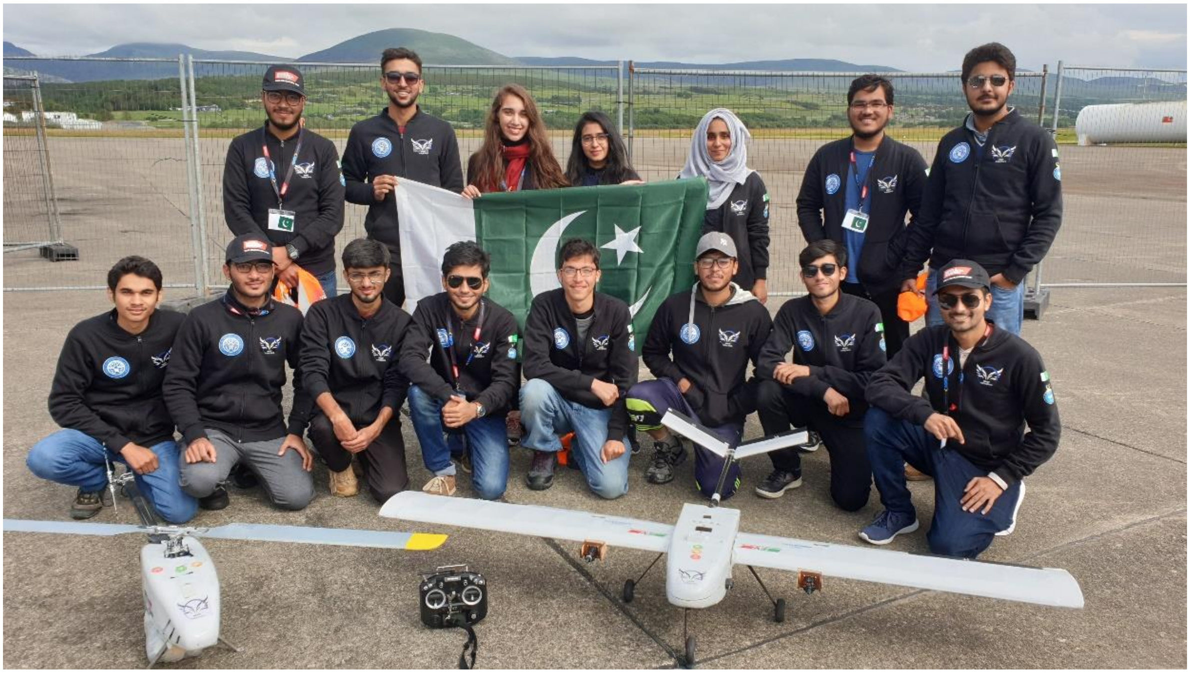
UNMANNED AIRCRAFT SYSTEMS CHALLENGE PAKISTAN 2022



COMPETITION RULES

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Disclaimer: The word “IMechE”, wherever it appears throughout the document, refers to IMechE Pakistan Group.

Caution: The following is Issue 0.9 of Rulebook. Revisions may follow. Teams should regularly check their emails for news and updates.

Abbreviations:

AGL	Above Ground Level
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CDR	Critical Design Review
CG	Centre of Gravity
COTS	Commercial Off The Shelf
FRR	Flight Readiness Review
FSO	Flight Safety Officer
FTS	Flight Termination System
FW	Fixed Wing
GCS	Ground Control Station
GPS	Global Positioning System
KIAS	Knots: Indicated Air Speed
MTOM	Maximum Take-Off Mass
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
RW	Rotary Wing
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
VLOS	Visual Line of Sight
WP	Waypoint

1. Introduction

1.1. Challenge Overview

The competition will engage university Undergraduate teams in the design of an Autonomous Unmanned Aircraft System (UAS). With a Maximum Take-off Mass (MTOM) limit of 6.9kg which will comprise both the payload and UAV. Operating within Visual Line of Sight (VLOS), the Unmanned Aircraft (UA) will be designed to be deployed for spraying crops with insecticide for locust swarms. The system will be required to operate automatically, performing a series of tasks such as navigating waypoints, accurately spraying at required areas and returning to base via a defined route.

The competition will be held annually over an academic year. For 2022, the challenge will be launched in March 2022. The competition is divided into two stages with the first taking place from March to July while the second will commence in July and end by September.

The first stage will be held virtually where the teams will research on, design and submit reports on their UAV models. During this phase teams will work on designing their UAV, submitting a CAD model simulated in X-plane workspace under real-time flight conditions and presenting their business case. Each team's score will be calculated and those clearing to the next stage will be announced

The qualifying teams will then enter the second stage which includes fabrication of the UAV and performing tests on the models in a Fly-off event. This period will be structured into development and demonstration stages and a flying demonstration contributing to the final scoring. All awards will be announced at the end of this stage.

Keeping in view the ongoing pandemic, the competitions' rules allow entrants to participate both live and virtually. In the event of lockdowns being imposed the organizing committee reserves the right to cancel the live event.

1.2. Objectives of the event

The competition has several objectives, in particular to:

i. Provide a challenge to students in systems engineering of a complex system, requiring design 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 agricultural UAS field and enhance employment opportunities in the sector.
iv. Foster inter-university collaboration in the UAS technology area and provide a forum for interdisciplinary research.

v. Support deserving students with monetary awards to promote UAV development in the country

1.3. Scenario

The challenge for 2022 is based on the real-life problem of identification and dispersal of Locust Swarms in the country. Locusts attack crops in the form of swarms, destroying huge areas of crops in a short amount of time. This leads to a massive loss in the harvest which results in a financial loss for farmers, affects relevant industries and in turn reduces the company's GDP due to low exports and greater imports. One of the solutions to battle these swarms is the use of insecticide sprays. Using manual labor for this process can be tedious, slow and inefficient. The use of UAV can allow for early detection and swift insecticide sprays on the swarm.

The mission for the UAV will be to operate autonomously throughout its task. It will take off from the given location, transit between the waypoints, spray at the required areas, return to the GCS via a different route (to allow for any other UAV to use the same initial route). Participants will design comprehensive preflight checklists, safety procedures (ON and OFF aerodrome), storage procedures, mission plan and system safeties. Learn to effectively perform and analyze the listed preflight operations, normal takeoffs, landings and traffic pattern procedures.

2. Competition Overview

2.1. Challenge Schedule

The dates for key activities for 2022's UAS Challenge Pakistan are as follows:

Month	Activity
Feb	Team Registrations Go Live
March	Registration deadline
STAGE I: VIRTUAL EVENT	
April	Preliminary Design Report submission
May	Critical Design Report submission
June	X-Plane Model submission
	Business Presentations
STAGE II: FLY-OFF EVENT	
July	Announcement For Qualifying Teams
September	Flight Readiness Video
September	Flight Demonstrations

2.2. Eligibility and Team Structure

The Competition is open to all Pakistani Universities.

2.2.1. Team Composition

Teams will be put forward by each University and will constitute members drawn from only undergraduate cohorts in any year of study. However, no team member can be an employee of the university. Each team should constitute a maximum of 10 and a minimum of 5 members.

2.2.2. Team Supervisors

Each team must appoint a Faculty Advisor.

- The **Faculty Advisor** is a member of the academic staff that is offering support, guidance and advice throughout the project.
- If your team is unable to find academic support, you can assign a **Team Supervisor**. The Team Supervisor should be a postgraduate student.
- All delivered documents must be approved and signed by the Academic Lead.

Each team must also appoint a Team Leader.

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

At the 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 organizers.
- Ensure the team adheres to the event schedule and turn up for scrutineering, business case presentation and fly-off on time.

2.2.3. 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 to register as an IMechE member to supervise a team. Free IMechE membership is available only for students.

2.2.4. University Alliance

Universities may form an alliance to enter a joint team. The competition, whilst having a set of defined performance objectives to achieve, is also about the development and demonstration of team working skills.

2.2.5. Universities entering more than One Team

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

The numbers of students in each team will be entirely determined by each University in case of entering more than one team. However, each team should have no more than 10 members.

2.2.6. Plagiarism

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

2.2.7. Industry Support

Universities are at liberty to approach potential industry sponsors at any time prior to or during the competition for both financial and technical assistance. Note that where technical advice is received from industry, the judges will need to be sure that majority of the development work has been undertaken by the students themselves. For details of financial assistance, refer to **Section 2.4: Cost and Funding**

2.3. Availability of Certified Pilots

A pool of certified pilots (paid) will be available, in the scenario that any team wishes to employ them, at their discretion and risk.

Note: Team IMechE does not bear any liability for any accidents incurred during flights. Participants are expected to observe all safety rules at all times and take precautions for their and their fellow team's safety.

2.4. Cost and Funding

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 industrial support, both technical and financial. Such support must be fully acknowledged in the Design Review submissions.

The Team Registration Fee is PKR 5,000 /-

2.4.1. Financial Support from Industry

For financial assistance from the industry, the sponsorship agreement will be between the team and the industry directly. IMechE will not be linked with any industry for such a sponsorship.

2.5. COVID Restrictions

Keeping in view the ongoing COVID situation, the competition's rules cater to entrants to participate both virtually and live. In the event of lockdowns being imposed the organizing committee reserves the right to cancel the live event.

3. Design and Operational Requirements

The UAS shall be designed to perform the mission defined at Annex A while being compliant with the specification defined in this section. The term ‘shall’ denote a mandatory requirement. The term ‘should’ denote a highly desirable requirement.

3.1. UAS Design Requirements

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

3.1.1. Design Models

Participating teams will be required to submit 2 separate models during the course of the competition. The first model will comprise the detailed CAD assembly on any available CAD software. This CAD assembly is expected to be as detailed as possible. Scoring will be dependent on the keen emphasis of the team on the manufacturability and feasibility of the design concept. The second model will be the design model on X-Plane software. Teams are expected to build their expertise on X-Plane software. Judgement will be dependent on resemblance to the CAD model. Moreover, the X-Plane model is expected to be showcasing clear representations of airframe, control surfaces, propulsion sources and payload provision.

3.1.2. Airframe Configuration and Mass

Following Airframe Configuration is allowed

i. Fixed Wing
ii. Rotary Wing
iii. VTOL

The Maximum Take-off Mass (MTOM) shall not exceed 6.9 kg which will comprise both the payload and UAV. The UA shall be designed for rapid assembly/disassembly to fit into the Storage Container. (Refer to **Annex A Fly-off Mission Details**)

Note: - Necessary safety precautions must be taken. Failure to do so may result in ramifications due to activities on the ground and in the air.

3.1.3. Propulsion

Electric motors and internal combustion both are allowed. However electric motors are preferred by IMechE due to their environment-friendly nature.

3.1.4. Autonomy

The UAV shall operate in a fully automatic manner, from the take-off to navigating waypoints, spraying at the target till the landing. UAVs flown manually will result in a deduction in points. Marking depends on the following categories:

i. Fully Autonomous Flight

ii. Semi-Autonomous Flight

Note: Semi-Autonomous flight means the team will be able to do manual take-off and landing while at cruise altitude the UAV will follow the waypoints. However, marks will be deducted for semi-automatic operation.

3.1.5. Payload Carriage

The payload for the UAV will be the water to be sprayed at the identified areas. The payload must be a minimum of 500ml.

The UAV design must incorporate a mechanism to attach the tank for the insecticide as well as a mechanism to spray the insecticide. Spraying chemicals is not allowed. Only water can be used for that purpose.

All teams need to send in the Flight Review Report to show that the UAS is stable at both extreme locations of the center of gravity- when the UAS is fully loaded and when the payload is empty.

The tank's specification is given in **Section 3.1.6: Spray Tank Specification.**

3.1.6. Spray Tank Specification

The Tank can be detachable from the UAS or fixed to its design. In the case of being detachable, it should be able to be re-attached in the shortest amount of time possible.

The Tank should have a minimum capacity of 500 ml of water (to simulate insecticide) and should be made from a material that does not react with the insecticide. (Material should comply with UL 94, V0 flammability standard)

The teams are advised to cater for sloshing however they may like as it may affect flight performance.

3.1.7. Limits on use of COTS Items

The UAS airframe should be designed from scratch (refer to **Section 2.2.6: Plagiarism**) and not based on commercially available kits. 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 parts include motors, batteries, servos, sensors, autopilot and microcontroller boards. All the COTS items must be of known brands to ensure safety.

The limit of the maximum value of COTS components used is PKR 250,000. A Bill of Materials and costs will be required as part of the design submission. Cost-efficient solutions will score more points.

Note: The manufactured UAS brought to the competition must match the detailed engineering drawings provided in the reports sent.

3.1.8. Radio Equipment

Compliant with PTA directives, and licensed for use in Pakistan. Reliable operating range of 1 km. Control of the UA and the FTS is 'Spread Spectrum' compliant to 100mW spread spectrum conforming to IR2030 and CE marked 4.

3.1.9. Flight Termination System

Teams are required to design and install their own Flight Termination Systems keeping in mind the following guidelines:

- The UA shall automatically return to the take-off/landing zone or terminate the flight after a loss of data link of more than 30 seconds.
- The UA shall automatically terminate flight after the 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 such as a parachute.
- 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 power-off recovery in a minimum energy manner at a spot on the ground no more than 150 m radii 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.

3.1.10. Tracking System

A GPS Data Logger shall be fitted permitting both real-time and post-flight evaluation of the 3D trajectory. Logs from the data logger will be provided by the teams for post-flight analysis by judges.

3.2. Operational Requirements

3.2.1. Design Mission Range and Endurance

On contrary to flight demonstration, the X-Plane models will be simulated in an X-Plane Flight Simulator environment. The presented models by the team must have the capability to perform flights under real-time flight and weather conditions. The control capacity and airworthiness of the models is expected to be emphasized in the models submitted.

Operational performance of the model will involve the X-Plane models being subjected to a flight simulation environment where models will follow the known and defined flight path under defined flight parameters. Take-off and landing of design models will be part of flying demonstrations and will be marked. However, the take-off and landing approaches presented by the teams will be incorporated in demonstrations. Flights will involve take-off, climbing to the cruising altitude, flight paths defined by waypoints in a circular path, descending and then landing. Teams are expected to first demonstrate this flight plan before submitting their models.

To size the fuel/battery load, the design team should plan on a typical target Mission flight path with a distance of no more than 2-4 km, from take-off to landing.

A separate battery can be created as detachable to operate the insecticide during the main mission or the power for the sprayer can be derived from the same battery. In the first case, means of firmly securing the second battery should be in place and the battery itself should be attached in the shortest amount of time possible.

The Mission may require the UAV to operate further than 500 m up to 1000 m, which may be acceptable where the UAV can be safely flown and tracked within the segregated airspace. The UAV will fly at its maximum altitude which can reach 100m.

3.2.2. Take-off and Landing

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 UAS required to stop within the box.

3.2.3. 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
    1. Heading
    2. Altitude (angles)
    3. Battery Level/Consumption
    4. Current Consumption
- Local Airspace including any No-Fly Zones.
- Search Area Boundaries.
- Height AGL (QFE).
- Indicated Airspeed (KTS).
- Information on UA Health.

3.2.4. Weather limitations

The UAS should be designed to operate in winds of up to 20 kts gusting up to 25 kts, and light rain. The UAS shall typically be capable of take-off and landing in crosswind components to the runway of 5 kts with gusts of 8 kts. Teams are expected to incorporate these flight conditions with their X-Plane models to ensure any confusion and reservations.

3.3. Safety and Environmental Requirements

The UAS shall comply with the Safety Requirements given below:

3.3.1. General Safety Requirements

- The UA shall have a maximum Take-Off Mass (MTOM) of 6.9kg.
- 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 and safety of Critical Systems.

3.3.2. 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.
  - Use materials that are highly resistant to corrosion (such as nickel or nickel-coat copper). If contact plating is an issue, use contact plating on the terminals.
  - Be sure to use a battery pack, make sure the battery pack from being ejected if the equipment is dropped or receives a sudden impact.
- The fuel tank needs to be made of a suitable material that will not react with the fuel mixture, especially during high temperatures or get a fire. (Material should comply with UL 94, V0 flammability standard)

3.3.3. Operational Safety Requirements

- The UA shall remain within Visual Line of Sight (VLOS) of the Remote Pilot, and remain below 100m AGL.
- The UA shall not be flown within 30 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 10 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.

3.3.4. 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.

4. Statement of Work

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

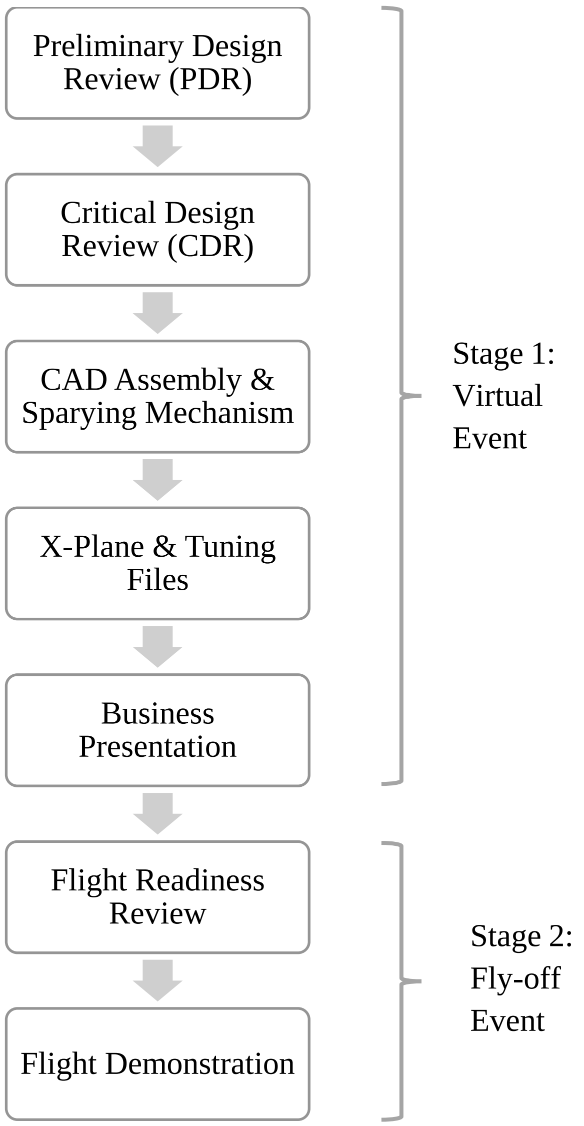
4.1. Mission Tasks

The challenge is to design a small autonomous UAS to fly a mission that is modelled on the real-life scenario of tackling Locust Swarms described in **Section 1.3: Scenario** The exact mission is presented in **Annex A Fly-off Mission Details**. The competition will typically seek to test several characteristics, such as:

- The maximum mass of Insecticide that can be carried.
- Navigation accuracy via waypoint coordinates provided on the day.
- Airworthiness of the designed models.
- Flight controls and stability of the designed models.
- The extent of automatic operations from take-off to landing.
- Safety: demonstrating safe design and flight operations throughout.
- Minimum environmental impact, notably low noise levels.
- Maximum payload / empty weight ratio.

4.2. Challenge Stages

The competition for 2022 will comprise of the Design, Fabrication and Demonstration stages. As scheduled in **Section 2.1: Challenge Schedule**, the key events in the competition are:



4.2.1. 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 & prescription.
- Preliminary weight report.
- Preliminary safety report.
- System requirements, with functional descriptions & schematics for each of the systems, including:
    - Airframe
    - Propulsion
    - Flight controls
    - Navigation & mission control
    - Sensors
    - Payload delivery
    - Flight termination

As a guide, the body of the report should be no longer than 10 pages. (For detailed information, refer to **Annex B Documents Requirements**)

4.2.2. 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. Teams should mention how they will approach towards manufacturing the components of their aircraft if that component is not included in the COTS item and is an integral functional part of the UAS. Furthermore, if teams were to procure any component from overseas, they should cater to the shipping time that may be required. Hence, teams are encouraged to use locally procured items for their UAS.

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 25 pages, supported by appendices where appropriate plus the design dossier. (For detailed information, refer to **Annex B Documents Requirements**)

4.2.3. Computer-Aided Design (CAD) Model & Spraying Mechanism

This stage holds critical importance in this challenge as at this stage you will be presenting the complete model. CAD model must be the complete replica of your physical model, representing all the key features and components presented in the reports submitted.

CAD model must be carefully designed as it will be the base of judgement for following submissions of the X-Plane model. CAD model must hold detailed considerations for all working mechanisms. Dimensions parameters will be counterchecked with the submitted reports. The placement of electrical and other auxiliary components is expected to be shown in the CAD assembly. Teams are expected to work on their CAD model with clear manufacturability, harnessing and packaging in mind. Design and manufacturing defects will cost marks.

Along with the CAD model, teams are required to submit their spraying mechanisms as well. Teams are required to fabricate the spraying mechanism as it is described and indicated in their reports. Then video recording of the working spray mechanism is to be submitted. The video will serve the purpose of demonstrating the clear working of the spraying mechanism. The size and integration of the system needs to be the same as described in their reports and CAD model. For score break down, refer to **Annex B Documents Requirements**)

4.2.4. X-Plane Model and Tuning

Submission of the X-Plane model and its respective tuning files will serve as the counterpart of flight demonstration. That means the X-Plane model needs to be as capable as you want your flying model to be.

As the CAD model has been finalized at this stage, teams are required to generate the same model in X-Plane – Plane Maker workspace. Marks will be allocated to close the resemblance between the CAD and X-Plane models. X-Plane model will be used to simulate a flight path hence this model does not need to have any electrical or non-flying related components like batteries, telemetry, wiring etc. However, the external body needs to be well defined according to the CAD model as it will play a crucial role in flying simulation. Dimensional and inertial parameters will be checked at this stage as well so it is expected that teams will pay close attention to these parameters.

As the First Stage of this competition will be carried out in a virtual environment, there will be a tradeoff between roles played by participating teams and the organizing committee. Teams will be submitting the design and flying models. However, the flying simulations will be performed by the organizing team. Being held virtually, flight simulation will not be holding significant marks as it will be performed by the organizing committee. However, the marks will be justified through the control and stability of the presented models.

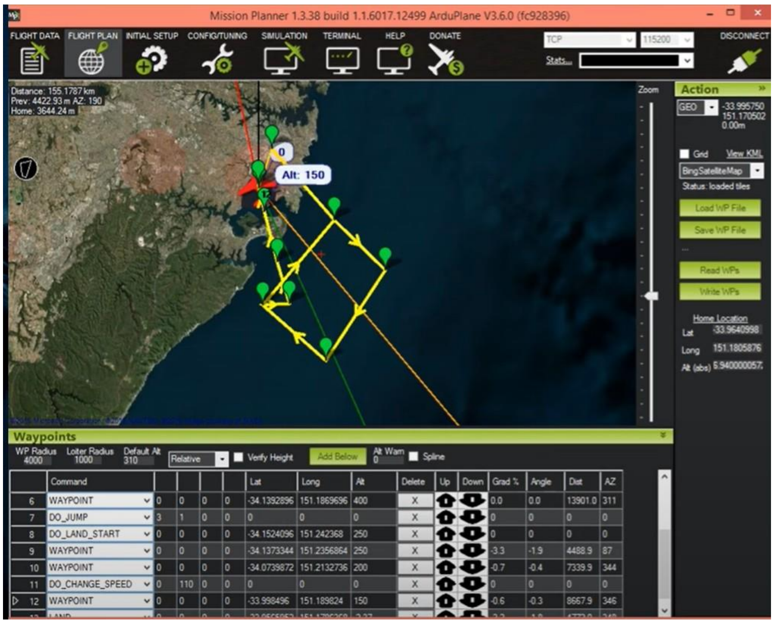


Figure 1 Waypoints for X-Plane Simulation

Teams are required to submit their approaches for all phases of flight as they will be used while performing flight simulations. It comprises of take-off approach, following the selected flight path in the air followed by approach and finally the descending/landing approach. The actual position of WPs will be provided to the teams. However, a brief flight plan will be shared with teams before the X-Plane model submission. For score break down, refer to **Annex B Documents Requirements**)

4.2.5. Business Presentation

During the flight demonstrations at the specified location, each team will be required to give a presentation consisting of 10 slides on their business case. This takes the form of an illustrated pitch (PowerPoint presentation) to a group of judges. This should demonstrate the team's understanding of the potential market, outline a revenue model (direct sale, lease, operate, etc.), the scale of the opportunity and how their design will be competitive. The team also needs to show how they have promoted the competition and their design locally with schools (if possible due to the Covid situation), the media and social media.

4.2.6. 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 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. The physical test should include a subsystem test, as well as flight testing of the complete UAS. Failure to submit your complete FRR on time may result in exclusion from the Demonstration Event.

- A 10-minute video showing evidence of the development testing undertaken, including a continuous flying sequence showing at least a fully autonomous take-off, controlled flight, including any transition, landing and payload deployment.
- A full statement and justification of any changes introduced since the critical design review with any impact on the safety or performance of the vehicle.
- A pre-flight checklist
- Confirmation that the team pilot has experience of operating the UAS during development testing.

This is your confirmation that you are Flight Line ready and can safely proceed to the Flight Demonstration event. (For detailed information, refer to **Annex B Documents Requirements**)

4.2.7. Flying Demonstration - Mission

The Pre-Flight Inspection will comprise of the following tests:

Static Examination:

The model will be examined while its engine power is shut down. Important aspects considered in the test will be the structural and electrical integrity of the model.

- Verify all components are adequately secured, fasteners are tight and 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
- Verify if all controls operate in the correct sense or not.
- Check general integrity of the payload and deployment system.
- Verify correct operation of the fail-safe and flight termination systems.

Verify the following list

1. Weight should be not more than the above-mentioned limit.
2. Centre of Gravity
3. Compass heading matches with reference headings
4. GPS Lock has been achieved
5. The battery is more than 90% charged

Dynamic Test:

The model will be examined on a testing bench with full throttle. Important aspects considered will be the structural and electrical integrity of the model. After testing all Radio controls will be tested.

On satisfactory completion of the Inspection and Testing, the inspector will allow the team to proceed in the event. The Flight Safety Officer shall have absolute discretion to refuse 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 Fly – Mission.

Upon successful issue of a Permit to Fly, the Mission will be flown, as explained in Annex A. 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.

The competition will be assessed across eight elements, comprising:

Element	Score
Virtual Events	
PDR	50 points
CDR	100 points
CAD Model & Spraying Mechanism	90 points
X-Plane Model	100 points
Outreach	50 points
Business Case	100 points
Total Points	**490 points**
Fly-off Events	
Flight Readiness Review	60 points
Flying Demonstration	200 points
Total Points	**260 points**

Detailed information on the scoring of the PDR, CDR CAD Modeling, X-plane is provided in **Annex B Documents Requirements**, and of the Flight Demonstration in **Annex A Fly-off Mission Details.**

5. Prizes and Awards

There are a number of categories for which prizes will be awarded. The cash prize will only be awarded to the winning team and runner up.

Prize	Award Criteria
Winner	Highest aggregate score from the Design & Development and the Flight Demonstration
Runner Up	2^{nd} highest aggregate score from the Design & Development and the Flight Demonstration
Value 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.
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, the UAS exhibits practical safety features and demonstrates safe operation.
Autonomous Operations	For the entrant demonstrating the greatest degree of autonomy in operations, from take-off to touchdown.
Net Zero	For the UA demonstrating the most environmentally sustainable design in materials, noise and energy usage.
Communications	For the team which engages most effectively with local media, schools, social media, to promote participation and engagement with the Challenge.
Pioneer	For the team which develops the most technologically advanced UAV.
Distinguished Design	Will be awarded to the team with the most points in the virtual stage of the competition

6. Guidance to Teams (UAS Configuration)

Rotary Wing, UAS (R), and Fixed Wing, UAS (A), each has their advantages and drawbacks. The UAS (R) may descend accurately to spray the insecticide, but maybe 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).

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.

Annex A Fly-off Mission Details

A.1. Mission Overview

The mission comprises a mandatory 'core' challenge.

A.1.1. Core Challenge

The mission scenario is an Unmanned Aircraft (UA) flying to pre-determined areas affected with locusts and then carrying and then spraying anti-locust chemicals on Spray Zone (SZ) via defined Waypoints (WP), within a specified time limit.

For navigating to the affected area, there will be three routes from the base station to the SZ, a short, medium and long-distance route. A longer route scores greater number of points. Teams will need to plan their tactics carefully and be familiar with the performance of their UA.

The teams will be required to effectively spray the affected area and will be scored accordingly.

The UAS shall be stored and transported in a box or container, and assembled simply and quickly to be ready for deployment at a 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. The challenge aims to test the structural efficiency, flight performance, navigation, modularity, and load carrying capacity of the UAS designs.

A.2. Mission

This comprises the pre-flight preparation, recon operation and the chemical spraying task. The actual position of WPs 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 to the airside.

Starting with the UAS stored in its Container, the team shall unpack the UAS, and prepare it for flight, including airframe assembly, connecting the battery and flight controls, loading the spray container, check of the pre-programmed mission, check of control functions. This shall be a timed task, supervised by a Scrutineering Official. The task completes successfully when the Official is satisfied that the pre-flight safety checks have been completed thoroughly and safely. It is important therefore that the team members demonstrate the safety checks clearly to the Official.

Maximum marks will be given 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 Flight Safety Officer (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. This should take no more than 2 – 3 minutes, and there is a maximum time limit of 5 minutes for this task.

A.2.1. Task 2: Recon Operation

A.2.1.1. 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 take-off, climb out in a controlled manner and head towards the first WP.

A.2.1.2. Task 2b: Navigation and Search

The UA shall navigate to the Spray Zone (SZ) via several Waypoints (WP) located on the airfield. The GPS coordinates of these way points will be given to the teams before the initiation of this task.

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

Points shall be scored according to:

- The path chosen
- Number of WP crossed

A.2.1.3. Task 2c: Spraying the anti-locust chemical

Continuing the task, the UA having overflown the waypoint, shall effectively spray the SZ with the insecticide. The SZ will be of 4m × 8m dimensions having 64 boxes.

Points will be scored according to accuracy of spray (most boxes covered) and the load carried.

A.2.1.4. Precision Landing

After accurately spraying on the SZ, the UA will return towards the launch area and then land within the 20m landing box.

A.2.2. 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 (Refer to **Section A.3.4**)

A.3. Scoring

The scoring is presented in **Section A3.4**. Teams should study this carefully when selecting the UA concept and defining the performance characteristics at the start of the design process.

A.3.1. 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.

Exceeding the time T2 will result in penalty points being applied, as set out below.

A.3.2. Route distances

The organizers will provide details of the routes from the Launch Point to the Spray Zone at the start of the demonstration event; as guidance for the teams, the approximate distances are expected to be:

Route A: 4.0 km; Route B: 3.0 km; Route C: 2.0 km

The pre-defined route around waypoints from the Spray Zone back to the Launch Point is expected to be less than 0.5 km. All distances quoted are the straight-line distances (displacement) between waypoints, and do not account for positioning maneuvers or turn radii.

A.3.3. Scoring of Repeated Mission attempts

If there is time in the flying schedule, teams may be allowed up to two attempts at the mission. All **flying events will occur on Day 2 only**.

The score which is used in the final judging will be the score of the last attempt. If only one attempt is made, the judging will use the score from that single attempt. However, if a second attempt is made, the score of the first attempt will be ignored.

Example 1: If Team A scores 120 points on Attempt #1, and doesn't have a second 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 score of the Attempt#2 i.e., 60 points.

A.3.4. Flight Demonstration Scoring

Task	Scoring
Pre-Flight Preparation 20	
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 30 points.
Preparation and Time, T1	Time to assemble and ready the UAS for flight, starting with the UAS packaged in the closed Storage container. Includes the installation of batteries, loading pre-programmed route, initializing GPS, and performing all control function and other pre-flight checks to the satisfaction of the Scrutineering Official. Score 20 points for time ≤ 5 minutes (300 s). Score 0 points for time ≥ 15 minutes. Score = 30 – (0.03333 x T1), rounded to nearest integer, where 'T1' is in seconds. Example: Assembly and check-out takes 8:30 min: sec (510 s). Score: 13 points.
Spray Chemical 130	
Spray Chemical Mass and Distance	Mass of cargo delivered to the Spray Zone (kg) x the straight distance of the Route taken (km) x X points. (Total Marks = 75) Note: X = 3.75 / (maximum spray chemical delivered on event day) Example: 4.8kg delivered via Route A (4 km), 5kg maximum spray chemical delivered on event day – total points 3.75 × (4.8 × 4) = 72 points.
Accuracy	Score 0.86 × B points for accuracy, where B is the number of boxes filled. For a box to be counted as filled, more than 50% of the box needs to be filled. (Total Marks = 55) Example: 26 boxes filled more than 50% - total points = 0.625×26 =22.36 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.

Navigation 50	
Score	5 points for each WP successfully navigated around the declared Route up to a maximum of 50 points. Example: Route A may comprise Launch - WP1 – 2 – 3 – 4 – 5 – SZ – WP9. Total 7 WPs including the SZ. Score 35 points. Route B may comprise 4 WPs. Score 20 points. Total 55, but limited to max 50 points.
Missed WPs	Score zero for each missed WP. This is where the UA 'cuts the corner', failing to turn around the correct side of the WP.
Mission Duration	
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.
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 30m by 20m box. Deduct 10 points if UA completed landing more than 15m away from the nearest edge of the landing box.
Automatic Operation	
Penalty for non-automatic operation	In case of semi-automatic operation (takeoff and landing done manually), reduce 15% score for the whole core mission.

Annex B Documents Requirements

B.1. Deliverable Documents

This Annex covers the mandated requirements and guidance on the structure and content of the deliverable documents. Documents must be submitted as a **.pdf file**. The judges will be seeking evidence that you have understood the Engineering Challenges summarized below. which indicates what the Judges are looking for throughout the competition. It is important that each deliverable is submitted on time. **10 points** will be deducted for each day late.

Engineering Challenges

- A methodical **system 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.
- **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**; organizing the team to divide up roles and responsibilities. Good communication 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.
  Note: This is just an engineering challenge, in the competition you may use any type of operation whether it is fully autonomous, partially autonomous or it is manually operated
- 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 minimizes energy consumption, and attention to minimizing use of hazardous materials.

Teams will be given preliminary scores following each submission, but this will not be formalized 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 of supervisor
- Sketch or image of your aircraft
- Signature of person compiling the document (normally team leader)
- Signature of person authorizing its issue (normally Supervisor). Ideally an additional signature that your mentor has checked the submission.
- Sponsor logos (if applicable)

B.2. Preliminary Design Review (PDR) (50 points)

The Preliminary Design Review 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 10-pages of text out of which 2-page must be of drawings/sketches.

You should use the 10-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.

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

- Clear articulation of your concept (5 marks)
- Extent of Innovation in the Outline Design (5 marks).
- Adherence to the rules (5 marks).
- Depth and extent of underpinning engineering analysis (10 marks).
- Consideration of safety and airworthiness requirements (5 marks).
- Evidence of sound project management, planning, budgeting (5 marks).
- Demonstrating a well-considered business case (5 marks).
- Demonstrating good teamwork and organization (5 marks).
- Overall Quality of PDR submission (5 marks).

B.3. Critical Design Report (CDR) (100 points)

This is a detailed description of your design of no more than 25-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 PDR

Summary description of the design (2 A4 page maximum)

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

Project Management (3 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 program. It should show lead times and dependencies that will have to be managed.
- A table summarizing 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.):

Requirements	Verification
All up mass <= 6.9 kg	Detailed weight budget has been produced with 10% contingency.
Compliant with PTA directives, and licensed for use in the Pakistan. Reliable operating range of 1 km. Control of the UA and the FTS is ‘Spread Spectrum’ compliant to 100mW spread spectrum	Control and FTS transmissions are 100mW spread spectrum conforming to IR2030 and CE marked.
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 autopilot with motor power cut within 1s and controls set for spiral dive.

Design Description (10 A4 pages maximum) (40 points)

- A Functional Description, and the rationale for selection of each of the proposed systems, including Airframe, Propulsion, Flight Controls, Navigation & Mission Control, Sensors, Image Processing, Autonomy / Automatic Operation, Payload Carriage and Spraying mechanism, 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 (4 A4 page maximum) (15 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. Damage to public property.
Major	Single major injury to a participant. Single injury to a member of the public
Catastrophic	Multiple injuries. Death of any party

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

Manufacturing and support description (2 A4 pages maximum) (10 points)

- Describe the proposed manufacturing process and construction techniques to be used, including any safety and environmental issues and how they will be addressed. Any special equipment should be listed. Final assembly should be undertaken in-house and any outsourcing of major subsystems must be justified.

- Describe the support equipment, handling and storage fixtures necessary to the development flight trials and prototype customer demonstration at the event.
- Highlight any innovative aspects.

Qualification Test Plan (2 A4 page maximum) (5 points)

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

S.No.	Objective	Method	Success Criteria	Test Results and Date
1	MTOW of 6.9kg	Weighing scales – aircraft fully loaded and with dummy weighted tracker	≤6.9kg	Awaiting manufacture.

Cost Breakdown (2 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 **Section: 3.1.7: Limits on use of COTS Items**

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.

Summary Chart for CDR

Team name	
Team Lead and Supervisor name	
Review Items	• Requirements & Compliance • Project Approach • Manufacturing Approach / Progress • Testing Approach / Progress • Schedule • Safety • Risks
Changes since PDR	
Main issues arising and actions to be taken	
Supervisor + Team Leader Signature	

B.4. CAD and Spray Mechanism (90 points)

Submission	Scoring
Design Concept and Detailing	The overall design of the model will be analyzed with reference to the PDR and CDR. Resemblance will carry points. Mechanical systems will carry significant points. Movement of control surfaces and payload mechanism detailing will be marked. Dimensional accuracy will be checked with the submitted reports. Dimensions of control surfaces, placement of components and corresponding CG balance will be marked.
Parameters	Teams are required to incorporate all the desired material selections into their model. Weight limitations is to be kept in mind because exceeding weight will cost significant marks
Spraying Mechanism	Mechanical integration of the system, Overall working, Ease of installation and refilling. Compactness and compatibility with the UAV.

B.5. X-Plane Model (100 points)

Submission	Scoring
X-Plane Model (40 Points)	
Design concept and Dimensional accuracy	Design detailing, dimensional accuracy, and placement of control surfaces as per the CAD model. Placement of CG and air foil definition will be marked.
X-Plane Simulation (60 Points)	
X-Plane SITL Simulation	The model of the teams will be simulated on virtual environment and score will be given based on the performance of stability, controllability and time to complete the mission.

B.6. Flight Readiness Review (FRR) (60 points)

The Flight Readiness Review (FRR) submission should include:

- 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 lists.
- 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 3.
    - The design and build quality are 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.

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 rigor of testing to demonstrate the performance and safety features of the UAS.