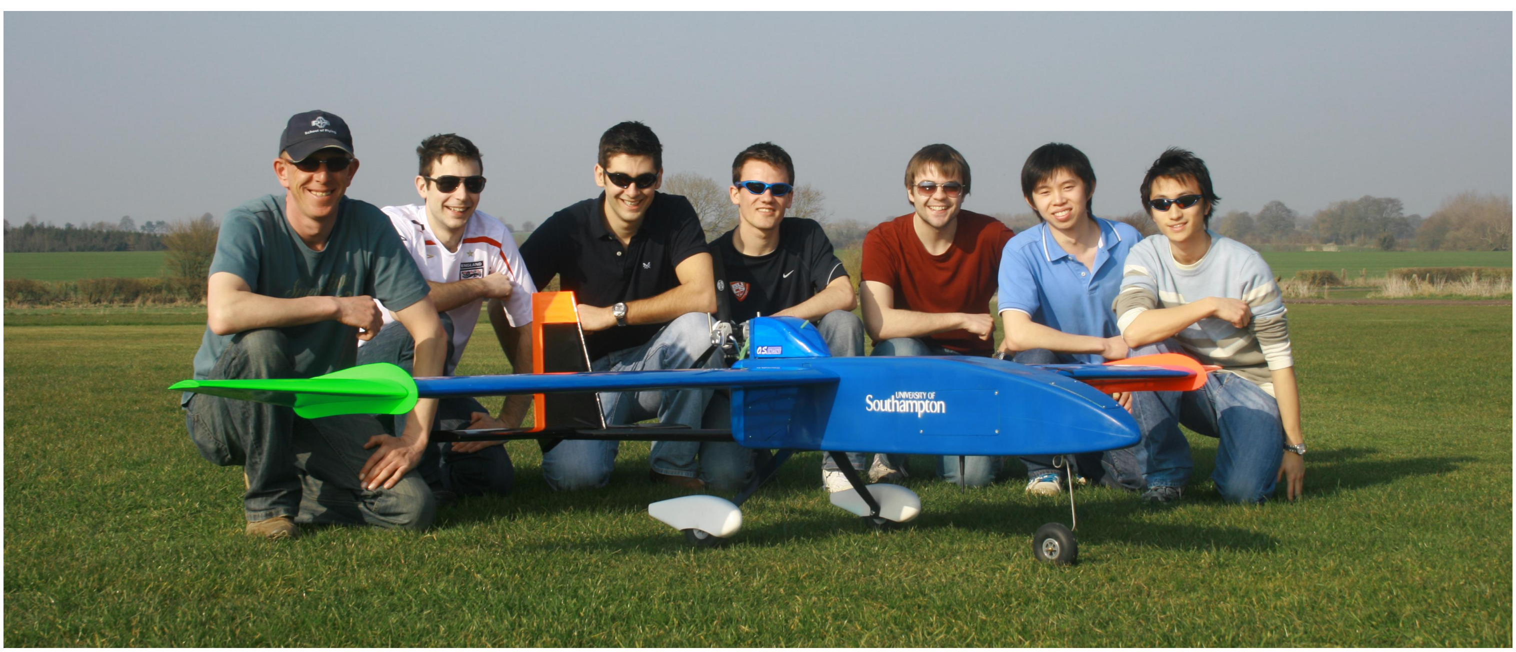
Institution of MECHANICAL ENGINEERS

University UAS Challenge 2015

Competition Rules



Improving the world through engineering

University UAS Challenge 2015

Mission and Competition Rules

Issue 2, July 2014

Contents

Glossary and Abbreviations

AGL	Above Ground Level
BMFA	British Model Flying Association
BRS	Ballistic Recovery Systems
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CDR	Critical Design Review
FMC	Flight Management Computer
FSO	Flight Safety Officer
FTS	Flight Termination System
GCS	Ground Control Station
KIAS	Knots: Indicated Air Speed
MTOM	Maximum Take-Off Mass
PDR	Preliminary Design Review
QFE	Q-Code Field Elevation - Altimeter zeroed at runway height
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
VFR	Visual Flight Rules
VLOS	Visual Line of Sight

1 Introduction

1.1 Competition Overview

The competition will engage University Undergraduate teams in the design, construction, development and demonstration of an Autonomous Unmanned Aircraft System (UAS). With a Maximum Take-off Mass (MTOM) limit of 7kg, 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 a payload and returning to base via a defined route.

The competition will be held annually over the duration of an academic year, with the first competition commencing September 2014, and the flight demonstration being held in June 2015. This period will be structured into design, development and demonstration phases, with a Design Review presentation contributing to the scoring, as well as the flying demonstration.

Teams will be put forward by each University, and will constitute members drawn from undergraduate cohorts in any year of study. A pair of Universities may form an alliance to enter a joint team. Some specialist industry support is to be allowed where specific skills and knowledge are required outside the scope of the undergraduate students.

1.2 Objectives of the Event

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

i. Provide a challenge to students in systems engineering of a complex system, requiring design, development and demonstration against a demanding mission requirement;

ii. Provide an opportunity for students to develop and demonstrate team working, leadership and commercial skills as well as technical competence;

iii. Stimulate interest in the civil UAS field, and enhance employment opportunities in the sector;

iv. Foster inter-university collaboration in the UAS technology area, and to provide a forum for interdisciplinary research;

1.3 Scenario

The real life scenario is set in the near future. A natural disaster has occurred, with a large stretch of remote coastal area devastated by an earthquake and tsunami. It is known that 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 autonomously, transiting rapidly via pre-planned waypoints to the devastated area, with image recognition used to identify and locate the supply drop zone, and delivering the aid safely and accurately to the local people. It returns to base via a different route to ensure de-confliction with other Rescue UAS operating in the area, to refuel and reload another aid payload. 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.

2 Eligibility and Team Structure

The Competition is open to any UK University. Whilst expected to be predominantly a UK event, entrants from overseas universities will also be considered.

Teams will be put forward by each University, and will constitute members drawn from undergraduate cohorts in any year of study.

A pair of Universities may form an alliance to enter a joint team. Some specialist industry support is to be allowed where specific skills and knowledge are required outside the scope of the undergraduate students.

The numbers of students in each 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 competition, whilst having a set of defined performance objectives to achieve, is as much about the development and demonstration of team working skills.

Please note that attendance at the Demonstration Event is likely to be limited to no more than 8 members per team.

Universities are at liberty to approach potential industry sponsors at any time prior to or during the competition. Note that where technical advice is received from industry, the judges will need to be sure that by far the majority of the development work has been undertaken by the students themselves.

3 Schedule

The competition will be launched at the start of the academic year in September each year, with the first competition starting in September 2014. Key activities and dates are as follows:

Date	Activity	Deliverable
April 2014	Competition published, entries invited	-
June 2014	Competition Launch publicity event with demonstration flying	-
14th Sept 2014	Mission details & assessment criteria provided to entrants	-
1st Oct 2014	Deadline for entries to be received	-
Dec 2014	Preliminary Design Review	Written PDR report
April 2015	Critical Design Review report	Written CDR report
May 2015	Flight Readiness Review submission (2 weeks before FRR)	Written FRR report
June 2015	Design Presentation	
June 2015	Flight Readiness Review	FRR inspection
June 2015	Certification Test Flight	Flight Test
June 2015	Demonstration Event - Mission	Flight Demonstrations

4 Costs and Funding

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.

Universities must fund the costs of their UAS design and development, and their attendance at the Design Review and Demonstration events.

Universities are free to seek industry support, both technical and financial. Such sponsorship must be fully acknowledged in the Design Review submissions. A list of potential industry sponsors may be available from the organisers.

5 UAS Specification

The UAS shall be designed to meet the following constraints and have the following features:

5.1 Safety and Airworthiness

The UAS shall comply with the Requirements given at Annex B;

5.2 Autonomy

The UAS shall operate in a fully automatic manner as far as practicable, including automatic take-off and landing. UAS which are manually operated will not be excluded, although manual operation will score considerably fewer points.

5.3 Payload Carriage and Delivery

The UA shall be designed to carry and release up to two payloads as specified in Section 5.15 below.

The payload(s) shall be individually deployable from the UA by either manual or automatic command. Only one payload shall be jettisoned at any one instant, i.e. payloads may not be ganged together and dropped simultaneously.

The UA design may incorporate features to provide protection and cushioning of the payload to keep it intact during the deployment and ground impact, but the payload shall not itself be modified, for example by permanent reinforcement.

It shall be possible to remove and replace the payload from any protection system with the minimum of effort, for example unlatching a cover or releasing a retaining strap.

To score maximum points, the payload shall remain intact through the deployment and after impact with the ground.

5.4 Airframe Configuration

Fixed wing or rotary wing solutions are both permissible.

5.5 Propulsion

Electric motors or internal combustion engines are permitted for propulsion.

5.6 Design Mission Range and Endurance

For the purpose of sizing the fuel / battery load, the design team should plan on a typical target Mission flight path distance of around 2km, from take-off to landing. For a UAS delivering both its payloads in a single sortie, this might equate to a Flight Time of around 2 minutes from take-off to touchdown. Note that this time does not account for any time spent in pre-flight checkout, nor for any contingency associated with search time to locate targets, or other delays in completing the mission.

The Mission may require the UAS to operate further than 500 m from the pilot, which may be acceptable where the UAS can be safely flown and tracked within the segregated airspace.

5.7 Operating Box

The UAS shall be designed to operate from within a 10m x 30m box, orientated within 30° of the wind direction. Landing includes touchdown and roll-out, with the UA required to stop within the box.

5.8 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 shall be typically be capable of take-off and landing in crosswind components to the runway of 5 kts with gusts of 8 kts;

5.9 Limits on use of COTS Items

The UAS airframe and control systems should 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.

Permitted Commercial Off The Shelf (COTS) stock component parts include motors, batteries, servos, sensors, and control boards such as the Pixhawk or Ardupilot platforms.

A guideline maximum value of COTS components used is £1,000. A Bill of Materials and costs will be required as part of the design submission. Cost efficient solutions will score more points.

Teams must also demonstrate that manufacture of the airframe and integration of the UAS involves a significant proportion of effort from the students themselves, rather than being substantially outsourced to a contractor.

5.10 Radio Equipment

All radio equipment and datalinks must comply with EEC directives, and must be licensed for use in the UK.

5.11 Camera / Imaging System

The UA may carry a camera system and target recognition capability to autonomously refine the location of the target, and to identify the alphanumeric code within the target area.

5.12 Flight Termination System

A flight termination system, suitably approved through the safety case and inspection process, shall be fitted to the UAS;

5.13 Tracking System

A GPS Data Logger shall be fitted permitting both real time and post-flight evaluation of the 3D trajectory.

5.14 Environmental Impact

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.

5.15 Payload Specification

The payload shall be a standard commercially available 1 kg bag of flour, provided to the teams by the organisers at the demonstration event.

6 Statement of Work

6.1 Mission Tasks

The challenge is to design, build and demonstrate a small autonomous UAS to fly a mission which is modelled on the real life humanitarian aid scenario described in Section 1.3. The exact mission will be published to competitors on the start of the competition, and a sample mission is presented at Annex A. The competition will typically seek to test a number of characteristics, such as:

- Accuracy of payload delivery to pre-determined points on the ground;
- Maximum mass of cargo that can be safely transported in an allocated time;
- Quickest time to compete the payload delivery mission;
- Navigation accuracy via waypoint co-ordinates provided on the day;
- Search object recognition, detecting, recognising and geo-locating objects;
- Extent of automatic operations from take-off to landing;
- Safety, demonstrating safe design and flight operations throughout;
- Minimum environmental impact, notably noise levels;
- Maximum payload / empty weight ratio.

6.2 Competition Phases

The competition is structured to follow the design, development, manufacture, certification and demonstration phases of a typical aerospace project.

As scheduled in Section 3, the key events in the competition are:

- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Submission of FRR pack
- Demonstration Event, comprising the
    - Design Presentation
    - Flight Readiness Review, leading to a Permit to Test;
    - Certification Test flight, leading to a Permit to Fly;
    - Flying Demonstration - Mission.

The deliverables required for each design step are detailed below.

At the conclusion of each design review a Chartered IMechE member or recognised aerospace expert is required to sign off that the UAS design is fit for purpose and meets the safety requirements of the competition. If a UAS passes through each of these process steps successfully then the entrant will be deemed to be approved and a signed Permit to Fly will be issued by the competition organisers.

The Demonstration Event will be held over two days in June, with a third day in reserve in case of bad weather. It will comprise the Flight Readiness Review and the Certification Test Flight which are both scheduled on Day 1, and the Flying Demonstration event itself on Day 2.

6.3 Preliminary Design Review (PDR)

This is a written report including a Technical Section with an outline of the proposed technical solution and the rationale for the approach adopted; a Project Management section describing the team organisation and roles and a project plan; a Commercial section summarising the estimated costs; and a Safety section giving an initial view of the approach to 'Certification and Qualification', the safety risks and their mitigation. The key features should include:

- UAS Requirements;
- UAS Overall Layout & Description;
- System Requirements, and Functional Description & Schematic for each of the systems, including Airframe, Propulsion, Flight Controls, Navigation & Mission Control, Sensors, Payload Delivery, Flight Termination;
- Preliminary Weights Report;
- Preliminary Safety Case;

As a guide the body of the report should be no longer than 15 pages.

6.4 Critical Design Review (CDR)

The CDR comprises a written submission. The report should follow the structure of the PDR report, giving full technical details of the UAS and its subsystems, including a rationale for their selection / design specification. It should include engineering drawings, analysis of the projected flight performance, a structural analysis of the airframe; assessment of the search and navigation performance, and analysis of the payload delivery dynamics.

A Project Management section should note any update to the information presented in the Project Outline. A Commercial section should include an update of the materials (and external labour) cost estimates.

The Safety Case section should present the approach to demonstrating the airworthiness of the UAS. It should summarise the key safety risks and their mitigation, with arguments supported by evidence from design, analysis or test.

The key features should include:

- UA Structural Loads Analysis;
- UA Performance Analysis;
- Weights Report;
- Requirements Verification & Validation Matrix for each of the systems: Propulsion, Flight Controls, Navigation & Mission Control and Payload Delivery;
- Design Dossier and Bill of Materials with costs for COTS components;
- Design Dossier and Bill of Materials with costs for Manufactured components;
- Qualification Test Plan;
- Updated Safety Case;
- Preliminary Environmental Impact Statement;
- Business case: discussion on how the design would scale into a useful operational system, including sales projections, manufacturing methods and production costs.

As a guide the body of the report should be no longer than 40 pages, supported by appendices where appropriate plus the design dossier.

6.5 Flight Readiness Review and Design Presentation

On Day 1 of the June Demonstration Event, the Flight Readiness Review (FRR) will be conducted for each entrant reaching this stage, consisting of a 15 presentation by each team of their Design to the Assessment Panel, followed by 15 minutes of Questions and Answers, a review of the Safety Case deliverables, and a physical inspection of the UAS.

The panel will have read the PDR and CDR reports, so this presentation is a chance for the team to demonstrate their communication skills and knowledge of the design process, to provide any updates to the information presented in the CDR report, and to offer the panel the chance to probe further into any aspects of the design.

FRR deliverables required a minimum of two weeks prior to the FRR include:

- Copies of the reports and signed declarations from all preceding reviews;
- Update to UAS Performance Analysis;
- Qualification Test Report;
- Final Safety Case;
- A signed declaration by IMechE member or recognised aerospace expert;

During the FRR, the assessment panel will be looking for evidence that:

- The UAS is compliant with the requirements noted in Section 5;
- 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;

On satisfactory completion of the Flight Readiness Review, a 'Permit to Test' will be issued by the Flight Safety Officer, and an amber sticker, signed by the FSO shall be applied to the UA denoting that it has been granted a Permit to Test.

6.6 Certification Flight Test

Following satisfactory completion of the FRR, a Flight Test will be conducted to assess the Basic Operation, to include:

- Take-off from the designated Take-off and Landing area. After take-off the UAS shall maintain steady controlled flight at altitudes above 100 ft and less than 400 ft AGL. Take-off under manual control with transition to automatic control is permitted.
- Demonstrate manoeuvrability by flying a figure of eight, in the same flight;
- Loiter in a 'race-track' pattern over the airfield at a defined point for a period of 2 minutes at a height of 100 ft;
- Land, back at the take-off point;

- An element of ground-based assistance for take-off and landing would be acceptable, but the craft should operate automatically during other phases of flight;
- Demonstrate switch between manual and auto flight.

The assessors will be looking to confirm that the team operating the UAS is competent as well as confirming the airworthiness of the UAS itself.

On satisfactory completion of the Certification Flight Test, a 'Permit to Fly' will be issued by the Flight Safety Officer, and a green sticker, again signed by the safety officer, shall be applied to the UA denoting that it has been granted a Permit to Fly. This is a simple visual way of confirming that a UAS has clearance to participate in the flying event.

Issue of a 'Permit to Fly' will be a pre-requisite for teams progressing to the Flying Demonstration event.

> Note that the assessment panel and safety officer have the discretion to refuse a team permission to proceed through the Demonstration stage, if they consider that the entrant is not of sufficient standard, that flight safety may be compromised, or that the design requirements may not have been satisfied.

6.7 Flying Demonstration - Mission

Upon successful issue of a Permit to Fly, the Mission will be flown, as scoped by the competition requirements. This will be flown on Day 2 of the competition.

A detailed briefing will be given prior to the Demonstration event covering the logistics and timings for the event, rules and good conduct for safe operations, pre-flight briefings etc.

7 Adjudication and Scoring Criteria

The competition will be assessed across five elements, comprising:

- Design (150 points);
- Manufacturing (25 points);
- Environmental Impact (25 points);
- Business case and cost analysis (50 points);
- Flying Demonstration (250 points).

A maximum of 500 points is therefore available.

7.1 Design

The design element is worth 150 points, and is assessed across three elements:

Preliminary Design Review report (25 points). 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, payload handling etc;
- Extent of Innovation in the Outline Design;
- Adherence to the rules;
- Depth and extent of underpinning engineering analysis;
- Consideration of safety and airworthiness requirements;
- Evidence of sound project management, planning, budgeting;
- Demonstrating a well-considered business case;
- Demonstrating good teamwork and organisation;
- Overall Quality of PDR submission.

Critical Design Review report (75 points). The assessment panel will be looking for:

- Factors as for PDR plus:
- Technical assessment of UAS Detail Design;
- Integrity and depth of Design Data Pack and supporting analyses;
- Design of safety features such as FTS;
- Extent of scratch design vs. COTS procurement;
- Overall Quality of CDR submission;

Design Presentation (50 points). The assessment panel will be looking to test each team's communication skills as well as technical knowledge:

- Demonstrating a clear and concise presentation of key features of the design and development programme;
- Good responses to questions.

7.2 Manufacturing

The manufacturing element is worth a maximum of 25 points, and the assessors will be looking at issues including:

- Build quality;
- Attention to detail;
- Aesthetics.

7.3 Environmental Impact

The Environmental Impact is worth a maximum of 25 points, and the assessors will be looking for evidence that the team has demonstrated efforts to minimise the environmental impact of the design, with issues including:

- Non-hazardous materials;
- Low energy consumption;
- Low or zero pollution;
- Low Noise;
- Consideration given to disposal / recycling.

7.4 Business case and cost analysis

The Business Case and cost analysis is worth 50 points. The business case might be for a scaled or otherwise altered version of the UAS prototype if this is justified by the requirements of the chosen market.

A full cost breakdown of the UAS is required, and points awarded for low cost solutions. In addition, a business case is required for series production of the UAS, to include:

- Potential markets, target market size and sales forecast;
- Key features of the envisaged production UAS design, and how this differs from the competition design;
- Financial projections, including manufacturing costs for production at the projected quantities;
- Profitability;
- Marketing strategy;
- Company organisation and operations.

7.5 Flying Demonstration Event

The Flying Demonstration is worth a maximum of 250 points, if:

- two payloads are delivered intact and precisely onto the ground marker;
- mission completed within the target time;
- accurate navigation demonstrated via the waypoints;

- target code(s) correctly identified;
- mission completed fully automatically.

Note that the FRR and Certification Flight Test are not scored in the overall assessment; these are pass/fail qualifying events necessary to gain a ‘Permit to Fly’ for the main Flying Demonstration.

The Demonstration will be judged according to the criteria set out in the mission description, published in September at the start of the Competition. A typical mission is set out at Annex A.

8 Prizes and Awards

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

8.1 Design

For the entrant showing greatest overall merit with regard to the systems engineering approach to the design process, the technical element of the design and underpinning analysis, the degree of innovation, conformance to the competition rules, and organisation of the design team.

8.2 Most viable Business Proposition

For the entrant with the most promising business case, reflecting a well-articulated understanding of the market and good alignment of the UAS capabilities and cost projections with the target market.

8.3 Safety and Airworthiness

For the entrant developing the best combination of a well-articulated safety case, with evidence that safety and airworthiness have been considered throughout the design and development phases, the UAS exhibiting practical safety features, and demonstrating safe operation.

8.4 Autonomous / Automatic Operations

For the entrant demonstrating the greatest degree of autonomy in operations, from take-off to touchdown.

8.5 Manufacturing

For the entrant with the best manufactured UAS, in terms of innovative use of materials, construction techniques, manufacturing quality, attention to detail, finish and aesthetics.

8.6 Flying Operations

For the entrant which completes the mission demonstrating the best overall score for accurate navigation, supply drop accuracy, minimum mission time, and target recognition accuracy.

8.7 Most Promise

For the entrant which couldn't quite make it all work on the day, but where the team showed most ingenuity, teamwork, dedication, and a promising design for next year's competition.

8.8 Overall Grand Champion

For the entrant who most impressed the judges with overall excellence in design, business case safety, manufacturing and demonstration.

9 Guidance to Teams

9.1 UAS configuration

The UA may be designed to carry a single payload, in which case return to the landing site for replenishment will be required to drop a second payload, possibly incurring time penalties; alternatively it may be designed to carry two payloads, allowing delivery of payloads to be accomplished in a single mission.

Rotary Wing, UAS(R) and Fixed Wing UAS(A) each have their advantages and drawbacks. The UAS(R) may descend to place the payload on the ground accurately and without damage, but may be slower in transit to the target area, and may have reduced payload capacity compared to the UAS(A); The UAS(A) pose a greater challenge in achieving a direct hit on the target than for the UAS(R).

The UAS(A) may require a more sophisticated payload protection or retardation system to minimise impact damage compared to the UAS(R). Alternatively it may be decided from looking at the scoring, that some damage to the payload will be tolerated and traded against the additional complexity and weight of a protection system.

Either electric or internal combustion engines are permitted. Note there are marks for quiet and environmentally friendly operations.

The assessment panel will be looking for teams to explain their rationale in making their system design decisions and trade-offs.

9.2 The Route to a Permit to Fly

For background reading on the wider regulations applicable to 'aerial work' 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.

Annex A Sample Mission

A1 Objective

The overall objective is to drop or place two Payloads, representing humanitarian aid, as accurately and quickly as possible onto a ground marker, navigating via pre-planned waypoints, and return to base safely.

The UAS will also need to autonomously identify an alphanumeric code located within the target area to score maximum points.

The Payloads should remain intact after dropping to score maximum points.

The UA should take-off and land / stop within the designated 10m x 30m box.

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

Figure A2 below shows a typical Mission scenario. Maps together with waypoint and target co-ordinates will be provided to teams at the start of the demonstration event.

A2 Mission Tasks

Take-off: Take-off shall be conducted within the designated take-off and landing box, into wind. After take-off the system shall maintain steady controlled flight at a height of 100 ft AGL. Take-off under manual control with transition to automatic flight is permitted, though a higher score will be given to automatic take-off.

Waypoint Navigation: The UAS shall automatically fly around selected waypoints WP1, WP2, WP3, whilst remaining inside the designated flying zone, and avoiding no-fly zones. The accuracy of the navigation will be evaluated by analysis of the GPS data logger after the flight, and by flight marshals at the Waypoints.

Payload Delivery: Having identified the target, the UAS shall automatically position itself to deliver one payload onto the target. It may then go around and reposition to deliver a second. Alternatively it may return directly to the landing area to resupply and fly the next sortie.

Landing: The UAS shall return and land at the designated take-off and landing zone. Transition to manual control is permitted for landing, though a fully automatic landing will score more points. The mission is complete after the final payload delivery sortie when the UAS comes to a halt and the engine is stopped.

A3 Rules

Mission Time: Each team will have a slot time for their Mission, and UAS must be prepared and ready to launch by the allocated slot time. Penalties will be incurred if the UAS is not ready to launch within 5 minutes of the allocated slot time. The Mission time will be measured from the launch signal, until the UAS touches down for the final time at the end of the mission. If the UA requires more than one sortie to complete the Mission, the timer keeps running until the final touchdown of the Mission.

The target Mission time is **120 seconds**.

Multiple Sorties: The UAS may carry two payloads in one flight, locating and dropping the Payloads sequentially, to minimise the Mission time. Alternatively it may be designed to carry a single Payload, returning after the first sortie to reload the second payload and conduct the second sortie etc. If the UAS reloads a payload, it is permissible to refuel / reload fresh batteries at the same time.

Target Identification: The team will be provided with the co-ordinates of the target, and the UAS may use a camera system with target recognition capability to autonomously refine the location accuracy.

A4 Scoring Criteria

The scoring for the Flying Demonstration will be awarded as follows:

125 points are awarded for each of up to two sorties, where each sortie attempts to deliver a single payload. Two payloads delivered in a single sortie will earn a maximum of 250 points.

For each sortie, this maximum score will be reduced by the penalties set out below.

Sortie penalties	
Delivery accuracy	-(D_m^2/20) pts, where D_m is the miss distance from the central area of target, up to a maximum of -50pts; Thus for example miss by 10m is -5pts, miss by 20m is -20pts, miss by 30m is -45pts. -50 pts for no payload delivery (per payload)
Payload integrity	-10 pts for major damage, -5 pts for partial spill;
Navigation accuracy	-10pts for each waypoint missed or incorrect order
Landing accuracy	-10 pts for final touchdown outside the landing box; - 5 pts for stopping outside the landing box;
Mission penalties	
Mission duration	-1 pt for every 5 s over the defined target time; -10 pts/min for starting late (> 5mins after slot time);
Correct ID of code	-20 pts for incorrect or no code;
Control penalties	
Autonomy	-100 pts for manual operation only; -10 pts for manual take-off; -10 pts for manual landing; -10 pts for manual (via datalink / video image) ident of target code; -10 pts for manual payload delivery -20 pts for manual navigation

A5 Ground Marker Description

The ground marker shown below in Figure A1 is a red 2m x 2m central square, incorporating an alphanumeric code in white letters within the square. To help identification of the ground marker, an 8m x 8m white border will surround the central area.

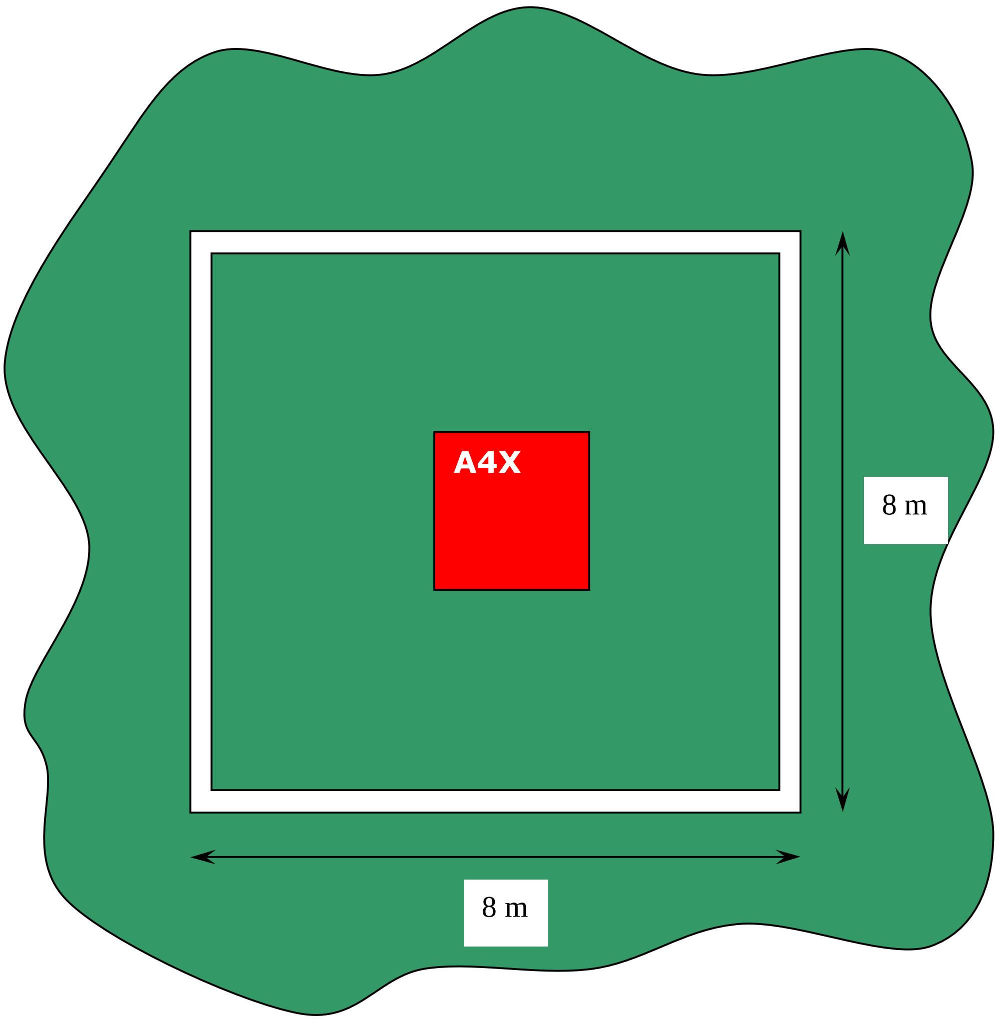
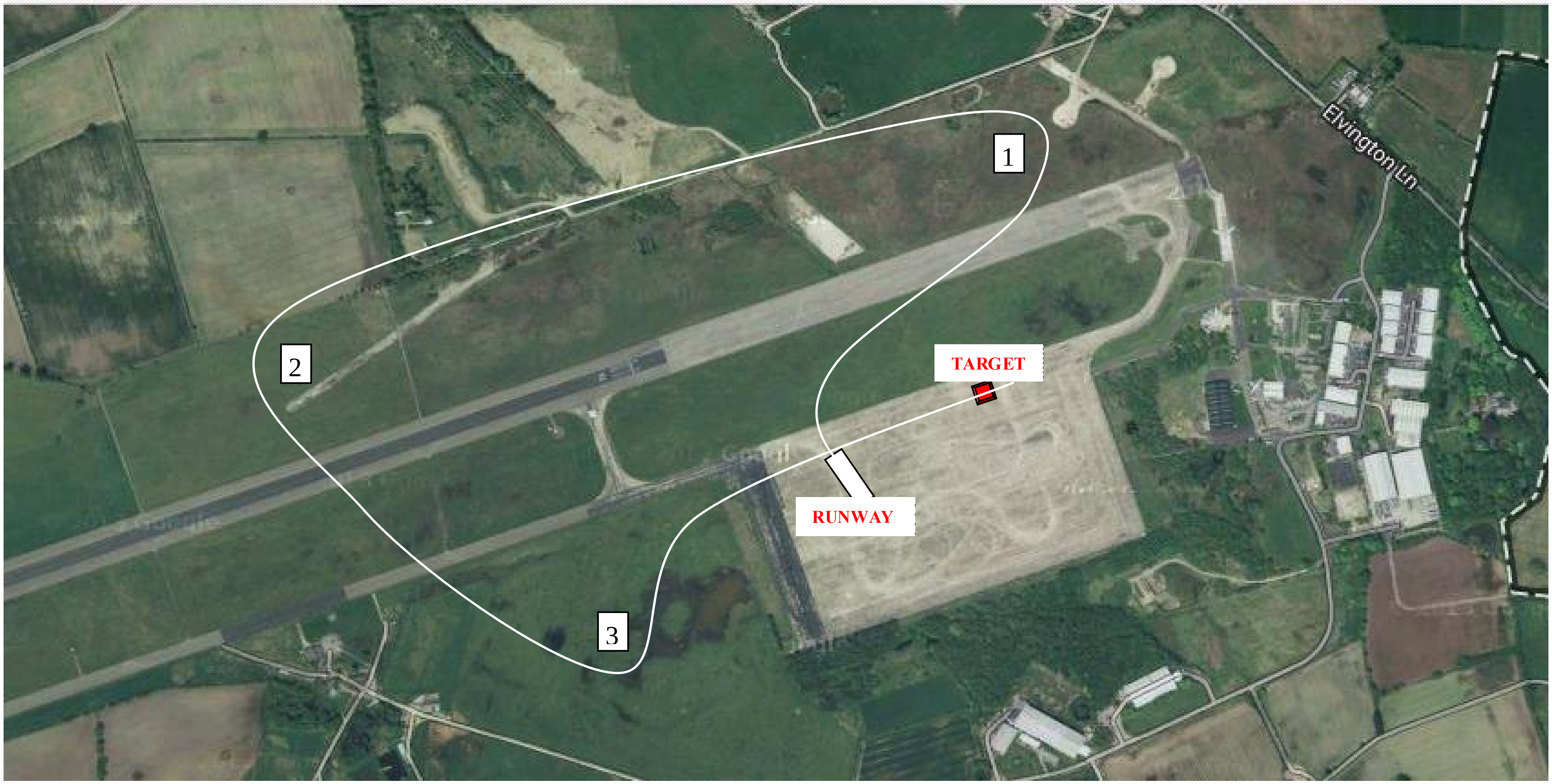


Figure A1: Ground Marker Dimensions.

Figure A2:TypicalMission Scenario.



Annex B UAS Safety Requirements

This section presents the safety related requirements and guidance with which the UAS must comply before being permitted to fly in the Demonstration Event.

B1 General Safety Requirements

- The UA shall have a maximum Take-Off Mass (MTOM) of 7kg or less;
- The maximum airspeed of the UA in level flight shall not exceed 60 KIAS;
- 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.

B2 Command and Control

- The UAS shall provide sufficient information to the judges to ensure it is operating within the defined airspace and avoiding any no-fly zones;
- The UA shall be capable of manual override by the safety pilot during any phase of flight.

B3 Flight Termination

- The UA shall automatically return to the take-off / landing zone or terminate flight after loss of data-link of more than 30 seconds;
- The UA shall automatically terminate flight after loss of signal of more than 3 minutes;
- The 'Return Home' signal, if installed, shall be capable of activation by the safety pilot;
- Flight Termination commands for fixed wing UA without an alternate recovery system (such as a parachute) shall ensure that the engine is cut and the UA descends at slow speed and preferably in a gentle turn. Alternatively a deep stall descent is permissible;
- For other than fixed wing UA, similar safety requirements will be assessed which result in a power off recovery in a minimum energy manner at a spot on the ground no more than 150 m radius on the ground from the point of the termination command;
- A Fail Safe check will demonstrate flight termination on the ground by switching off the data-link for 30 seconds and observing activation of the flight termination commands.

B4 Design Safety Features

- 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 shall be a bright colour to facilitate visibility in the air and in the event of a crash;
- Any fuel / battery combination deemed high risk in the opinion of the judges may be disqualified.

B5 Flight Readiness Review

The Flight Readiness Review (FRR) includes an evaluation of the safety and airworthiness evidence, a physical safety inspection, a fail-safe check and a flight termination check by a designated competition Flight Safety Officer to provide evidence that:

- The UAS is compliant with the requirements noted in Section 5;
- The design and build quality is satisfactory;
- Airworthiness aspects have been addressed satisfactorily;
- The system has been tested, both by modelling and demonstration to evaluate the performance and reliability;
- The UAS is acceptably safe, with appropriate fail safe mechanisms and a risk register completed;
- The team members preparing and operating the UAS are suitably competent to ensure safe operations.

The physical inspection will include:

- Visual assessment of the structural integrity;
- Verify that all components are adequately secured, fasteners are tight and are correctly locked;
- Verify propeller structural and attachment integrity;
- Visual inspection of all electronic wiring to assure adequate wire gauges have been used, wires and connectors are properly supported;
- Radio range check, motor off and motor on;
- Verify all controls operate in the correct sense;
- Check general integrity of the payload and deployment system;
- Verify correct operation of the fail safe and flight termination systems;

On satisfactory completion of the FRR, the inspector will issue a 'Permit to Test', allowing the team to undertake the Certification Flight Test.

The Flight Safety Officer 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' will be eligible to enter the Flying Demonstration – Mission.

B6 Operation

- The UA shall remain within Visual Line of Sight (VLOS) of the Remote 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 Remote Pilot; during take-off or landing, however, the UA must not be flown within 30 m of any person, unless that person is under the control of the Remote Pilot.
- No radio operation will be permitted except after authorization from the Safety Officer. Radio Transmitters will be deposited for safety considerations with the Safety Officer and only issued back to the team when radio operation has been allowed.

- During the entire flight the UA shall remain in controlled flight and within the boundary of the demonstration zone;
- Any UA appearing uncontrolled or moving into a 'No Fly' zone shall be subject to immediate manual override. Failure of manual override shall result in Flight Termination being activated.

B7 Ground Control Station

The Ground Control Station shall display the following information and be visible to the Operators, Flight Safety Officer and Judges:

- Current UA position on a moving map;
- Local Airspace including any No Fly Zones;
- Search Area Boundaries;
- Height AGL (QFE);
- Indicated Airspeed (kts);
- Information on UA Health;

B8 Payload Carriage and Delivery

The Safety Case shall include demonstration by analysis and test, that the risk of inadvertent jettison of the Payload and subsequent injury to persons on the ground is acceptably low. Consideration shall be given to the reliability of the system, and the trajectory safety trace of the released Payload under failure conditions.