flight.

A.3.2 **Task 6: Area Search**

During the demonstration event, the organisers shall provide the teams with co-ordinates of a rectangular area on the airfield, within which a single Ground marker is located, as defined at A.6. The UA shall search this area, locate the Ground Marker and automatically identify and report the GPS co-ordinates, colour of the inner square, and the Alphanumeric character. This data shall be interpreted on the UA and relayed automatically to the base station during the flight.

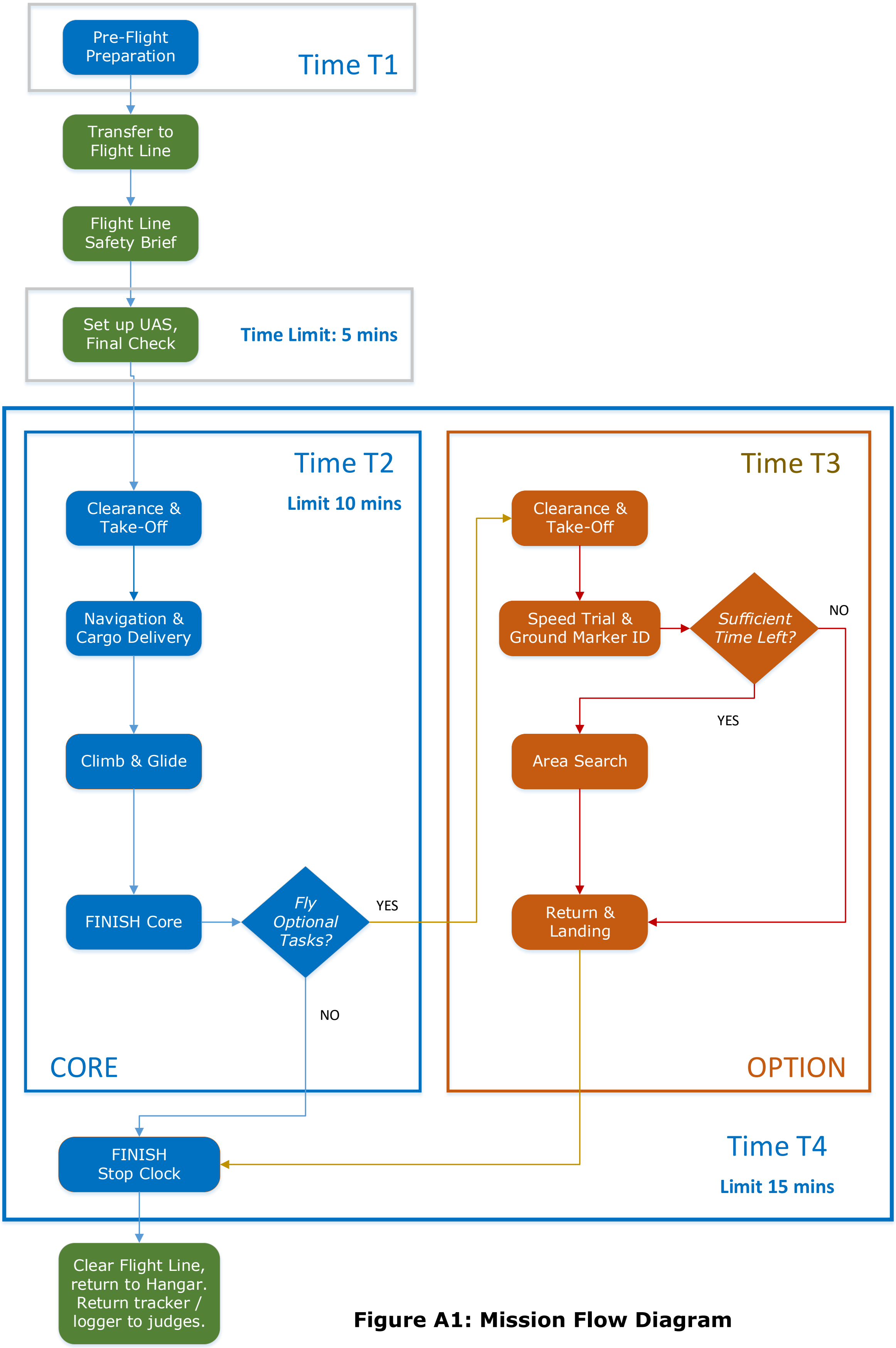


Figure A1: Mission Flow Diagram

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 Mission Times

There are several measured times related to the Mission:

- The pre-flight preparation time T1 is measured, but this is not a hard time limit. A shorter preparation time will result in a greater score. (Note this refers to the ground-side preparation, before transferring to the Flight Line).
- Once at the Flight Line, after the safety brief the team has up to 5 minutes to prepare the UA for take-off. This is a hard time limit, and the Flight Safety Officer will use his authority to substitute another waiting team if the time limit is breached.
- The Core mission time limit, T2 is 10 minutes.
- The Optional mission time T3 is measured, and limited by the time left available within the 15 minute overall mission time limit, having completed the Core mission.
- The overall mission time T4 is measured, being the sum of T2 and T3. The overall mission time limit is 15 minutes.

Exceeding the T2 and T4 time limits will result in penalty points being applied, as set out in A.4.4 below.

For flight safety reasons, the FSO may enforce a pause between completing the Core mission and clearing take-off for the Optional Mission. In this event the clock will be stopped between the end of T2 and starting T3.

Note: Any pause requested by the FSO shall not be used for any pre-flight preparations (i.e. tinkering, re-calibrating systems to improve performance etc) unless directed by the FSO for flight safety reasons (e.g. check landing gear after heavy landing).

A.4.2 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 approximate distances are expected to be:

Route A: 5.0 km; Route B: 3.0 km; Route C: 2.0 km

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.

A.4.3 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.4.4 Core Mission Scoring

Task	Scoring
Pre-Flight Preparation	40
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 20 points.
Preparation Time, T1	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 20 points for time ≤ 3 minutes (180 s). Score 0 points for time ≥ 10 minutes. Score = 28.57143 – (0.04762 x T1), rounded to nearest integer, where 'T1' is in seconds. *Example: Assembly and check-out takes 6:30 min:sec (390 s). Score: 10 points.*
Cargo Drop	100
Cargo Mass and Distance	Mass of cargo delivered to the Drop Zone (kg) x the straight distance of the Route taken (km) x 2.5 points. *Example: 4.8 kg delivered via Route A (5.1 km) – total points 2.5 x (4.8 x 5.1) = 73 points.*
Accuracy	Score $\frac{M(50-D)}{10}$ 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)/10 + (4.5 x 34)/10 = 31.6 / 2 drops = 16 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 10 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 10 x 4.7 = -47 points.*
Climb and Glide	40
Score	Score 6 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 6 x 6.2 = 37 points.*
Navigation	40
Score	4 points for each WP successfully navigated around the declared Route up to a maximum of 40 points. Example: Route A may comprise Launch - WP1 – 2 – 3 – 4 – 5 – DZ – WP9 – Land. Total 7 WPs including the DZ. Score 28 points. Route B may comprise 4 WPs. Score 16 points. Total 44, but limited to max 40 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.
Flight Performance Efficiency	40
Work Done / Energy used	Flight Performance Efficiency, defined as the 'Work Done' / Energy used. The 'Work Done' is the Cargo mass x distance (kg x km) measured in the Cargo Drop calculation above. Energy usage is defined below. Round answer to nearest integer. Maximum score of 40 points.
Energy used	Energy is measured by the Power Logger (Integration of Current draw x Voltage over mission time), and measured in MJ. *Example: Total energy consumed as measured by logger is average 50A x 22.8V = 1,140W, continuous for 10 minutes (600 s) = 0.684MJ. Work Done is Mass x distance carried from Cargo Drop calculation above = 21.5 kg.km. Efficiency = 21.5 / 0.684 = 31.4. Rounded to **31** points.*
Mission Duration	-
Core Mission Time T2	Incur penalty for exceeding the core mission time limit, T2. Score -2 points for every five seconds over the limit, and round up. *Example: actual core mission duration recorded as 10:35 min:sec, against T2 limit of 10 mins. Penalty incurred of -14 points.*
Overall Mission Time T4	Incur penalty for exceeding the overall mission time limit, T4. Score -2 points for every five seconds over the limit, and round up. Note that this is additional to any penalty for exceeding the core mission time T2 above. *Example: actual overall mission duration recorded as 15:30 min:sec, against T4 limit of 15 mins. Penalty incurred of -12 points.*
Precision power-off landing	-
Precision landing	Deduct 10 points if the UA completes a power-off landing more than 50 m away from the nearest edge of the landing box.
Automatic Operation	-
Penalty for non-automatic operation	Reduce score for the whole core mission by 50% if any parts of the flight operation are performed manually, including take-off, landing, navigation and cargo delivery.

A.4.5 Optional Mission Scoring

Task	Scoring
Speed Trial	40
Score	Score maximum 40 points for a maximum average speed (V) of 60 kts, defined as the course straight line distance around the waypoints divided by the total time clocked to fly the course. Score 0 points for speed ≤ 20 kts. Note the maximum average speed limit of 60 kts must **not** be exceeded. Speed Score = V – 20, where V is average speed in kts. Example: Average speed = 42 kts. Score = 42 - 20 = 22 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 average speed limit of 60 kts is exceeded, measured as an average around the course.
Ground Marker ID	50
Score	Maximum score of 50 points for identifying four Ground Markers correctly, made up from the three scoring elements below.
Ground Marker co-ordinates	Score 4.5 points for successfully and automatically identifying each of four Ground Marker GPS co-ordinates, within an error of 10 metres from the measured position. Maximum 18 points.
Ground Marker colour	Score 3 points for correctly reporting the colour of each Ground Marker inner square. Maximum score 12 points.
Ground Marker alphanumeric	Score 5 points for correctly and automatically reporting the alphanumeric character of each Ground Marker. Maximum score 20 points.
Automatic Reporting	Score zero for each ground marker where the data has to be manually interpreted from the on-board video or still picture.
Area Search	50
Score	Maximum score 50 points for locating the hidden Ground Marker, and automatically and correctly reporting the GPS location (35 points) and the colour of the inner square (15 points).
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 for GPS location.
Alphanumeric	Give your team a massive high five if you also correctly identify the alphanumeric. No extra points though.
Automatic Reporting	Score zero where the GPS co-ordinates have to be manually interpreted from the on-board video or still picture.
Automatic Operation	-
Penalty for non-automatic operation	Reduce score for the whole optional mission by 50% if any parts of the flight operation are performed manually, including take-off, landing and navigation.
Precision landing	-
Precision landing	Deduct 5 points if UA completes a landing but fails to touch down and come to a complete halt within the 30 m x 30 m box. Deduct 10 points if the UA lands more than 50 m away from the nearest edge of the box.

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.

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.

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

A.6 Ground Marker Description

The ground marker shown below in Figure A2 is a coloured 1 m x 1 m central square, incorporating an alphanumeric code in white, approximately 0.75 m high, within the square. To help identification of the ground marker, a 2 m x 2 m white square will surround the central area.

The alphanumeric will be restricted to a set of 35 characters including numbers 1 – 9 and Upper Case (capital) letters.

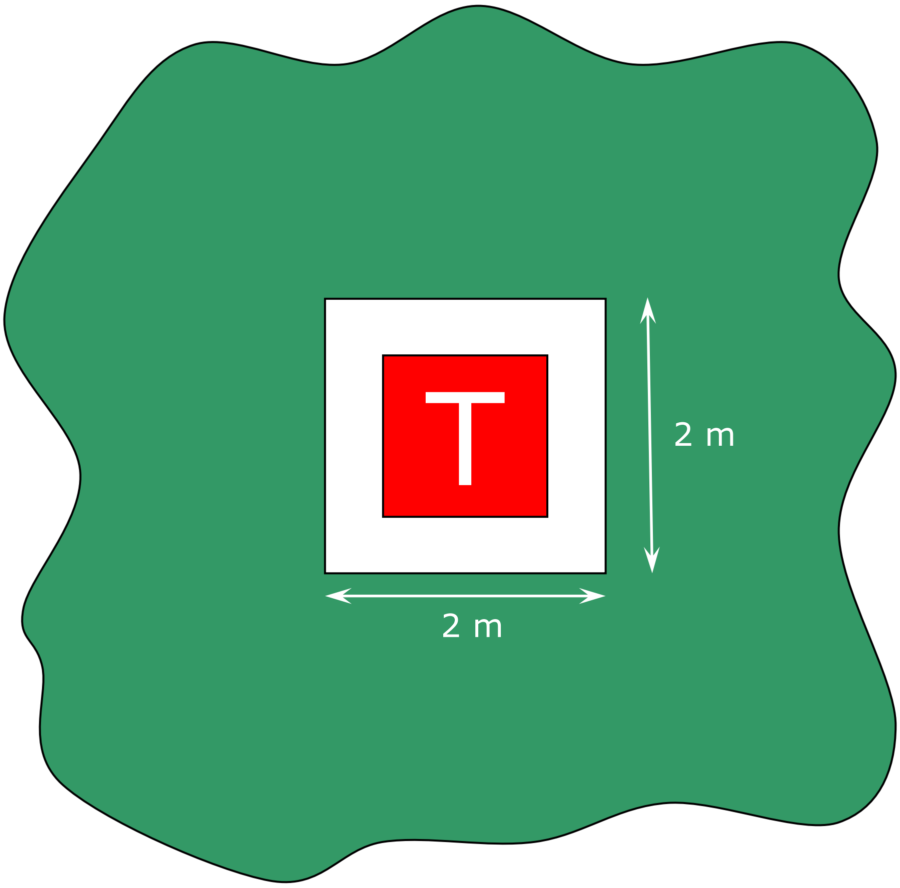


Figure A2: Ground Marker Dimensions

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.

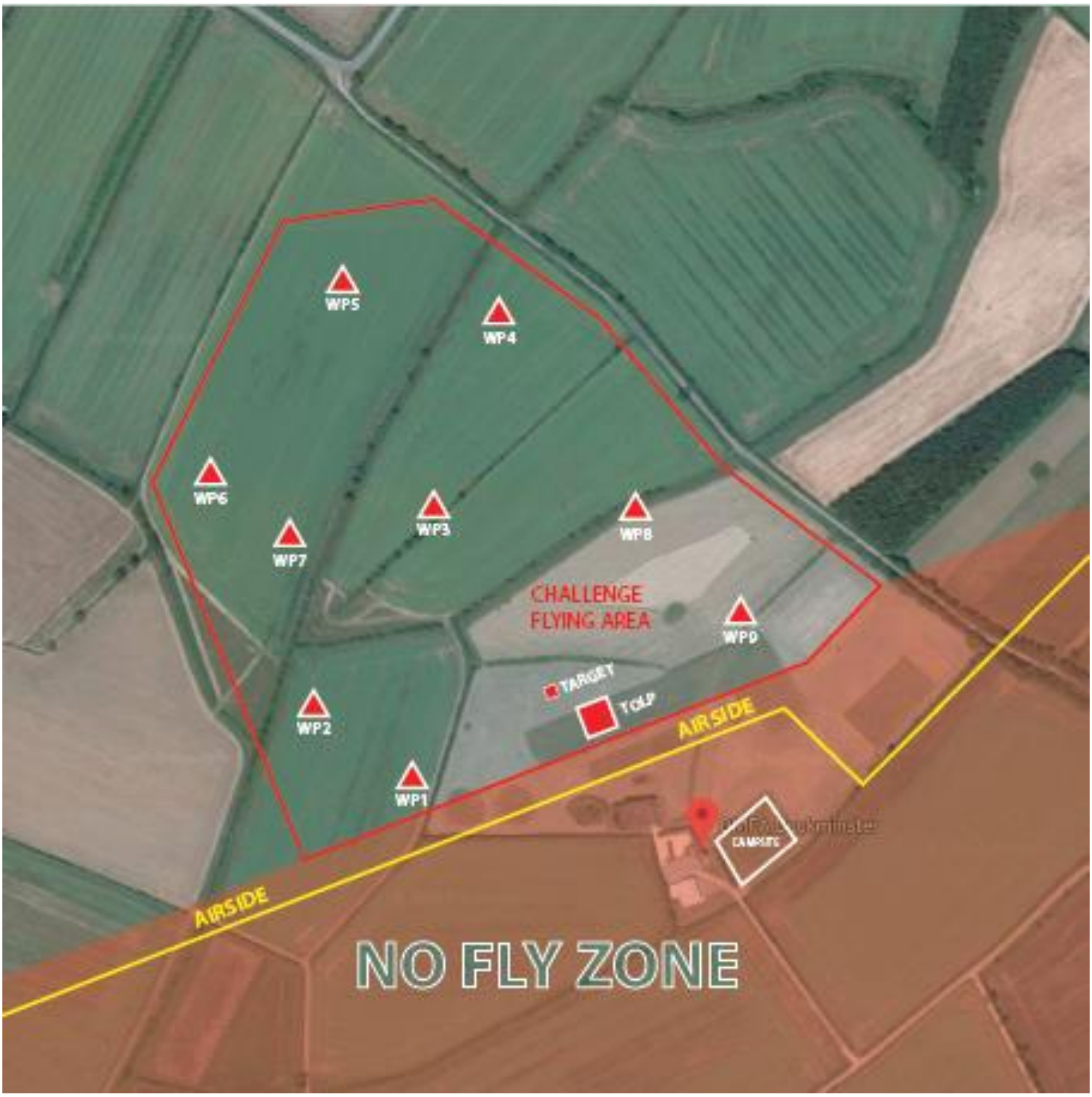


Figure A3: BMFA Airfield showing example Waypoints and Drop Zone

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	Electrical load is compatible with Power Logger. 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 alphanumeric and 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	Design includes storage and handling box.
3.1.14 GPS Tracker and Power Logger	The design of the UA shall ensure that the Tracker and Power Logger 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 30 m x 30 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 not be permitted to re-load fresh batteries between core and optional tasks. 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.

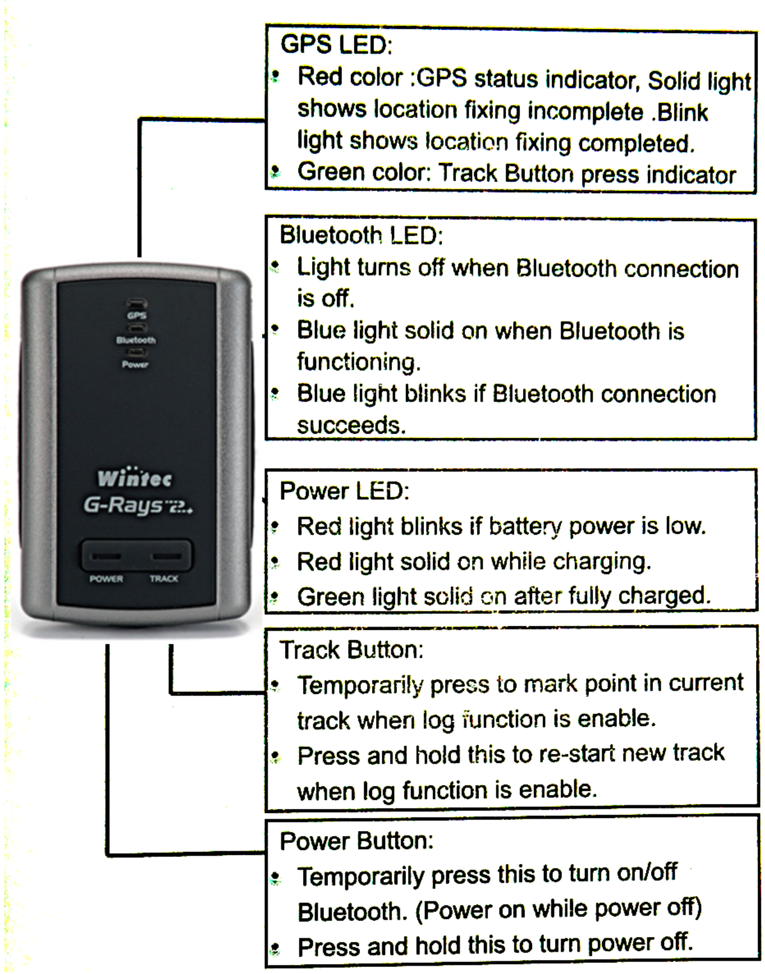
The tracker runs on a continuous data loop lasting in the region of 6 hours. The plan for the Challenge is that the RIN staff will hand over a live tracker leaving the competitors to position it on the vehicle and double-check the status LEDs. Teams should not attempt to operate the trackers unless instructed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

Key Characteristics

Length:
59 mm

Width:
38 mm

Depth:



Annex D Power Logger Specification

The Eagle Tree Systems eLogger V4 shall be used for monitoring power usage of your aircraft, computed from the voltage and current sampled at regular intervals.

Teams are advised to buy their own eLogger for development testing purposes, although the IMechE will have some eLoggers available for use by Teams during the demonstration event.

To score points in the measure of flight performance efficiency, the following specification must be met:

- The power consumption of every thrust-generating device shall be logged or estimated as described below. It is not necessary to measure the power consumption of the avionic systems, although this may be measured in which case it will be included in the total.
- Normally, there should be a single eLogger connected directly in series with the battery, before the supply is distributed to the motors.
- Where the total system draw exceeds the power logger limits given below, multiple power loggers may be used: one in series with every battery, or one in series with every motor or thrust-generating device.
- For complex electrical architectures where the system can be divided into multiple identical parts it is acceptable to monitor one of these parts in order to estimate the energy usage of the complete system. For example, a log of the power drawn by one electric motor could be recorded, which would be multiplied up by the number of motors.
- At each logger location, the power source circuit shall be fitted with a Female Deans XT60 connector, and the circuit which it supplies shall be fitted with a Male XT60 connector.
- The connectors shall be arranged such that they can connect side by side to an Eagle Tree Systems eLogger V4 as shown in the figure below.
- The aircraft shall have a means of securely attaching the eLoggers such that they remain attached throughout the flight, and are protected from impact in normal operation (e.g. in common landing scenarios).
- Installation/removal of the eLoggers shall be possible before/after each flight, within up to 5 minutes but typically less than 1 minute.
- Each monitored circuit shall have an operating voltage of 80 V or less.
- Each monitored circuit shall have a peak current of 100 A or less in operation.
- Each monitored circuit shall have a continuous current draw of 60 A or less in operation.

D.1 eLogger Specifications

Voltage Measurement:	approx 5V to 80V
Current Measurement:	up to 100 Amps peak
Current Draw:	approx 30 mA
Weight:	approx 0.8oz (22 grams)
Measurements:	approx 2.25" x 1" x 0.5" (57mm x 28mm x 13mm)

More detail (as of 31st July 2019) can be found at:
https://www.eagletreesystems.com/index.php?route=product/product&product_id=54

D.2 eLogger Operation

The eLogger will begin a log automatically as soon as the power is connected and will stop once the power is disconnected. Multiple logs of this type are stored: one for each connection of the power. Only the log corresponding to the mission flight will be used in the performance calculation. From the moment the battery is connected before the mission until the moment the battery is disconnected afterwards, all energy usage will be included in the performance calculation.

Annex E 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.

E.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.

E.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.

E.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.

E.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.

E.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.

E.6 Aid Package Specification and Deployment

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

E.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.

E.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.

E.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.

E.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 F Document Requirements

F.1 Deliverable Documents

The documents comprise a Concept Paper, delivered at the same time as your entry application to the UAS Challenge, a Design Report, two progress review statements, and a Flight Readiness Review. In the event of having to move to a Virtual Event, an additional document covering manufacturing, support and testing will be required together with a 3D printed scale model of the aircraft.

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, which indicates what the Judges are looking for throughout the competition. It is important that each deliverable is submitted on time and **10 points** will be deducted for each day late.

Teams will be given preliminary scores following each submission but this will not be formalised until judges have inspected the UAS at the Demonstration Event to confirm that the UAS is as described in the submissions.

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

- Team name
- University
- 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)

F.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, any image identification 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 when you intend to undertake formal design reviews. Your Review forms must be submitted on the dates specified in your project plan. The first delivery must be before 31st January 2021 and the second one before 14th April 2021. You should ensure that you have left plenty of time for testing and any design iterations that may be required.

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 deliverable plan/schedule
- Overall Quality of Concept Paper submission.

F.3 Design Report (140 points)

This is a detailed description of your design of no more than 20 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 should 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 main mission and tasks to be undertaken in optional mission

Project Management (2 A4 pages maximum) (10 points)

- A review of progress against your project plan with any necessary amendments and with further detail for the remaining steps in the programme. It 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 (8 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.

Safety (1 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 assessment panel 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 in the Outline Design;
- 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.

F.4 Review Reports **(30 points)**

Two intermediate Design Reviews should be undertaken during the project. These reviews need to take a critical assessment of your progress in the project and should be chaired by an independent person, ideally your academic supervisor or a Chartered Engineer. The timing of the reviews are at your discretion with the first to review your initial design against the requirements and the second to confirm that your design is sufficiently mature to commit to manufacture of the final product. Both of these reviews must be submitted when completed to the IMechE using the proforma to be provided. The proforma will have the following content:

Team #, name	
Chairman + position	
Team members present	
Review date	
Review purpose	
Review Items	Requirements & Compliance Project Approach Manufacturing Approach / Progress Testing Approach / Progress Schedule Safety Risks
Changes since Design Report or previous review	
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.

F.5 Flight Readiness Review Submission (Demo Event Only) **(30 points)**

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 a fully autonomous take-off, controlled flight, including any transition, and landing;
- A full statement and justification of any changes introduced since the Design Report 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 Report 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 Section 0;
    - 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 June, 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.

F.6 Manufacturing, Support and Test Report (Virtual Event only) (90 points)

In the event of a Virtual competition, each team will be required to deliver a report describing how you would have, or have, manufactured your vehicle, the storage container and any special support equipment that they would have, or have, made and the test programme that they would have, or have, undertaken. In addition you are asked to submit a one eighth scale 3D printed model of your vehicle.
This report shall follow the structure described below as the individual sections will be allocated to expert judges for review. Each section should be started on a new page.

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 your UAS.
- List and reason for all significant changes since the Design Report
- List any contributions from sponsors
- Weight of cargo to be carried in main mission and tasks to be undertaken in optional mission

Manufacturing description (4 A4 pages maximum) (30 points)

- Explain your material choices and any trade-offs undertaken.
- Describe the proposed manufacturing process and construction techniques to be used, including any safety and environmental issues and how they will be addressed. Describe the equipment used. If any manufacturing is to be outsourced, explain the reason for this choice. Support your description with diagrams and photographs.
- Highlight any innovative aspects.

Support description (3 A4 page maximum) (30 points)

- Explain your support philosophy to minimise the cost and skills necessary to undertake your humanitarian aid mission.
- Describe the support equipment, handling and storage fixtures necessary to undertake the development flight trials and prototype customer demonstration at BMFA. Support your description with diagrams and photographs.

Qualification Test Plan (3 A4 pages maximum) (30 points)

- Explain your approach to testing to ensure that your UAS meets all the mandatory requirements of the competition, will be safe to operate and will achieve your mission objectives.
- 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.

This should cover both sub-system and full system testing.

F.7 3D printed scale model (40 points)

- A 1/8th (one eighth) scale model of your aircraft including the cargo container.