CADE20005 AVDASI2
2024-25
REQUIREMENTS SPECIFICATION

Document control

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Amendment record

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Related documents

Ref	Title
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Notation

- ac aerodynamic centre
- AUM all up mass
- Ally aluminium alloy
- BEC battery eliminator circuit
- CFRP carbon-fibre-reinforced plastic
- CG centre of gravity
- CR cruise
- DRG drawing
- EMP empennage
- FCS flight control system
- FLT flight
- FUS fuselage
- GCS ground control station
- HTP horizontal tailplane
- LD landing
- LE leading edge
- MAC mean aerodynamic cord
- MBS machine building system
- MWP main wing plane
- OTS off-the-shelf
- P port
- PID proportional-integral-derivative
- RCS radio control system
- RF reserve factor
- RIB rigid inflatable boat
- RPN risk priority number
- S starboard
- STOL short take-off and landing
- TO take-off
- TE trailing edge
- TBC to be confirmed
- TMS telemetry system
- UAV uncrewed aerial vehicle
- UoB University of Bristol
- VTP vertical tailplane

1. Overview

Three unique UAVs are to be developed in the 2024-25 academic year. The design and build tasks are split into the wing, fuselage, pod, empennage and avionics assemblies, which are to achieve the aerodynamic, structural, actuation, sensing, control and dynamic performance according to the specifications and requirements in this document.

In the case that your team/division/company determines that you cannot satisfy a stated requirement, or that satisfying a requirement creates an unacceptable trade-off to performance or quality then you must ensure that you consult your customer at the earliest opportunity. There is, however, no possible flexibility on requirements that relate to:

- Safety, which includes component handing safety, materials hazards and operational safety (where, in this case operational safety is limited to the expected usage of the UAV during CADE20005).

- Risks of damage to UoB facilities and equipment by the UAV during manufacture or testing.

See DRG A2 for specified UoB FLT 2024 layout and dimensions.

1.1 UAV missions and mission variants

Company A, *Company B* and *Company C* will each build a UAV. Each companies' UAV will be designed to meet the requirements of a different mission:

- *Company A* will develop a UAV to meet the requirements of *Mission A*.
- *Company B* will develop a UAV to meet the requirements of *Mission B*.
- *Company C* will develop a UAV to meet the requirements of *Mission C*.

Furthermore, your customers require each company to optimise the Port and Starboard wing against different aerodynamic parameter values. This is to enable the development for 2 different use-cases that your customer's mission requires (variant 1 and variant 2). This is possible, as for this phase of the product development, the Aerodynamic assessment of the Port and Starboard wings will be carried out in separate wind tunnel tests.

The following text is a brief description of the missions, along with requirements for the Port and Starboard Wing aerodynamic optimisation.

Mission A – Medical logistics drone

Company A is to design and build a UAV for your customer *MediTrack Logistics*. Meditrack provide global high speed logistical support to medical institutions. The UAV will be for high-speed (emergency) shipment of human patient blood samples from small rural medical centres to regional medical analysis facilities. Fast diagnosis of potential infection outbreaks is crucial to the prevention of disease outbreak.

The UAV will take-off horizontally from short (& rudimentary) runways at the rural medical centres. The UAV will fly patient blood samples to the regional test centres for analysis.

Regional medical hub centres have no limitation on runway length and have established tarmac runways. The UAV is later returned to rural centre via road as the return route is not time critical. Travelling by road minimises the risk of loss of the UAV and allows the UAV battery to be re-charged enroute.

MediTrack wants to deploy this UAV model in 2 regions:

- Mission variant A1 (Port Wing) in region X, where the operator can mandate a mown grass strip at the clinics. This yields a *tyre-runway rolling friction coefficient* of μ_{r1}.
- Mission variant A2 (Starboard Wing) in region Y, where only rough scrubland (i.e. raked dirt) is possible. This yields a *tyre-runway rolling friction coefficient* of μ_{r2}.

Friction coefficient values are given in the specifications section of this document.

Each wing (Port and Starboard) should be optimised to achieve:

1. The shortest take-off length possible (i.e. lowest C_d - $\mu_r C_L$). This defines the minimum runway length that the medical centres are required to build/maintain.
2. Highest top speed (min C_{d0}). High top speed improves the response time to emerging infection by enabling fast diagnosis.

Mission B – Marine wildlife surveillance

Company B is to design and build a UAV for your customer *BlueWave Conservation*. BlueWave is a wildlife protection charity and your UAV is to be launched from their marine survey ship. The launch is catapult assisted, so take-off velocity is not a critical design characteristic.

The UAV will loiter above a defined ocean grid area and visually record surface breaches of an endangered whale species. The surface breaching behaviour is thought to be closely linked to this species breeding patterns. Longer time in the air improves the statistical quality of the analysis and reduces the number of required days at sea (or allows an increase in the number of surveys possible in a breeding season).

The UAV must land on a simple floating airstrip deployed near the survey vessel. The UAV and airstrip are later recovered back to the survey vessel. Arrestor gear or landing nets cannot be used as the airstrips direction cannot be controlled and can change quickly due to wind or sea-state changes.

Surveying will take place in the same ocean regions but must take place during both the summer and winter breeding seasons. The average wind speeds are different between the seasons, so BlueWave require that you optimise the two wing variants at two specific lift coefficients (to maximise endurance at the expected average air speed for that season).

You must produce wing profiles that are optimised to:

- Mission variant B1 (Port Wing). Summer season – Average windspeeds require optimisation at a *coefficient of lift* value of C_{L1}
- Mission variant B2 (Starboard Wing). Winter season – Average windspeeds require optimisation at a *coefficient of lift* value of C_{L2}

Each wing (Port and Starboard) should be optimised to achieve:

1. Best L/D @ the given C_L (to maximise endurance at the conditions above).
2. The slowest landing speed (to avoid ditching and to permit the minimum floating airstrip size).

<u>Mission C – Agricultural survey</u>

Company C is to design and build a UAV for your customer *AgriSight*. Agrisight is an Agricultural Survey provider to farmers and conservation institutions around the world. The UAV you build will function as a Short Take Off and Landing (STOL) UAV for agricultural surveying. The UAV is to be launched from an enclosed/limited space on the ground. The UAV will carry out photographic surveys close to the launch site and therefore endurance/range is not a critical requirement.

AgriSight wants to deploy this UAV model in 2 regions:

- Mission variant C1 (Port Wing) in region X, where the operator can mandate a mown grass strip adjacent to the survey sites. This yields a *tyre-runway rolling friction coefficient* of μ_{r1}.
- Mission variant C2 (Starboard Wing) in region Y, where only rough scrubland (i.e. raked dirt) is possible. This yields a *tyre-runway rolling friction coefficient* of μ_{r2}.

Friction coefficient values are given in the specifications section of this document.

Each wing (Port and Starboard) should be optimised to achieve:

1. The shortest take-off length possible (i.e. lowest C_d - $\mu_r C_L$). This defines the minimum take-off area that the farm is required to provide/maintain.
2. Maximum C_L to give the slowest landing speed possible. Slow landing speeds permit the shortest landing area and also minimise the risk of damage when landing in an area surrounded by vegetation.

1.2 UAV and wing differences

The majority of requirements listed in this document are identical for *Company A*, *Company B* and *Company C* UAVs. Where requirement parameter values differ (due to the mission and mission variants described above), this will be clearly stated against the requirement. If only a single requirement or parameter value is given, then it is the same for all UAVs (and for the Port and Starboard wings on the UAV).

2. Specifications

2.1 UAV general dimensional requirements

ID	*Specification*	*Date*	*Initials*
2.1.1	The AUM shall not exceed 10kg, where AUM includes fuel cells and payload and internal systems, including pressure tapping, but does not include external wiring or external attachments to the UAV (i.e. power supply or control wiring, or fixtures).	13/09/24	MG
	The UAV shall achieve the dimensional requirements and functionality of the following drawings:		
2.1.2	Drawing *A2 (General dimensions).*	13/09/24	MG
2.1.3	Drawing *B1 (Fuselage Configuration).*	13/09/24	MG
2.1.4	Drawing *B2 (Empennage Configuration)*.	13/09/24	MG
2.1.5	Drawing *B3* (Fuselage Pod Configuration)	13/09/24	MG
2.1.6	Drawing *B4 (Fus-MWP joint fitting for wind tunnel test)*.	13/09/24	MG
2.1.7	The UAV shall function within the wind-tunnel constraints of drawing *B5 (Fus/Pod/Emp wind tunnel test arrangement)*. Note: The fus/pod/emp may be rotated in yaw during the test, but it will not experience free-yaw.	13/09/24	MG
2.1.8	Drawing *C1 (Wing planform configuration)*. Note: The unit's Experimental Lead shall be consulted prior to the selection of wing pressure tapping locations.	13/09/24	MG
2.1.9	Drawing *C2 (Wing Section Configuration).*	13/09/24	MG
2.1.10	Drawing *C3 (Wing Schematic).*	13/09/24	MG
2.1.11	Drawing *C4a (Wing Root Joint).*	13/09/24	MG
2.1.12	Drawing *C4b (Wind tunnel wing root and test fittings).*	13/09/24	MG
2.1.13	The UAV shall achieve the loading arrangement as shown in drawing *C5 ("Graphite Goose" static structural test arrangement)*.	13/09/24	MG
2.1.14	The UAV design shall enable the wings and fuselage/empennage to be tested within the wind tunnel arrangement shown in drawing C7 (*Wing 7x5 wind tunnel test arrangement*)	13/09/24	MG

2.2 Electronics

ID	*Specification*	*Date*	*Initials*
2.2.1	**Systems**		
2.2.1.a	Aircraft control systems shall comprise a flight control system (FCS), radio control system (RCS), telemetry system (TMS), and ground control station (GCS), with associated power, wiring harnesses, antennae etc.	13/09/24	SB
2.2.1.b	Actuation systems shall comprise appropriate servo motors and other actuators as detailed in sections below.	13/09/24	SB
2.2.1.c	FCS, RCS, and TMS shall be Bristol Flight Lab research-grade equipment, which will be provided.	13/09/24	SB
2.2.1.d	Servos shall be ordered from a specified selection.	13/09/24	SB
2.2.1.e	A provided Battery Eliminator Circuit (BEC) shall be used to provide power to servo motors.	13/09/24	SB
2.2.1.f	GCS shall comprise a user interface (UI), implemented in the Company's preferred language, available via a laptop that integrates with the FCS and TMS and provides human-machine interaction with these systems. The laptop should be student-provided unless otherwise agreed.	13/09/24	SB
2.2.1.g	Appropriate data logging shall be implemented in order to produce plots of: pitch angle and rate; servo demand; and other parameters as required by the Company to meet deliverables.	13/09/24	SB
2.2.1.h	A bench-top prototype of full FCS, RCS, TMS, GCS, and associated systems shall be demonstrated working at *Gate 2a*.	13/09/24	SB
2.2.1.i	For prototypes and final UAV, all electronics, actuators, harnesses and other components shall be installed via mechanical fasteners such that they are removable for maintenance and end-of-life recycling.	13/09/24	SB

2.3 Fuselage, pod, and empennage (HTP, VTP)

ID	*Specification*	*Date*	*Initials*
2.3.1	**Form and geometry**		
2.3.1.a	The fuselage spar shall be tubular with fittings and fairings for pod, main plane wing and empennage attachment. Telescopic tube joints shall be bonded with an overlap length of ideally two diameters of the larger tube being joined.	13/09/24	IF
2.3.1.b	The empennage design shall use specified aerofoil types, tail coefficients and aspect ratio ranges: The VTP aerofoil shall be a symmetric NACA profile with a tail coefficient of 0.015* and aspect ratio between 1.0 – 2.0 The HTP aerofoil shall be a symmetric NACA profile with a tail coefficient of 0.375* and aspect ratio shall be between 3.0 – 5.0. The HTP form shall be “low-cruciform” i.e., just above the fuselage spar. VTP and HTP taper is optional. Tapering of the depth and chord from root to tip is permissible if it is deemed beneficial. *75% of typical sailplane coefficients – see Blackboard STRUCTURES/Loads document.	13/09/24	IF
2.3.1.c	The Empennage structure shall include a: main spar; a false rear spar; and ribs. Primary ribs shall be located at the root, elevator or rudder hinge points, and tip. The empennage spars should be perpendicular to the fuselage spar centreline.	13/09/24	IF
2.3.1.d	The empennage combined mass is not to exceed 0.5kg (which includes the fus-emp joint).	13/09/24	MG
2.3.1.e	The Aircraft CG shall be within the range 300-400mm from the forward datum of the fuselage spar-tube. I.e., between 0 to 100mm forward of the MWP joint centre.	13/09/24	IF
2.3.1.f	The pod shall consist of frames and longerons or frames and trusses and must include a deck allowing an axially moveable payload*. The end fairings and some side panels of the pod must be removeable for ease of access to payload and systems. Side panels must be rigid enough to carry shear for a frame/longeron arrangement. *The payload axial position must be manually adjustable to permit the adjustment of the aircraft CG. The CG adjustment shall be sufficient to achieve level flight with <5º (positive or negative) of elevator angle.	13/09/24	MG IF
2.3.1.g	The fuselage Pod must accommodate a payload cross-sectional area of 80mm x 80mm with a length of 500mm.	13/09/24	MG
2.3.1.h	The fuselage Pod shall be securely connected below the fuselage spar tube at four detachable locations, i.e., at the forward and aft ends of the pod and at both sides of the fus-MWP joint.	13/09/24	IF

ID	*Specification*	*Date*	*Initials*
2.3.2	**Materials, manufacture, and assembly**		
2.3.2.a	The **fuselage** spar shall be thin-walled tapered CFRP tube.	13/09/24	IF
2.3.2.b	The **pod** frames shall be laser cut plywood. Longerons or trusses shall be CFRP or birch rod. The pod deck shall be ally. Side panels and fairings shall be plastic, Styrofoam, or plywood. Forward and rear pod enclosures shall be moulded plastic, 3D printed plastic or Styrofoam.	13/09/24	IF
2.3.2.c	The **empennage** spars shall be thin-walled CFRP tube. Ribs shall be balsa or thin plywood.	13/09/24	IF
2.3.2.d	Assembly of all airframe parts, by bonding or mechanical fastening, shall be performed whilst secured in a jig to achieve acceptable geometric tolerance.	13/09/24	IF
2.3.3	**Systems**		
2.3.3.a	The fuselage pod shall provide a secure, but accessible and removable, mounting surface for the FCS. The mounting location should be close to the CG (inertial centre) of the aircraft.	13/09/24	MG
2.3.3.b	A horizontal tail plane (HTP) elevator with a bespoke electronic actuation mechanism shall be implemented.	13/09/24	SB
2.3.3.c	The elevator shall be actuated by (an) appropriately sized off-the-shelf (OTS) servo motor(s) from the specified selection.	13/09/24	SB
2.3.3.d	The elevator mechanism should be of the four-bar type.	13/09/24	SB
2.3.3.e	The elevator shall be controllable by both the TMS and the RCS. TMS control shall be able to demand specific elevator deflection angles.	13/09/24	SB
2.3.3.f	A vertical tail plane (VTP) rudder with a bespoke electronic actuation mechanism shall be implemented.	13/09/24	SB
2.3.3.g	The rudder shall be actuated by a single appropriately sized OTS servo motor from the specified selection.	13/09/24	SB
2.3.3.h	The rudder mechanism should be of the four-bar type.	13/09/24	SB
2.3.3.i	The rudder shall be controllable by both the TMS and the RCS. TMS control shall be able to demand specific rudder deflection angles.	13/09/24	SB
2.3.3.j	Calibration tables and/or equations shall be generated to determine control surface angle from servo input for elevator and rudder.	13/09/24	SB
2.3.3.k	A bench-top prototype of all mechanisms and associated systems shall be demonstrated working at *Gate 2a*.	13/09/24	SB
2.3.3.l	Mechanisms shall be developed and tested using provided OTS servo testers, prior to integration with the aircraft FCS. Appropriate wiring harness connectors should be used to permit assembly and disassembly of the full aircraft.	13/09/24	SB

2.4 Wing

ID	*Specification*	*Date*	*Initials*
2.4.1	**Form and geometry**		
2.4.1.a	The main wing shall be rectangular with zero sweep.	13/09/24	IF
2.4.1.b	To avoid asymmetry during structural testing, the main wing spar design shall be identical between the Port and Starboard wing. P/S wing teams shall agree a single spar design that meets the mission requirements of both variants 1 & 2.	13/09/24	MG
2.4.1.c	A NACA aerofoil shall be used, giving the best compromise for the specified flight conditions (see mission discussion and wing performance requirements). Other aerofoil series may be considered but must be acceptable to the unit aerodynamic advisor. The maximum aerofoil depth shall be between 12-18% of chord and the aerodynamic profile shall be prismatic.	13/09/24	TR IF
2.4.1.d	The wing structure shall consist of a tapered main tubular spar, ribs, tapered false rear spar, cross-bracing, and shrink wrap skin. A resilient leading-edge layer shall be included around the nose up to 30% chord on the top surface to maintain aerofoil shape under air loading. Spar tube splice joints shall be bonded with an overlap length of ideally two diameters of the larger tube being joined. The main spar root joint shall be a two-bolt couple joint connecting to a centre bar. The false rear spar root joint shall be a nominal pin joint connecting to a bespoke fuselage fitting. See DRG C1-C4 for configuration and dimensions.	13/09/24	IF
2.4.1.e	The mass of each wing (including the pressure sensor system but excluding any wing-mounted battery masses) shall not exceed 1.0 kg. For intended wing battery mass locations, see drawing C1.	13/09/24	IF
2.4.2	**Materials, manufacture, and assembly**		
2.4.2.a	The main spar shall be made from thin-walled tapered CFRP tubes.	13/09/24	IF
2.4.2.b	The false rear spar shall be made from thin-walled CFRP tubes.	13/09/24	IF
2.4.2.c	The ribs shall be made from laser-cut plywood, pressure-formed plastic, Styrofoam, or balsa (a rigid tip rib shall be provided to allow accelerometer attachment).	13/09/24	IF
2.4.2.d	A “resilient” leading edge shall be formed by hot-wire cut Styrofoam, balsa or plastic sheet.	13/09/24	IF

ID	*Specification*	*Date*	*Initials*
2.4.2.e	The fixed and moving trailing-edge, aft of the false rear spar, shall be made by hot wire cut Styrofoam, with an appropriate spar element if moving, and an edge support if wrapped. Wet-formed plywood may also be acceptable.	13/09/24	IF
2.4.2.f	The skin shall be made from lightweight shrink wrap. There shall be no significant length of any shrink-wrap edge that is unsupported/unattached anywhere on the wing (as this can lead to skin failure and/or undesirable aerodynamic effects).	13/09/24	MG IF
2.4.2.g	Assembly by bonding or mechanical fastening shall be carried out whilst secured in a jig to achieve acceptable geometric tolerance.	13/09/24	IF
2.4.3	**Systems**		
2.4.3.a	An inboard flap with a bespoke electronic actuation mechanism and control system shall be designed.	13/09/24	SB
2.4.3.b	The flap shall be actuated by an appropriately sized off-the-shelf (OTS) servo motors from the specified selection.	13/09/24	SB
2.4.3.c	The flap mechanism should be of the four-bar type or other approved scheme.	13/09/24	SB
2.4.3.d	The flap should be of the type: plain; simple slotted; or single-slotted Fowler.	13/09/24	SB
2.4.3.e	Flap position shall be sensed by an appropriate sensor independent of the servo motor.	13/09/24	SB
2.4.3.f	The flap shall be controllable by both the TMS and the RCS. TMS control shall be able to demand specific flap angles.	13/09/24	SB
2.4.3.g	An outboard aileron with a bespoke electronic actuation mechanism shall be implemented.	13/09/24	SB
2.4.3.h	The aileron shall be controllable by both the TMS and the RCS. TMS control shall be able to demand specific aileron deflection angles.	13/09/24	SB
2.4.3.i	The aileron shall be actuated by a single OTS servo motor from the specified selection.	13/09/24	SB
2.4.3.j	The aileron mechanism should be of the four-bar type.	13/09/24	SB
2.4.3.k	A bench-top prototype of all mechanisms and associated systems shall be demonstrated working at *Gate 2a*.	13/09/24	SB
2.4.3.l	Mechanisms shall be developed and tested using provided OTS servo testers, prior to integration with the aircraft FCS. Appropriate wiring harness connectors should be used to permit assembly and disassembly of the full aircraft.	13/09/24	SB
2.4.3.m	Wiring harnesses shall exit the wing at the root for connection to the fuselage FCS. Appropriate connectors for tunnel test and full vehicle integration shall be used.	13/09/24	SB
2.4.3.n	For bench-top demonstration and tunnel test integration with the full wireless FCS systems should be attempted. For redundancy a wired option should be available, with appropriate 5-metre extension harnesses manufactured.	13/09/24	SB

2.5 Joints (fuselage-wing and fuselage-empennage)

ID	*Specification*	*Date*	*Initials*
2.5.1	**Form and geometry**		
2.5.1.a	The fus-mwp and fus-emp joints shall allow quick UAV assembly and dissassembly. A fus-mwp joint fitting shall be connected to the fuselage spar tube by two M4 bolts at 100mm spacing and to the wing main spar tube through a “centre-bar” using two M6 bolts* at 50mm spacing, see DRG B1 and C4a. * The wing spar bolt axis must be horizontal (parallel with the main fuselage spar) to ensure optimum bolt loading, and so that the bolts interface correctly with the wind tunnel test fixturing. A temporary fixing, consisting of a machined ally joint with bearings, shall be used for the wind tunnel testing of the fuselage assembly, see DRG B4.	13/09/24	IF
2.5.1.b	A fus-emp joint fitting shall be connected to the fuselage by two M4 bolts at 100mm spacing with fittings for VTP and HTP spars according to your bespoke design.	13/09/24	IF
2.5.2	**Materials, manufacture, and assembly**		
2.5.2.a	3D printed plastic may be used as a joint fitting former but should not be relied on for significant load transfer. 3D printed formers used for highly loaded joints shall be reinforced with 2014a-T3 ally sheet straps or bearing plates. Fasteners for highly loaded bolted joints shall be a minimum of 8-8 grade bolts. Adhesive for highly loaded bonded joints shall be two-part epoxy (Araldite).	13/09/24	IF

2.6 Fairings

ID	Specification	Date	Initials
2.6.1	**Form and geometry**		
2.6.1.a	Fairings shall be designed for the gaps between the MWP and Fus, Pod and Fus, and Emp and Fus to control airflow and minimise drag. Fairings should be able to cope with aerodynamic loading and be lightweight and easy to assemble/ disassemble. The MWP-Fus fairings shall have a vertical split-line to permit testing of ½ of the MWP-Fus fairing on a single wing in the wind tunnel.	13/09/24	IF
2.6.2	**Materials, manufacture, and assembly**		
2.6.2.a	Fairings can be made from Styrofoam, plastic mouldings or 3D printed plastics.	13/09/24	IF

2.7 Propulsion

ID	Specification	Date	Initials
2.7.1	It is not required that your company considers Propulsion (or propulsion power source) designs for the current development of the project.	13/09/24	MG

2.8 Landing gear

ID	Specification	Date	Initials
2.8.1	It is not required that your company considers landing gear designs for the current development of the project.	13/09/24	MG

3. Performance requirements

3.1 Aerodynamics

ID	*Specification*	*Date*	*Initials*
3.1.1	**Fuselage / empennage**		
3.1.1.a	The UAV shall achieve a minimum pitch trim range (α_{max}-α_{min}) of 25º at a test speed of 10m/s.	13/09/24	MG
3.1.1.b	The UAV shall achieve for rudder deflection $\frac{dC_{yaw\,force}}{d\delta_r} > 2.3$ and for yaw angle $\frac{dC_{yaw\,force}}{d\zeta} > 2$	13/09/24	TR
3.1.1.c	The design of the pod shall be optimised to reduce aerodynamic drag. The drag shall be predicted via calculation. Pod load data shall be used to confirm the Pods aerodynamic performance.	13/09/24	TR
3.1.2	**Wings**		
3.1.2.a	The UAV shall achieve for aileron deflection $\frac{dC_{roll}}{d\delta_a} > 0.35$	13/09/24	TR
3.1.2.b	The Company A UAV shall meet the Mission A requirements, as described in section 1.1.	13/09/24	MG
3.1.2.c	Company A, Port Wing only (Mission variant A1). Optimise wing profile for shortest take-off length via minimisation of C_d - $\mu_r C_L$, where μ_{r1} = 0.1	13/09/24	TR
3.1.2.d	Company A, Starboard Wing only (Mission variant A2). Optimise wing profile for shortest take-off length via minimisation of C_d - $\mu_r C_L$, where μ_{r2} = 0.15	13/09/24	TR
3.1.2.e	Company A, Port and Starboard wings. Optimise wing profile for highest top speed, i.e. min C_{d0}	13/09/24	TR
3.1.2.f	The Company B UAV shall meet the Mission B requirements, as described in section 1.1.	13/09/24	MG
3.1.2.g	Company B, Port Wing only (Mission variant B1). Optimise wing profile for best L/D at C_{L1}, where C_{L1} = 0.5	13/09/24	TR
3.1.2.h	Company B, Starboard Wing only (Mission variant B2). Optimise wing profile for best L/D at C_{L2}, where C_{L2} = 0.3	13/09/24	TR
3.1.2.i	Company B, Port and Starboard wings. Optimise wing profile for slowest landing speed (i.e. Max C_L)	13/09/24	TR
3.1.2.j	The Company C UAV shall meet the Mission C requirements, as described in section 1.1.	13/09/24	MG
3.1.2.k	Company C, Port Wing. Optimise wing profile for shortest take-off length via minimisation of C_d - $\mu_r C_L$, where μ_{r1} = 0.1	13/09/24	TR
3.1.2.l	Company C, Starboard Wing. Optimise wing profile for shortest take-off length via minimisation of C_d - $\mu_r C_L$, where μ_{r2} = 0.15	13/09/24	TR
3.1.2.m	Company C, Port and Starboard wings. Optimise wing profile for slowest landing speed (i.e. Max C_L).	13/09/24	TR

3.1.3	**Fairings**		
3.1.3.a	The fairings, as described in 2.6, shall reduce aerodynamic drag of the UAV at all flight speeds and angles of attack.	13/09/24	MG
3.1.3.b	Fairings shall be removeable, where practical, to enable their aerodynamic contribution to be isolated during Wind Tunnel testing.	13/09/24	MG
3.1.4	**Systems**		
3.1.4.a	The wing shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of angle-of-attack variation under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.b	The flap shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of wing angle-of-attack variation while deployed and held at specified TO/CR/LD configurations, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.c	The flap shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of angle of deployment variation while the wing is held fixed at an angle-of-attack of zero degrees, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.d	The aileron shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range rotation, while the wing is held fixed at an angle-of-attack of zero degrees, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.e	The rudder shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of rotation, while the fuselage is held fixed at a pitch angle of zero degrees, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.f	The elevator shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of rotation, while the fuselage is held fixed at a pitch angle of zero degrees, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.g	The elevator shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of rotation, while the fuselage is free to move in pitch, under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)
3.1.4.h	The fuselage and empennage shall be sufficiently robust to withstand, without requiring emergency/reactive modifications, a full range of pitch angle variation under wind tunnel testing conditions of wind speeds up to 20 meters per second.	13/09/24	(MG)

3.2 Structures

ID	*Specification*	*Date*	*Initials*
3.2.1	**Design practice**		
	Standard factors, definitions, conventions, and load cases shall be adhered to throughout the design calculations.	13/09/24	IF
3.2.1.a	A proof factor of 1.0 and an ultimate safety factor of 1.5 shall be used. Unless otherwise stated, all ultimate reserve factors shall be greater than 1.0 with acceptable margins for uncertainties.	13/09/24	IF
3.2.1.b	Load cases shall include: 1) 6.0g limit symmetric vertical/pitching manoeuvre/gust case. 2) 6.0g limit lateral yaw/roll manoeuvre/gust case. 3) Spin recovery limit case with max rudder deflection at 30m/s. Loading shall be initially calculated using preliminary mass estimates and later refined for your specific design.	13/09/24	IF
3.2.2	**Design checks**		
3.2.2.a	Design checks shall account for stiffness, strength and stability and shall confirm RF’s for all major structural items.	13/09/24	IF
3.2.2.b	<u>Stiffness</u>: bending deflection and twist at limit load shall not exceed specified values for the fuselage and shall be reasonable and acceptable for the wing and empennage.	13/09/24	IF
3.2.2.c	<u>Strength</u>: the applied stress up to proof loading shall not exceed the proof strength of any part of the structure. The applied stress up to ultimate loading shall not exceed the ultimate strength of any part of the structure. Joint strength ultimate RF’s shall be greater than 2.0, All other ultimate strength RF’s shall be greater than 1.0.	13/09/24	IF
3.2.2.d	<u>Stability</u>: the applied stress up to ultimate loading shall not exceed the buckling strength of any critical structural element. i.e., ultimate buckling RFs shall be greater than 1.0.	13/09/24	IF
3.2.3	**Fuselage, pod, and empennage**		
3.2.3.a	The fuselage spar shall be checked under the critical load case, ensuring that the forward or aft fuselage spar ends do not deflect by more than 5mm or twist by more than 1.0° relative to the MWP joint at limit load.	13/09/24	IF

ID	*Specification*	*Date*	*Initials*
3.2.3.b	The pod shall be checked as a beam or truss frame according to your chosen configuration, including checks of frames and longerons, or truss members at ultimate loading for the critical load case.	13/09/24	IF
3.2.3.c	The empennage VTP and HTP main spars and ribs shall be checked under the critical load case, ensuring reasonable deflections at limit.	13/09/24	IF
3.2.4	**Wing**		
3.2.4.a	The main wing spar and ribs shall be checked under the critical load case, ensuring reasonable deflections at limit. To avoid flutter, compromised flap hinge lines, and compromised mechanism alignment, the wing and flaps shall be checked for excessive deflection or twist.	13/09/24	IF
3.2.5	**Joints**		
3.2.5.a	The wing root joint, wing to fuselage joint, pod to fuselage joints, and empennage to fuselage joints shall be checked under the critical load case, ensuring all failure modes have satisfactory RF's.	13/09/24	IF
3.2.6	**Fuselage and wing testing**		
3.2.6.a	To verify loading performance, a representative assembly of fuselage spar, wing spars and HTP spar "Graphite Goose" shall be tested by loading to limit under simulated resultant loads with reaction at forward fuselage cg and empennage spar positions to represent load Case 1). See DRG C5. A fuselage frame and a wing rib and primary joint fittings shall also be nominally tested using bespoke testing schemed by your UAV company. See DRG C6.	13/09/24	IF

3.3 Avionics

ID	*Specification*	*Date*	*Initials*
3.3.1	**Fuselage / empennage**		
3.3.1.a	The elevator shall be capable of deflection within an angle range of [-45,+45]° degrees with respect to the HTP aerofoil mean line.	13/09/24	SB
3.3.1.b	The elevator shall be capable of deflection and hold at angles specified through either of the modes of operation below:	13/09/24	SB
3.3.1.c	Elevator angle demand via Radio Control System (RCS) or Telemetry System (TMS) in 'manual' flight;	13/09/24	SB
3.3.1.d	The elevator shall be capable of achieving the commanded positions within one degree under loading conditions up to the ultimate design load.	13/09/24	SB
3.3.1.e	Pitch angle demand via TMS in 'automatic' flight using a PID controller. The controller shall be able to automatically adjust the elevator deflection to achieve the commanded pitch angle.	13/09/24	SB
3.3.1.f	The elevator's servo motor(s) shall be sized according to power and torque requirements, and spec'd in line with the availability of OTS products and suppliers.	13/09/24	SB
3.3.1.g	The elevator shall transition between maximum and minimum elevator angle less than 1.5 seconds.	13/09/24	SB
3.3.1.h	The rudder shall be capable of rotation within an angle range of [-40,+40]° degrees with respect to the VTP aerofoil mean line.	13/09/24	SB
3.3.1.i	The rudder shall be capable of achieving the positions to within one degree of demanded angle, under loading conditions up to the ultimate design load.	13/09/24	SB
3.3.1.j	The rudder control system shall provide rudder angle demand via RCS in 'manual flight'.	13/09/24	SB
3.3.1.k	The rudder's servo motor(s) shall be sized according to power and torque requirements, and spec'd in line with the availability of OTS products and suppliers.	13/09/24	SB
3.3.1.l	The rudder shall transition between its maximum displacement limits (i.e. maximum left and right deflection) in less than 1.5 seconds.	13/09/24	SB
3.3.2	**Wing**		
3.3.2.a	The flap shall be capable of rotation within an angle range of at least [0-30]° degrees from its undeployed configuration.	13/09/24	SB
3.3.2.b	The flap shall be capable of deployment and hold at specified take-off (TO), cruise (CR) and landing (LD) configurations through flap angle demand via TMS.	13/09/24	SB
3.3.2.c	The flap shall be capable of achieving the positions to within one degree of demanded angle, under loading conditions up to the ultimate design load.	13/09/24	SB
3.3.2.d	The flap's servo motor(s) shall be sized according to power and torque requirements, and spec'd in line with the availability of OTS products and suppliers.	13/09/24	SB
3.3.2.e	The flap shall fully deploy in less than 5 seconds.	13/09/24	SB
3.3.2.f	The flap shall fully retract in less than 5 seconds.	13/09/24	SB

3.3.2.g	The aileron shall be capable of rotation within an angle range of [-30,+30]° degrees with respect to the wing aerofoil mean line.	13/09/24	SB
3.3.2.h	The aileron shall be capable of achieving the positions to within one degree of demanded angle, under loading conditions up to the ultimate design load.	13/09/24	SB
3.3.2.i	The aileron's servo motor(s) shall be sized according to power and torque requirements, and spec'd in line with the availability of OTS products and suppliers.	13/09/24	SB
3.3.2.j	The aileron shall move between is maximum positive and negative displacements in less than 1.5 seconds.	13/09/24	SB
3.3.3	**Sensing**		
3.3.3.a	Flight data, including but not limited to wind speed (from wind tunnel equipment and/or pitot tube mounted to pod/wing), aerodynamic loads (from tunnel balance), wing angle of attack and fuselage pitch angle (from FCS and/or tunnel), flap, aileron, elevator and rudder angles (from mechanism conversion curve or selected device), pitch control behaviour, and static pressure (from wind tunnel and wing taps (differential)) shall be logged.	13/09/24	SB
3.3.3.b	Logging of all data should be at minimum 5Hz and ideally at >20Hz.	13/09/24	SB
3.3.4	**Control**		
3.3.4.a	A PID-based stability augmentation system (SAS) shall be implemented and tuned via the provided FCS in order to provide artificial damping and pitch angle hold to longitudinal control of the aircraft in pure pitch motion.	13/09/24	SB
3.3.4.b	The SAS shall be permitted to be enabled and disabled via TMS and RCS.	13/09/24	SB

3.4 Full UAV assembly

ID	*Specification*	*Date*	*Initials*
3.4.1.a	A full UAV assembly shall be delivered according to the project schedule.	13/9/24	MG

4. Verification, documentation, quality, and safety

4.1 Verification

ID	*Specification*	*Date*	*Initials*
4.1.1	Design verification shall include on-bench testing, structural testing and wind-tunnel testing. See appendix for schematics of the test arrangements and fixtures.	13/09/24	MG
4.1.2	During the fuselage/empennage wind-tunnel test, masses representing a motor of 1kg, flight battery of 1kg, and a payload of 1kg shall be securely attached within the fuselage, with some allowance for location and mass balance adjustment. See DRG B3.	13/09/24	MG
4.1.3	The UAV and its sub-assemblies must be inspected and pass-off tested prior to entry into the wind tunnel. Requirements of the pass-off/bench tests will be developed by the company and approved by the customer.	13/09/24	MG

4.2 Documentation

ID	*Specification*	*Date*	*Initials*
4.2.1	Autodesk Inventor will be used for all 3D CAD modelling and drafting (file formats: .ipt, .iam, .dwg).	13/09/24	MG
4.2.2	A General arrangement aircraft drawing, full sets of parts drawings, and assembly drawings shall be made available to the customer, fully defining the geometry of the UAV and its components.	13/09/24	IF
4.2.3	Electrical schematic drawings shall be created in SkyCAD and follow the conventions of BS EN IEC 61082:2015.	13/09/24	MG
4.2.4	Circuit diagrams (if required) will be created in KiCAD.	13/09/24	MG
4.2.5	A full set of drawings, including electrical schematics, shall be made available to the customer. Mechanical component drawings will be created according to BS 8888:2020 and use a 3rd Angle Projection system. The provided UoB drawing templates shall be used.	13/09/24	MG
4.2.6	The company must ensure adequate change control and secure storage of technical documentation. All document storage should be within the UoB provided OneDrive or Sharepoint systems. All important Company, Division and Team communications and documentation should be stored within the provided Microsoft Teams site and Private Teams channels.	13/09/24	MG

For further documentation requirements see *Deliverables Document*.

4.3 Quality

ID	*Specification*	*Date*	*Initials*
4.3.1	Your company must inspect any assembly prior to placement in the wind tunnel. You shall confirm that: - There are no loose surfaces or items on the UAV that may become displaced during testing. - All cables are properly tethered and cannot become dislodged, so as to enter/damage the tunnel fan.	13/09/24	MG

4.4 Safety

ID	*Specification*	*Date*	*Initials*
4.4.1	No system on the UAV, or directly connected to the UAV shall have any electrical voltage of more than 15 volts (DC or AC).	13/9/24	MG

4.5 Materials and Manufacturing Process

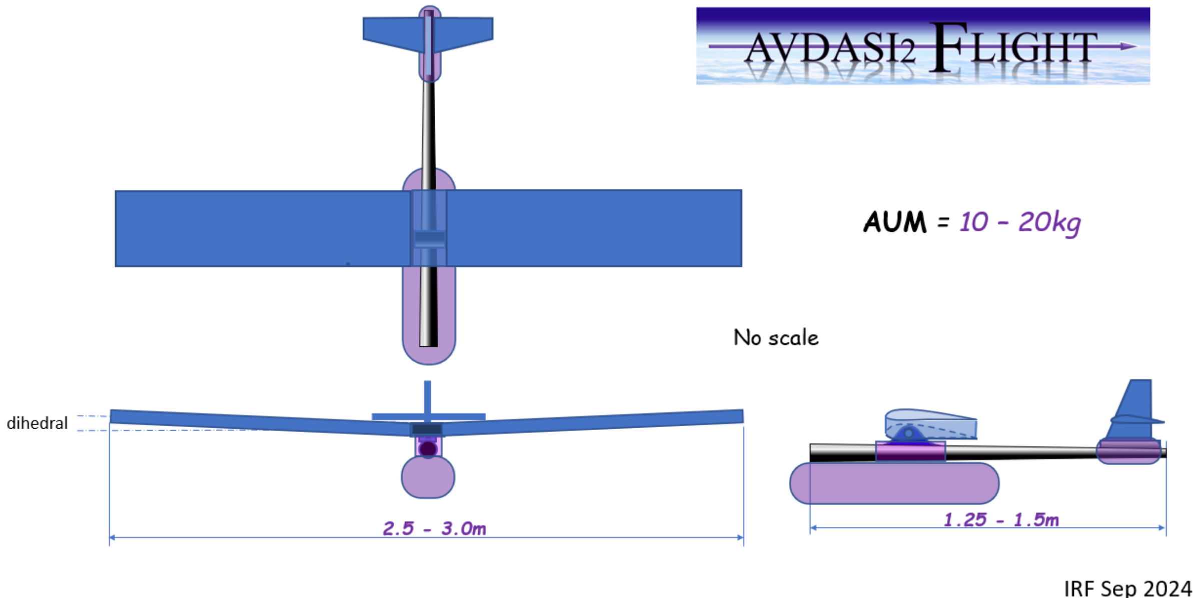
ID	*Specification*	*Date*	*Initials*
4.5.1	**Materials**. All materials shall be selected from the AVDASI2 sanctioned list. Other materials and manufacturing methods may be considered but must be agreed with a Unit academic.	13/9/24	MG
4.5.2	**Jigs**. Machine-building-system extruded ally sections to be used as Jig bases for optimum tolerance control.	13/9/24	MG

Note, these requirements are not exhaustive and further directives may be issued during the design and build stages. Please check Aerodynamic, Structures and Mechanism Actuation & Control documents on Blackboard for further detailed instructions.

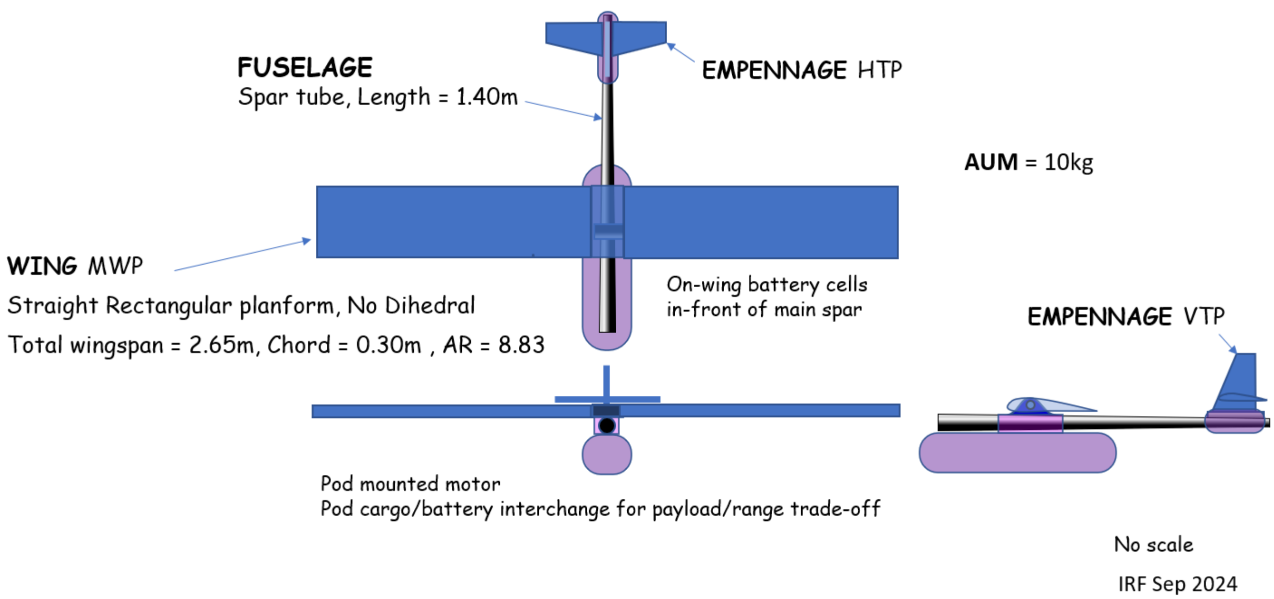
5. Appendix: drawings

5.1 Appendix A – UAV

Note: The dimensions in Drawing A1 represent potential ranges for future UAV development. For specific dimensions relating to your design exercise please refer to the 2024-UAV DRG's.

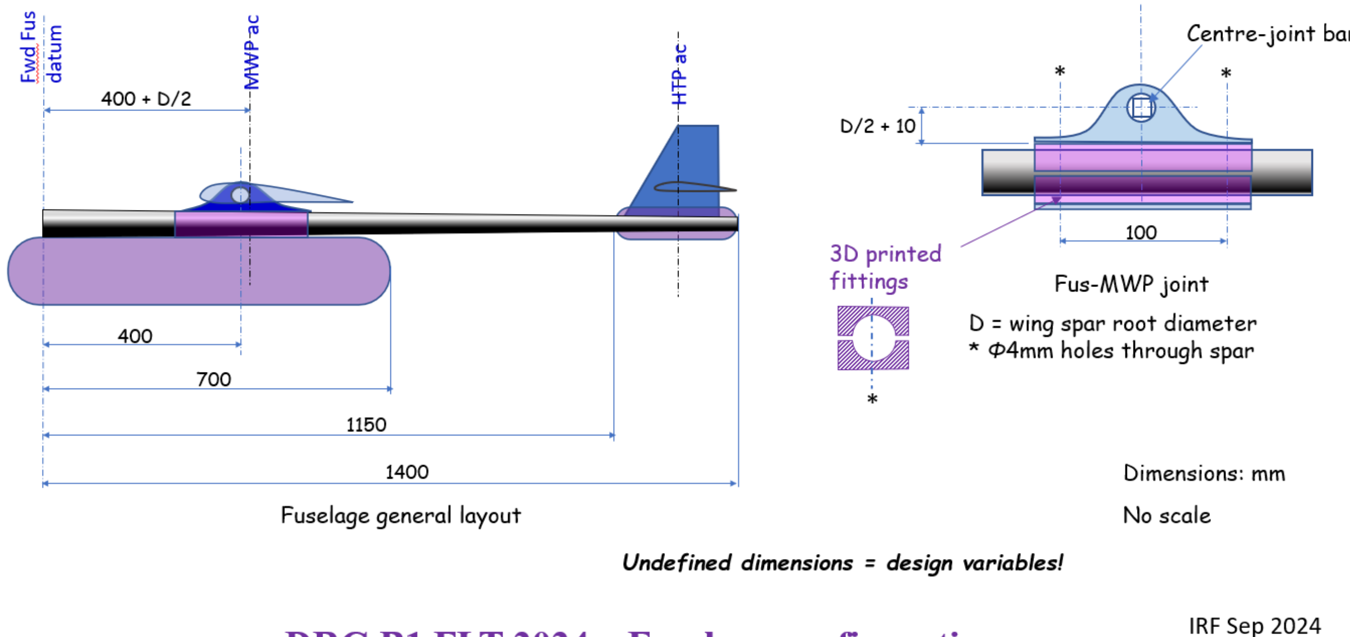


DRG A1 UoB ~~FLT~~ 20□□ - UAV

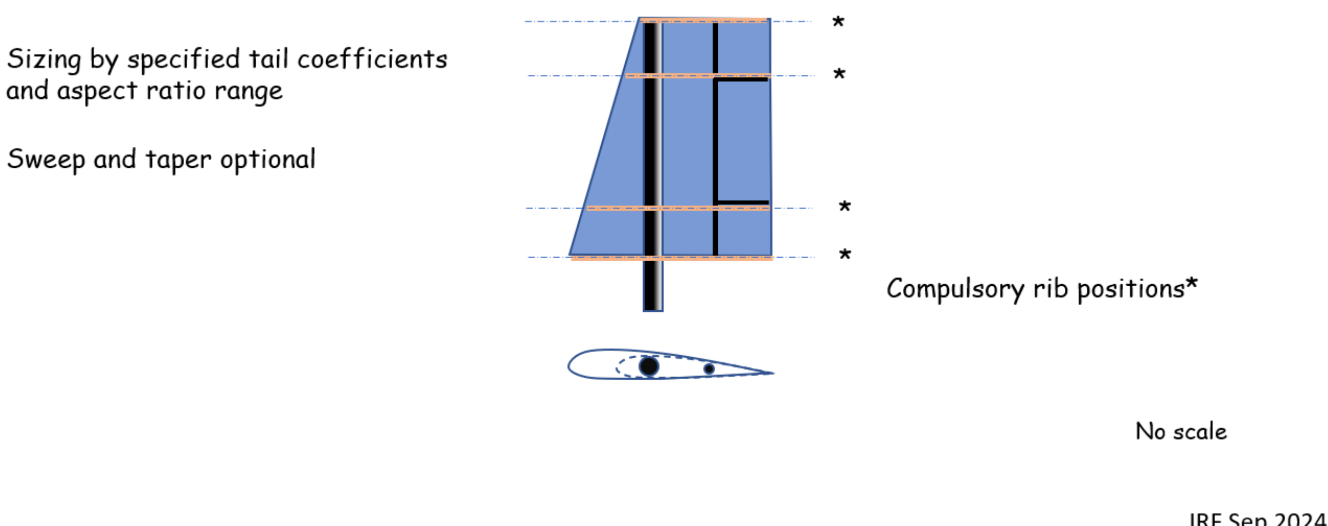


DRG A2 UoB FLT 2024 - UAV

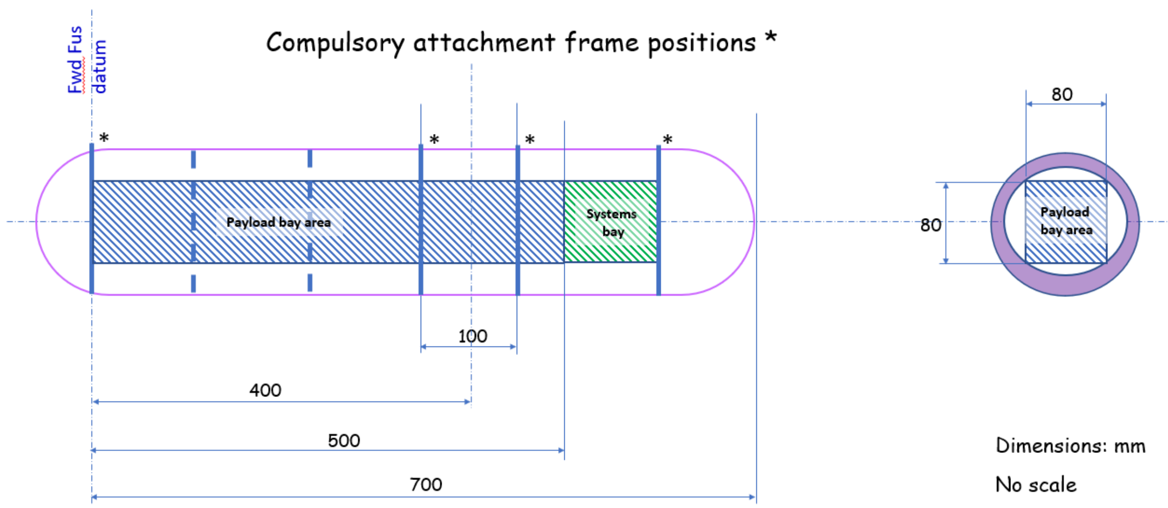
5.2 Appendix B – Fuselage, pod, and empennage



DRG B1 FLT 2024 – Fuselage configuration

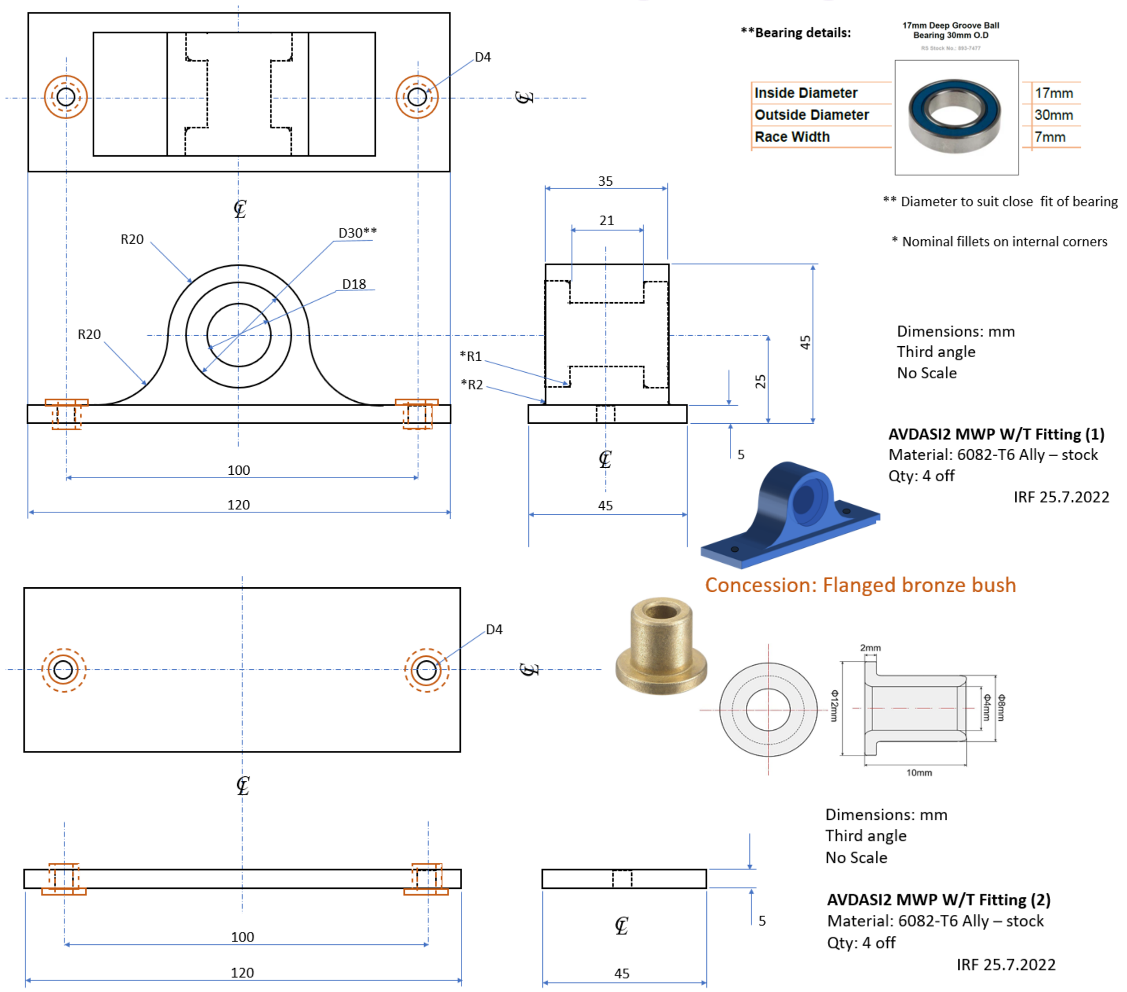


DRG B2 FLT 2024 – Empennage configuration

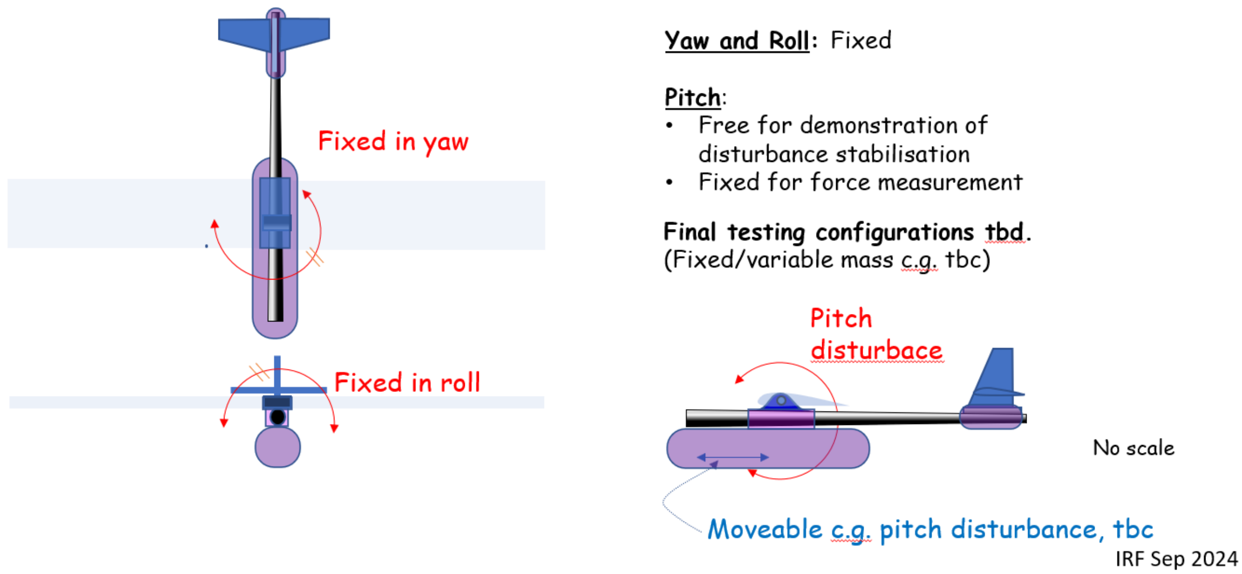


DRG B3 FLT 2024 – Fuselage Pod configuration

IRF Sep 2024

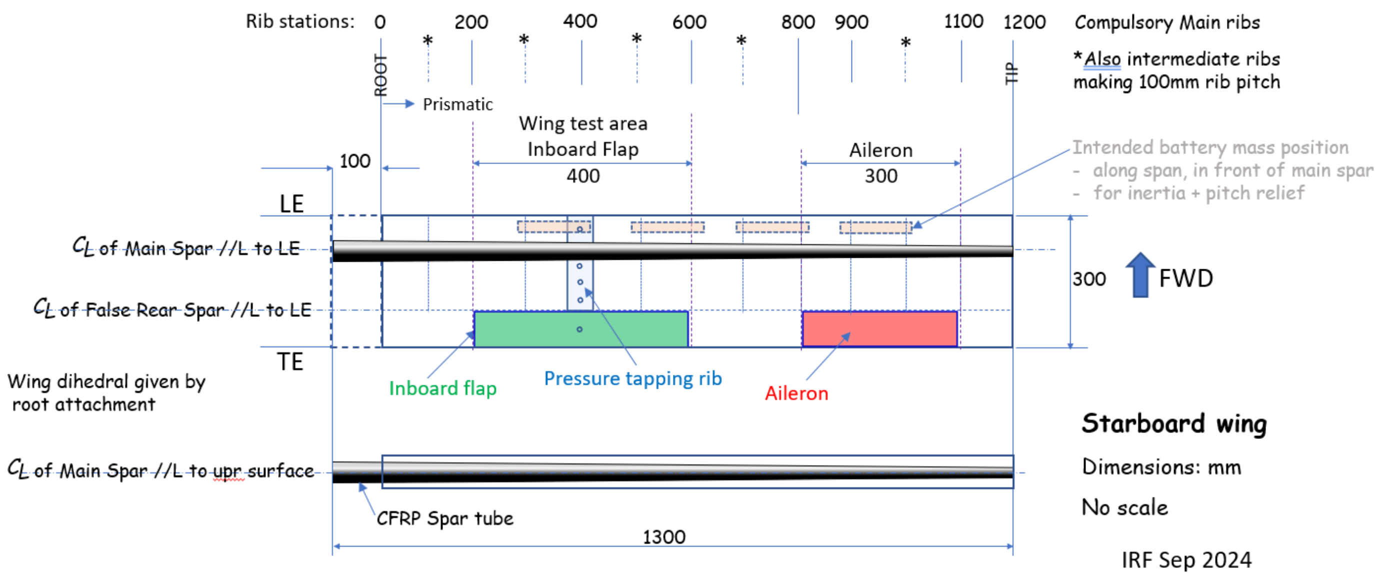


DRG B4 FLT 2024 – Fus-MWP joint fitting for wind tunnel test

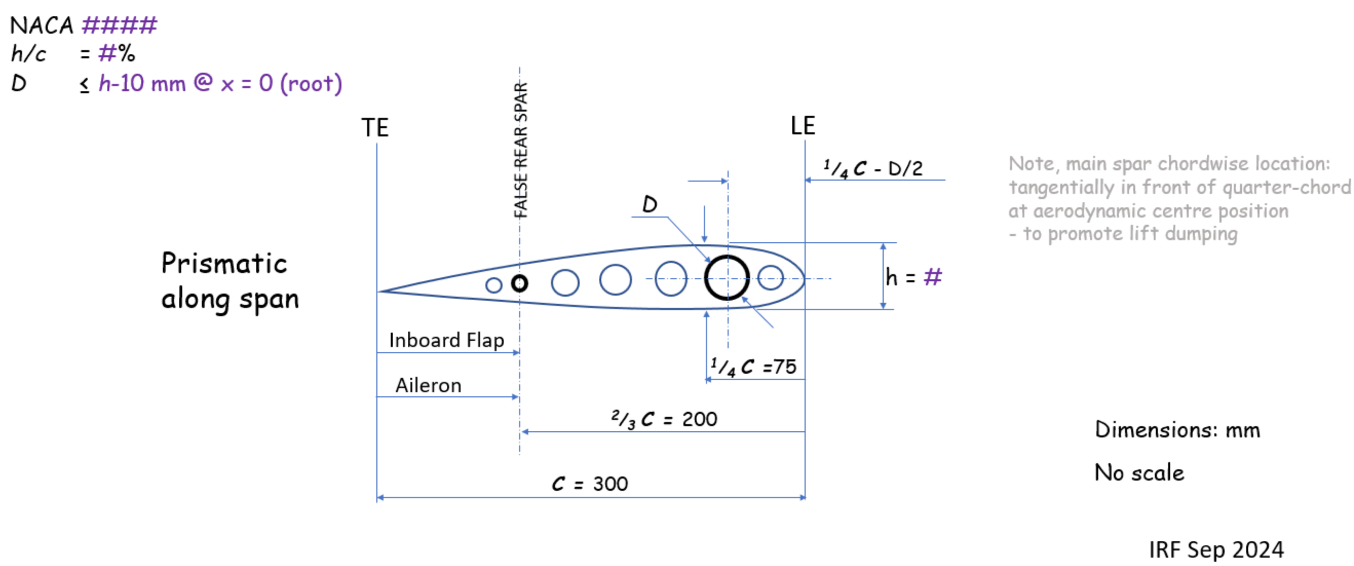


DRG B5 FLT 2024 Fus'/Pod/Emp' wind tunnel test arrangement

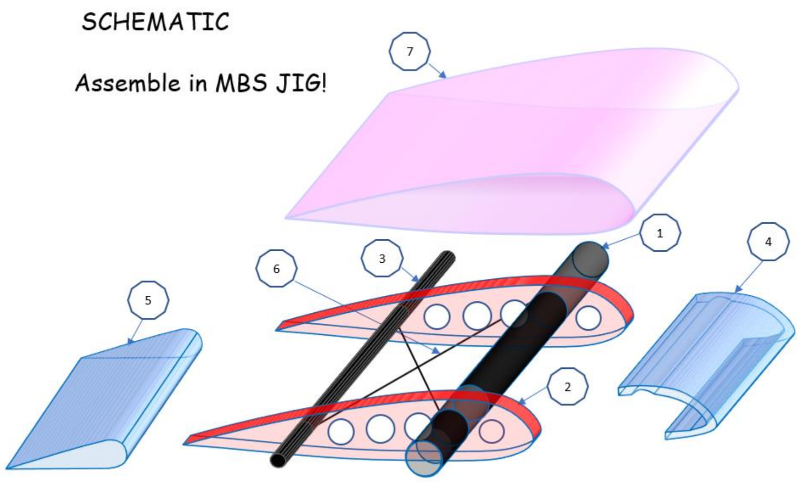
5.3 Appendix C – Wing



DRG C1 FLT 2024 - Wing Planform Configuration



DRG C2 FLT 2024 - Wing Section Configuration

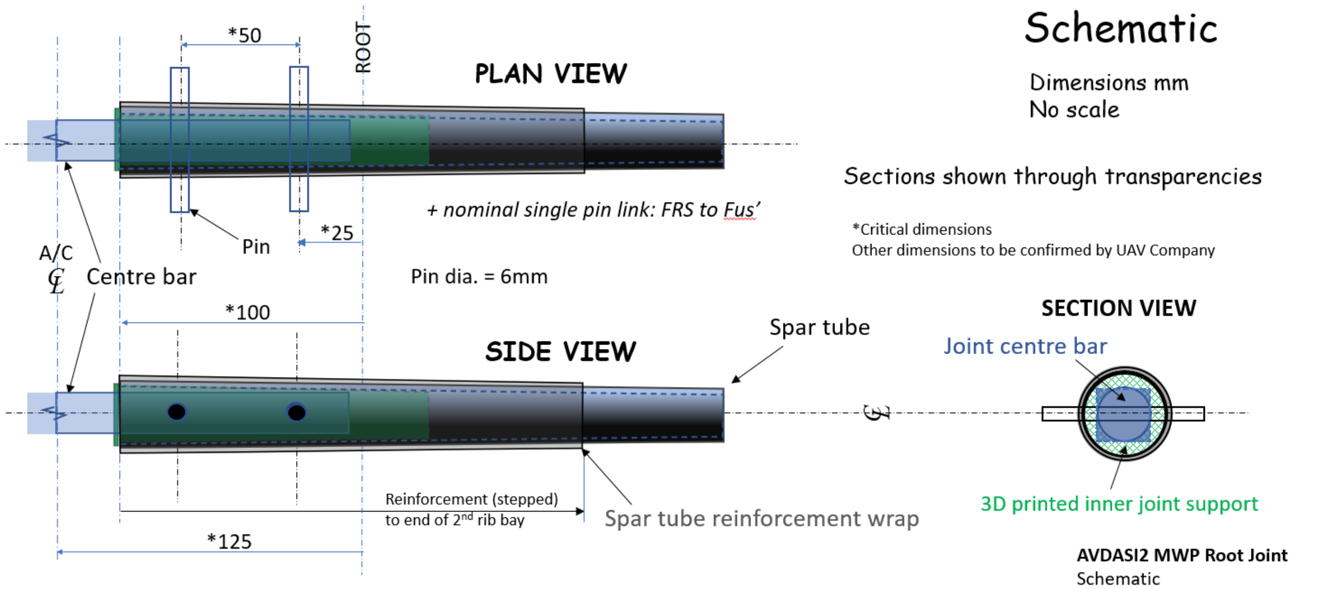


Item	Description
1	Main spar
2	Rib
3	False rear spar
4	Fixed Leading edge
5	Fixed Trailing edge
6	Cross bracing
7	Skin

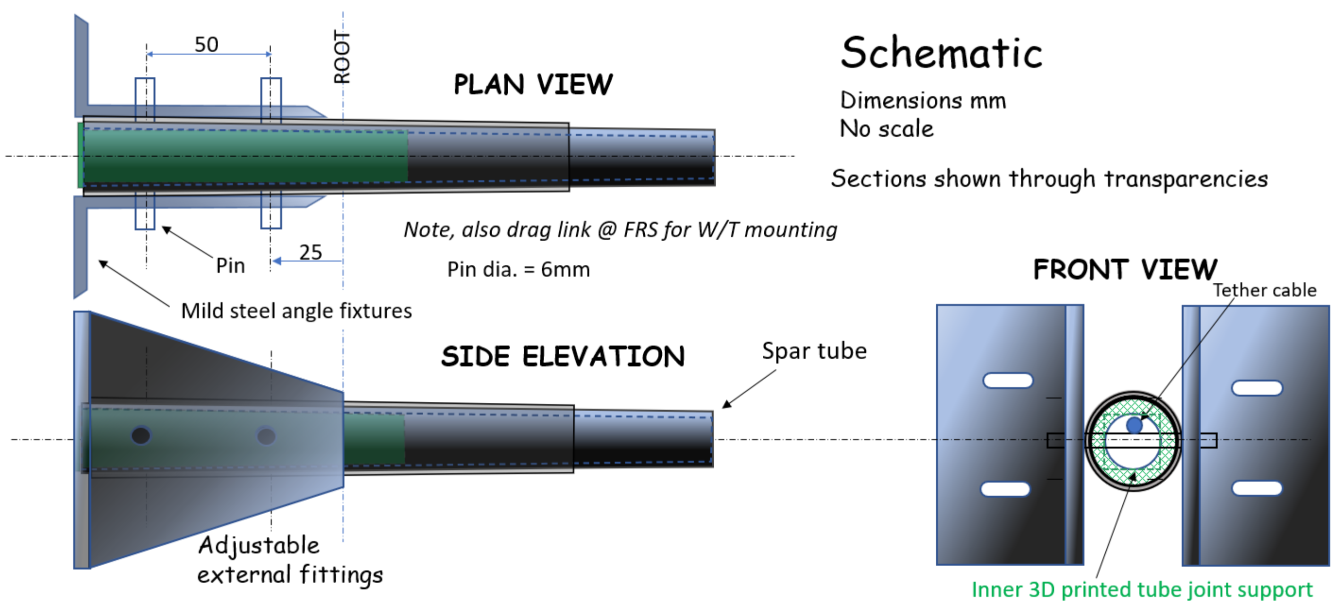
No scale

DRG C3 FLT 2024 - Wing Schematic

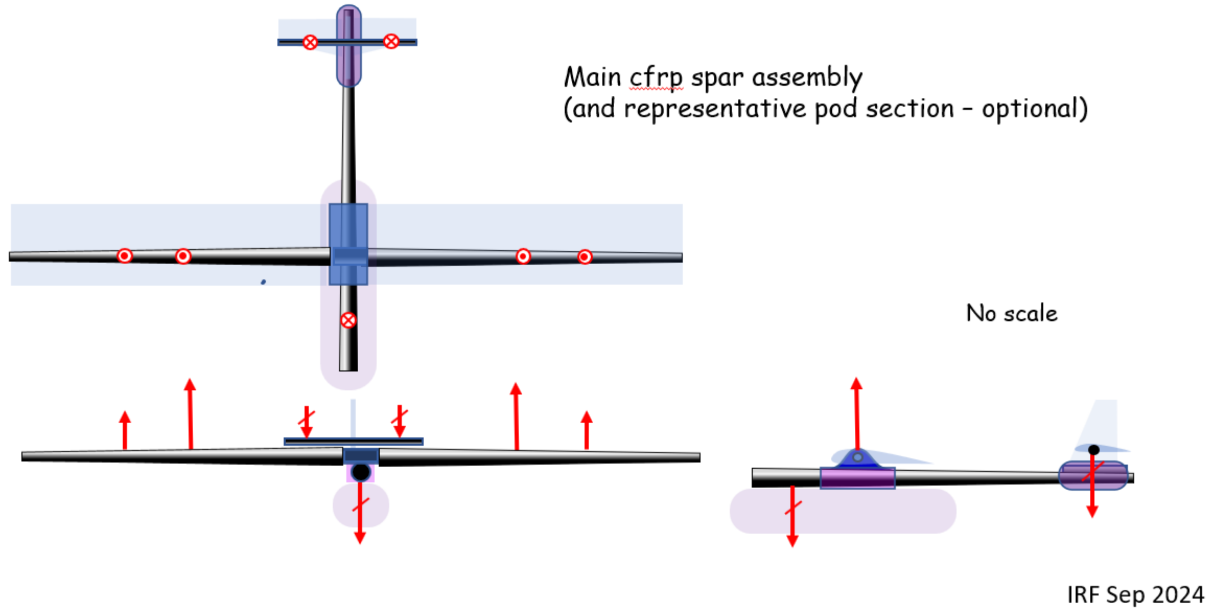
IRF July 2024



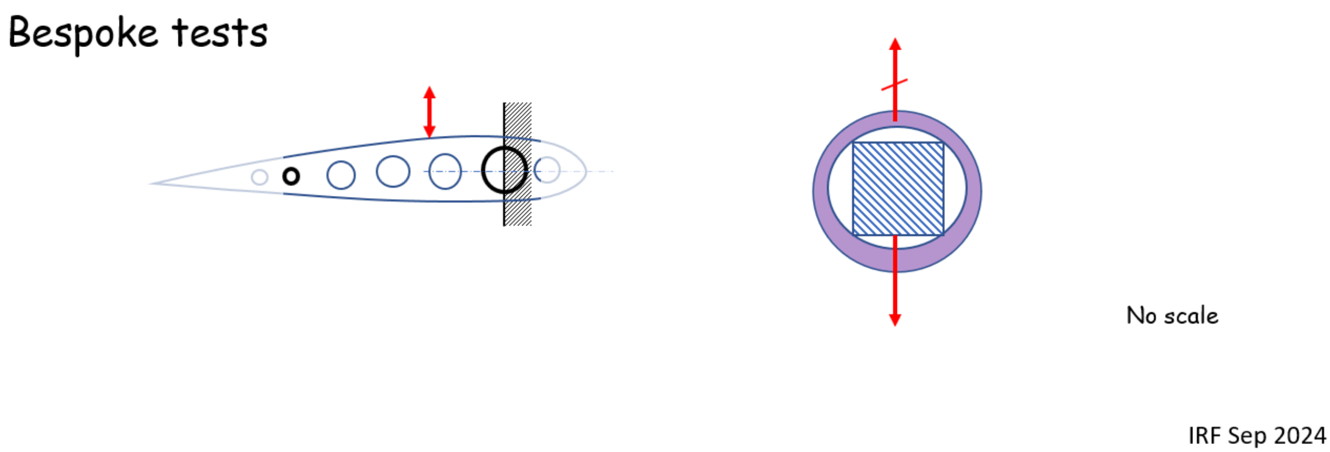
DRG C4a FLT 2024 –Wing Root Joint



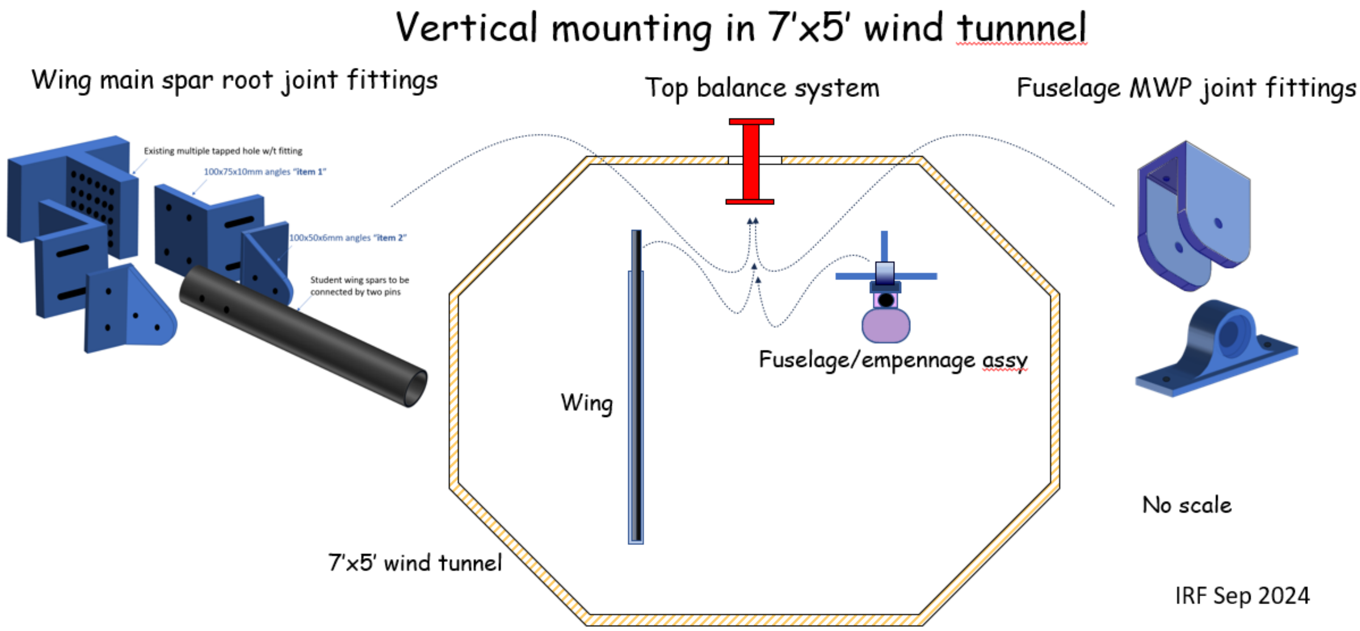
DRG C4b FLT 2024 – Wind tunnel Wing Root and Test Fittings



DRG C5 FLT 2024 “Graphite Goose” Static Structural test arrangement



DRG C6 FLT 2024 – Wing Rib and Fus frame Structural Test



DRG C7 FLT 2024 - Wing 7x5 wind tunnel test arrangement

End of document