Team 26 Technical Report to the 2025 EuRoC

TU Wien Space Team

September, 2025 - Vienna, Austria, Earth

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0 Abstract:

Lamarr is a bi-liquid propelled rocket project by the TU Wien Space Team. Designed and manufactured almost exclusively in-house, with the needed know-how slowly built up over precursor projects and the project's life cycle, the team has created a robust and lightweight rocket with the necessary testing and Ground Support Equipment to operate it safely. The rocket is designed to fly to an altitude of 9 km - thus being in the L9 launch category - using its engine powered by ethanol and liquefied oxygen and safely returning to the ground thanks to a two-stage recovery system. The engine design has been iterated over the years, with many improvements on every part from the injector over propellant feed and pressurization system and igniters to combustion chamber concepts. Special care has been put into safety throughout the project, ranging from refining checklists to be as clear as possible, over a remote-controlled oxidizer loading system to SRAD normally open vent valves and burst discs for passive depressurization. As liquid rockets need a lot more and more complex Ground Support Equipment than a typical solid-propelled rocket, a considerable amount of time has also been invested in simple and easy-to-use Mission Control software that can control both the rocket while on the pad and the GSE. The transported payload is a part of a bachelor's thesis from the Technical University of Vienna.

1 Introduction:

TU Wien Space Team is a student organization engaging in various projects in aerospace engineering. Our mission statement is to foster the know-how and enthusiasm for aerospace technologies in our peers by providing an accessible entry into rocketry and allowing members to learn. The team is working on several projects ranging from solid propelled two-staged rockets, which can reach the edge of space, to hydrogen-powered autonomous airplanes. As well as CubeSats and rockets with liquid and hybrid propulsion systems. Project Lamarr originates from previous year's project µHoubolt, which laid the foundation for the knowledge we gathered in our organization regarding building bi-liquid rocket engines. After the adventure of participating in the EuRoC 2022 and EuRoC 2024 we are now highly motivated to come back in 2025, while setting a new challenge with a more powerful liquid oxygen powered propulsion system.

Our mission objectives with our rocket named "Hedy", in memory of the Austrian actress and inventor Hedy Lamarr, are the following:

1. Flight to an altitude of 9 km
2. Successful recovery with two-stage parachute system
3. Gathering telemetry and performance data throughout the entire duration of the flight
4. Thorough documentation to preserve knowledge within our team
5. Performing a detailed test campange on subystem and integrated level

2 System Architecture:

2.1 Overview:

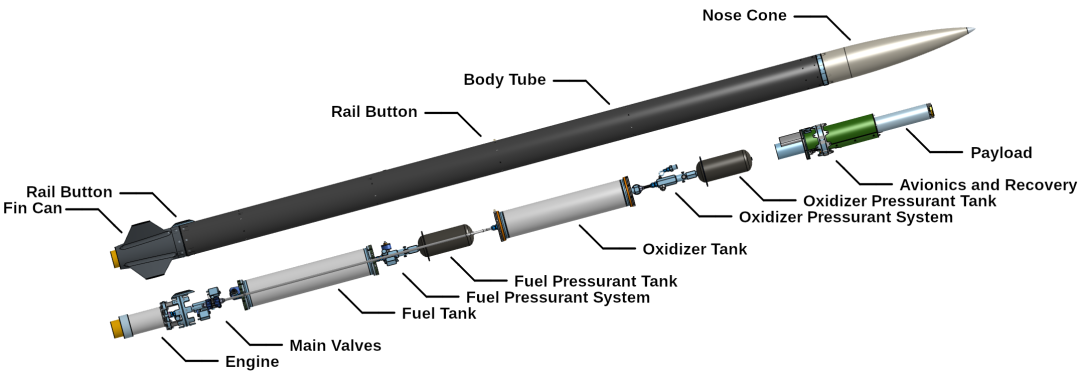


Fig. 2.1: Assembly of Hedy

2.2 Propulsion:

Thrust is provided by an SRAD pressure fed bi-propellant liquid propulsion system. It utilizes liquid oxygen and ethanol as propellants and is pressurized by two nitrogen tanks through mechanical pressure regulators. The system is optimized for simplicity, low mass and small size. All main subsystems are described in detail below: the pressurization systems, the propellant tanks with piping, valves and filling, the engine and thrust transmission. A diagram of the whole fluid system can be found in 2.8. The entire propulsion system, which is shown in figure 2.1, is assembled separately from the rest of the vehicle and can be tested stand-alone without it. It is installed into the airframe by sliding it into the body tube from the rear as one integrated component, only requiring the wiring harness to be plugged in and a few screws to be installed.

2.2.1 Pressurization Systems:

Two 1.2 L COPVs are holding nitrogen gas, pressurized to about 300 bar to pressurize each propellant tank. A two-stage pressure regulating system is located between the pressurant tanks and the propellant tanks. The first stage is a mechanical pressure reducer, originally intended for pressurizing paintball markers. In our testing, these regulators have shown some issues with providing sufficient massflow to the propellant tanks, which led to the decision to use them in a two-stage system. The first stage mechanical regulators are configured to provide 75 bar of pressure, which in theory provides the highest massflow.

Additionally, both mechanical pressure regulators are modified to ensure an even higher massflow and an output pressure of approximately 90 bar. The second stage utilises SRAD ball valves as pressurization valves that are actuated by servomotors. These motors open and close the valves to keep the propellant pressures at the entries of the venturis at a specified level. A check valve is placed after the second stage on the oxygen side to prevent the propellants from entering the pressurant tanks. After the pressurization valve in the fuel pressurization system and the check valve on the oxidizer pressurization system are custom made normally-open solenoid valves. These provide the ability to vent the propellant tanks at any point during and after the propellant filling procedure.

The mechanical pressure regulators include two burst discs, one 'high pressure' burst disc with a 517 bar burst pressure to protect the pressurant tank and one 'mid pressure' burst disc with a 124 bar burst pressure on the output. Since this output burst disc's burst pressure is much greater than the opening pressure of the magnetic vent valves and the 'low pressure' tank burst discs, this 'mid pressure' burst disc is not expected to be needed unless COTS paintball pressure regulator fails while the pressurant ball valve is fully closed off.

The pressurant system on the oxygen side consists of two manifolds that are connected through a carbon fiber encased PTFE tube which ensures a thermal decoupling between vent valve and pressurization valve, 'low pressure' burst disc and pressure sensor. The end of the smaller manifold which is screwed into the LOX tank also functions as a diffuser. Both pressurization system assemblies are axially supported by the connection to their respective propellant tank and on the oxygen side additional through the carbon fiber encased PTFE tube. Radial support against the body tube for the pressurant tanks is provided by 3D-printed plastic spacers.

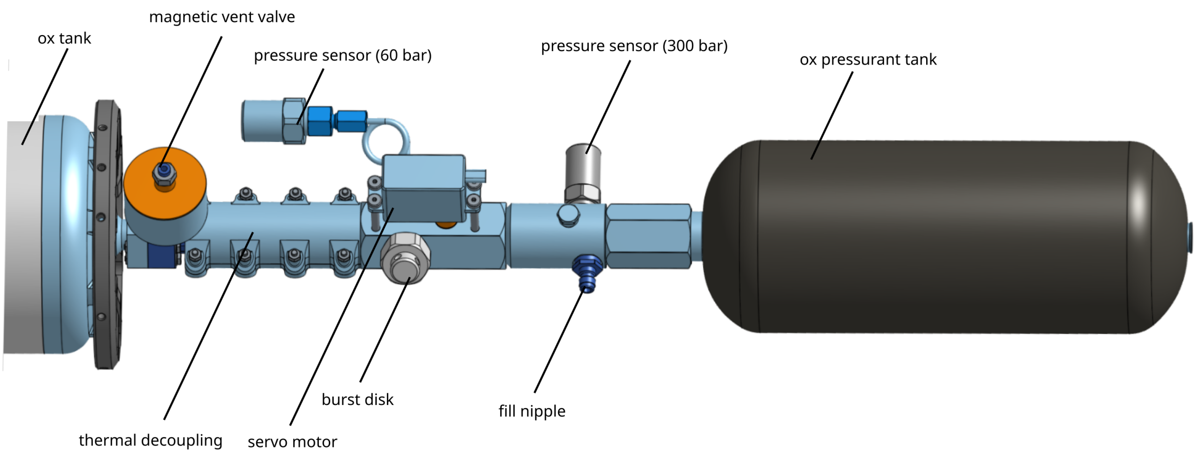


Fig. 2.2: Ox Pressurization System

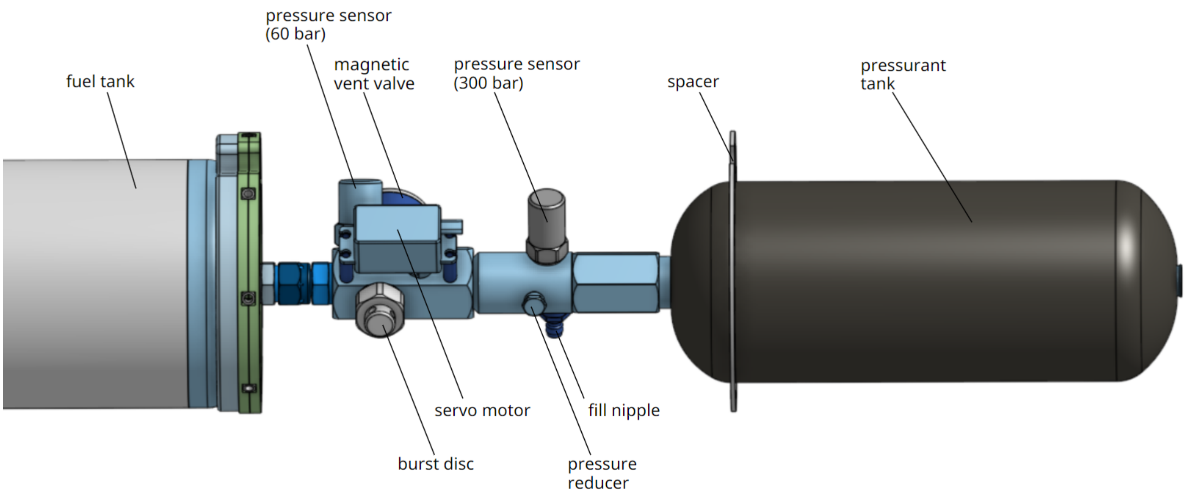


Fig. 2.3: Fuel Pressurization System

Filling:

For filling the pressurant tanks with nitrogen, two COTS quick connectors, each mounted to the mechanical pressure regulator stage, are used to connect to the filling system. The connection of both systems is done via a different type of COTS quick connector to avoid connecting the wrong connector. Filling liquid oxygen provides several challenges, especially the very low temperatures can be problematic, which is why we developed our own coupling mechanism.

2.2.2 Propellant tanks and piping:

The propellant tanks consist of three parts made from thermally curable EN AW 6082 aluminum which are welded together. The tank heads are standard toroispherical heads, milled from solid aluminium blocks with integrated connection points. The tank walls have a thickness of 2.5 mm and are welded to the tank heads using TIG welding.

The tanks were designed by the team, but are one of the few components manufactured externally. This allowed for a more optimized end-cap design to be manufactured and additionally the welds were done by a professional welder, assuring consistency. The tanks are designed to withstand an operating pressure of 50 bar with a safety factor of 2.1 before plastic deformation occurs. The tanks are designed for a burst pressure of 140 bar. Both tanks have the same shape and contain the same volume of propellant which is enough for a burn time of up to 9 s. Due to the higher density of the liquid oxygen and its natural boil-off its fill level is lower than the fill level of the ethanol at liftoff. The tanks have a diameter of 115 mm and a cylindrical length of 527 mm giving them a volume of 5.2 L and a mass of 1450 g

The main propellant lines are made out of an aluminium tube with 8 mm inner, and 10 mm outer diameter which are connected to the tanks and main valves with COTS fittings. On the LOX side the FKM o-rings in the fittings are changed to PTFE o-rings to withstand the low temperatures. The main lines below the main valves also contain the critical venturis. The main lines for LOX are also sleeved with a PTFE tube as insulation.

Both propellant tanks are held in place with milled aluminium plates that are screwed to the body tube and the tanks themselves. On the ox-side the screws allow an axial play of about 7 mm to compensate for the thermal contraction of the LOX tank without inducing mechanical stress.

2.2.3 Valves:

Main Valves:

Both main valves consist of different modified COTS ball valves, actuated by COTS servos. These modifications were necessary, particularly replacing the valve seats with materials capable of handling a cryogenic and/or a high-pressure environment, to ensure a reliable and leak-proof supply of liquid oxygen and ethanol to the engine. The valve seat materials are PTFE and PEEK. The fuel main valve housing is custom made to also accommodate a pressure sensor, mounting points for the servo, and the filling port. For the oxidizer main valve, only the flanges are custom made, for the same reasons as for the fuel main valve housing.

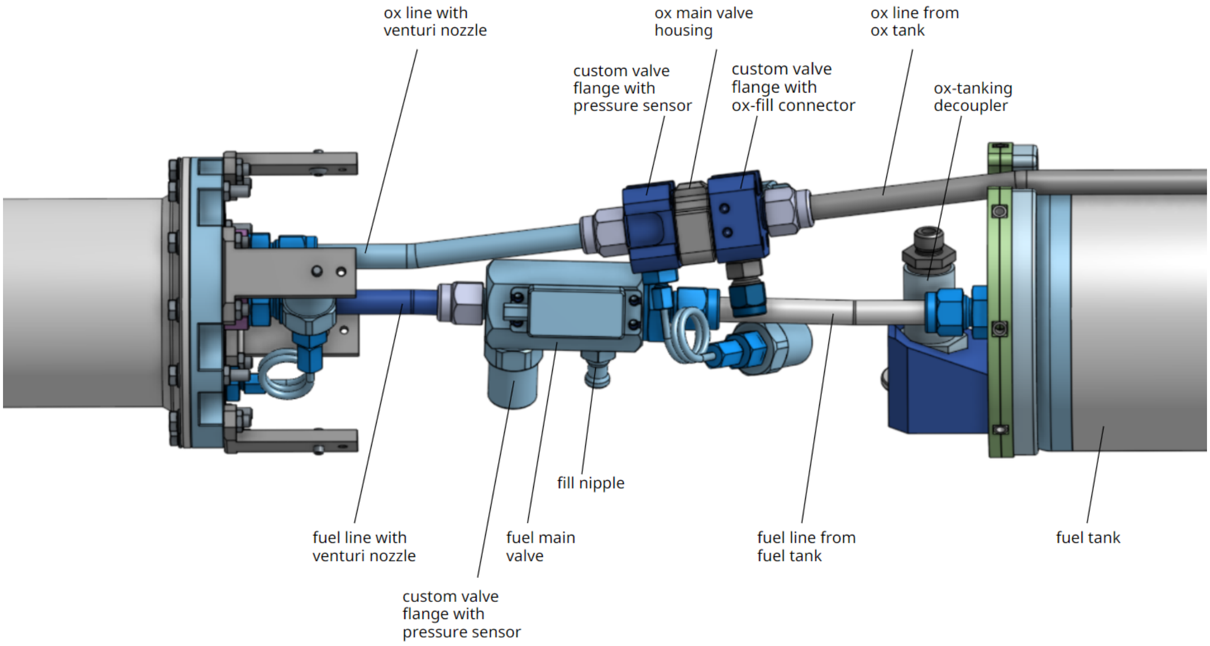


Fig. 2.4: Main Valves

Vent Valve

In order to vent our oxidizer tank filled with liquid oxygen, avoid over-pressurization of both propellant tanks and serve as a normally-open safety feature for scenario of electrical power failure each propellant system includes self-developed and manufactured vent valve (see 2.5). The mechanism involves an electromagnet (light-blue) and a steel plate (orange) that are being pulled together upon powering the magnet. The steel plate is connected to a piston-like stem that pushes a ball into an o-ring, fitted into the valve housing, through a spring mechanism. The valve is designed to open at a specific opening pressure, that is dependant on the electromagnets' force on the steel plate and the force created by the spring and o-ring compression.

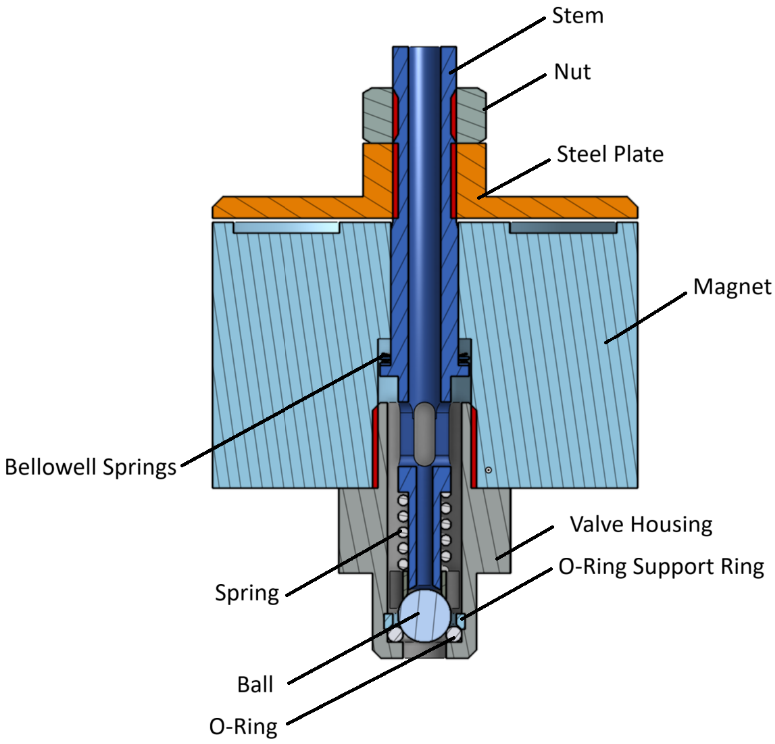


Fig. 2.5: Vent Valve

2.2.4 Engine:

The engine uses ethanol and liquid oxygen as rocket propellants with an oxidizer/fuel ratio of 1.2. A chamber pressure of 15 bar combined with a fuel rich O/F ratio is chosen to keep the temperatures in the combustion chamber relatively low, while still providing the necessary performance.

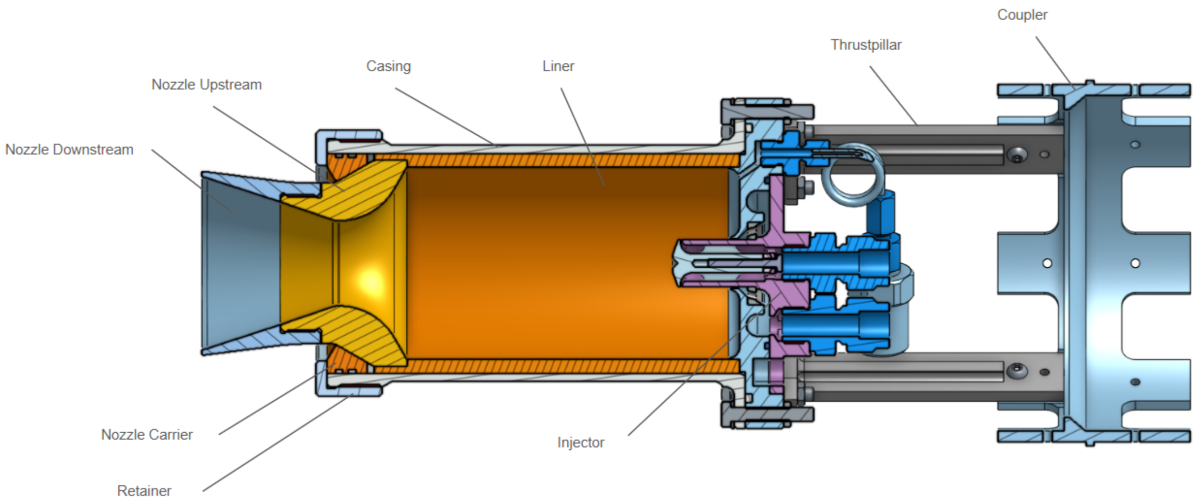


Fig. 2.6: Engine

Injector and Flow Regulation:

For the injector, we chose a pintle type with continuous liquid-liquid impingement. Pintle injectors generally offer good mixing behavior and consist of components that are typically easy to manufacture using conventional machines and tools. Both propellants enter the injector through PTFE sealed fittings. LOX flows through a rotation-inducing hole into the oxidizer distribution channel, where it overflows a lip onto the orifice plate. There, the flow direction is straightened, while the LOX flows through smaller holes aiming at a tilted surface and enters the burning chamber through the injection slit. Meanwhile, ethanol is fed through the center of the injector past the pintle with its flow straightening grooves and is injected at the pintle tip. The third fitting mounted to the injector holds the thermal decoupling for the pressure sensor. The flow regulation primarily consists of two cavitating venturis and the orifice plate, with the orifice plate solely used to direct the fluid flow. The cavitating venturis provide a constant mass flow independent of acceleration and downstream pressure. Decoupling the mass flows from the chamber pressure simplifies the feed system design and reduces the likelihood of feed-coupled instability. The cavitating venturis are pressed into the main propellant line and radially sealed with a PTFE o-ring. The cavitating venturi that regulates the fuel mass flow has a throat diameter D_t of 3.1 mm and the experimentally determined discharge coefficient C_d is 0.95. The mass flow through it for a given density ρ, vapor pressure p_{sat} and inlet pressure p is governed by the following equation, as long as the pressure drop is large enough to lead to cavitation at the throat:

$$\dot{m} = C_d * A_t * \sqrt{2 * \rho * (p - p_{sat})} \tag{2.1}$$

The critical venturi for the LOX side has a throat diameter D_t of 3.1 mm with a discharge coefficient C_d of 0.95. While p_{sat} at the ethanol side is negligible, it has a high impact on the mass flow at the LOX side due to the higher saturation partial pressure of liquid oxygen.

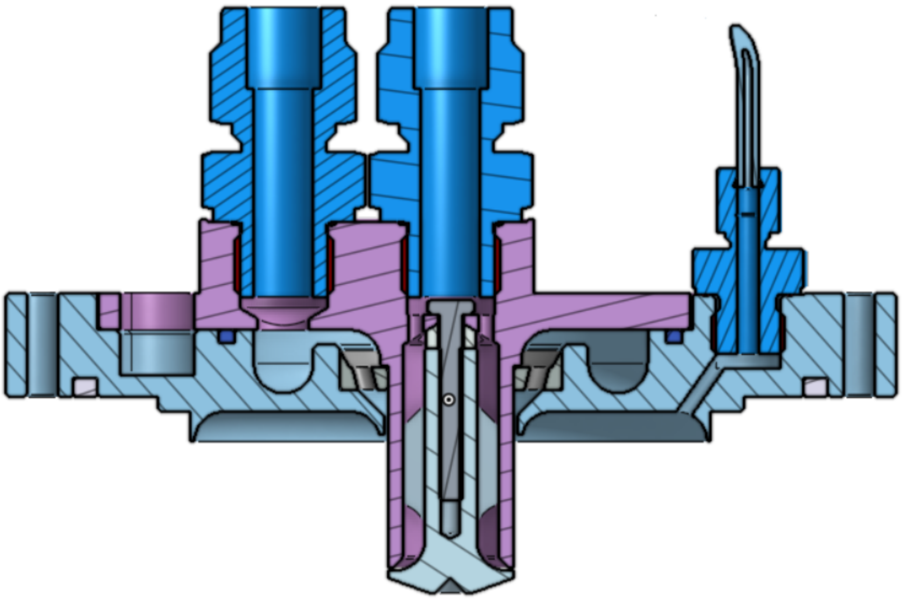


Fig. 2.7: Injector Section View

Ignition:

The ignition of the engine is achieved with an external pyrotechnic igniter that is mounted on the ground support equipment. A mixture of potassium nitrate, sorbitol and magnesium is stuck onto a wooden rod, with a 3D-printed body holding two redundant electric matches in place for the ignition of the pyrotechnic mixture. To maximize the chances of a successful engine ignition, the mixture is located in one of the thrust chamber's recirculation zones.

Mounting of the ignition system is done as one of the last steps before leaving the launchpad. Arming of this system is done remotely prior to launch.

Combustion chamber and nozzle:

The liner of the combustion chamber is made of phenolic resin and cotton, while the nozzle is made out of high-hardness graphite. During engine operation, the liner ablates, effectively insulating the surrounding casing from heat. With a wall thickness of 8 mm, the liner provides sufficient material for a burn time of 9 s at a chamber pressure of 15 bar. Due to the high temperature resistance of the graphite nozzle, the throat will ideally keep its manufactured throat diameter throughout the duration of the burn and the chamber pressure should therefore only depend on the performance of the feed system. To slow the heat transfer from the graphite nozzle to the aluminium casing an keep it from melting or getting structurally weak, the nozzle is supported by a carrier made of stainless steel. The chamber liner and nozzle are housed within an aluminium casing, which is bolted to the injector.

2.2.5 Thrust Transmission:

The thrust from the engine will be transmitted axially through aluminium pillars that connect the injector to a coupler. The lower railbutton of the rocket is connected to the coupler with two pins and two M4 screws. Additionally, the railbutton has a hook that rests on top of the coupler to better distribute the forces of the propulsion system during the hold down phase. The transmission structure is designed to withstand the full 2 kN produced by the engine for a full duration burn.

2.2.6 PnID

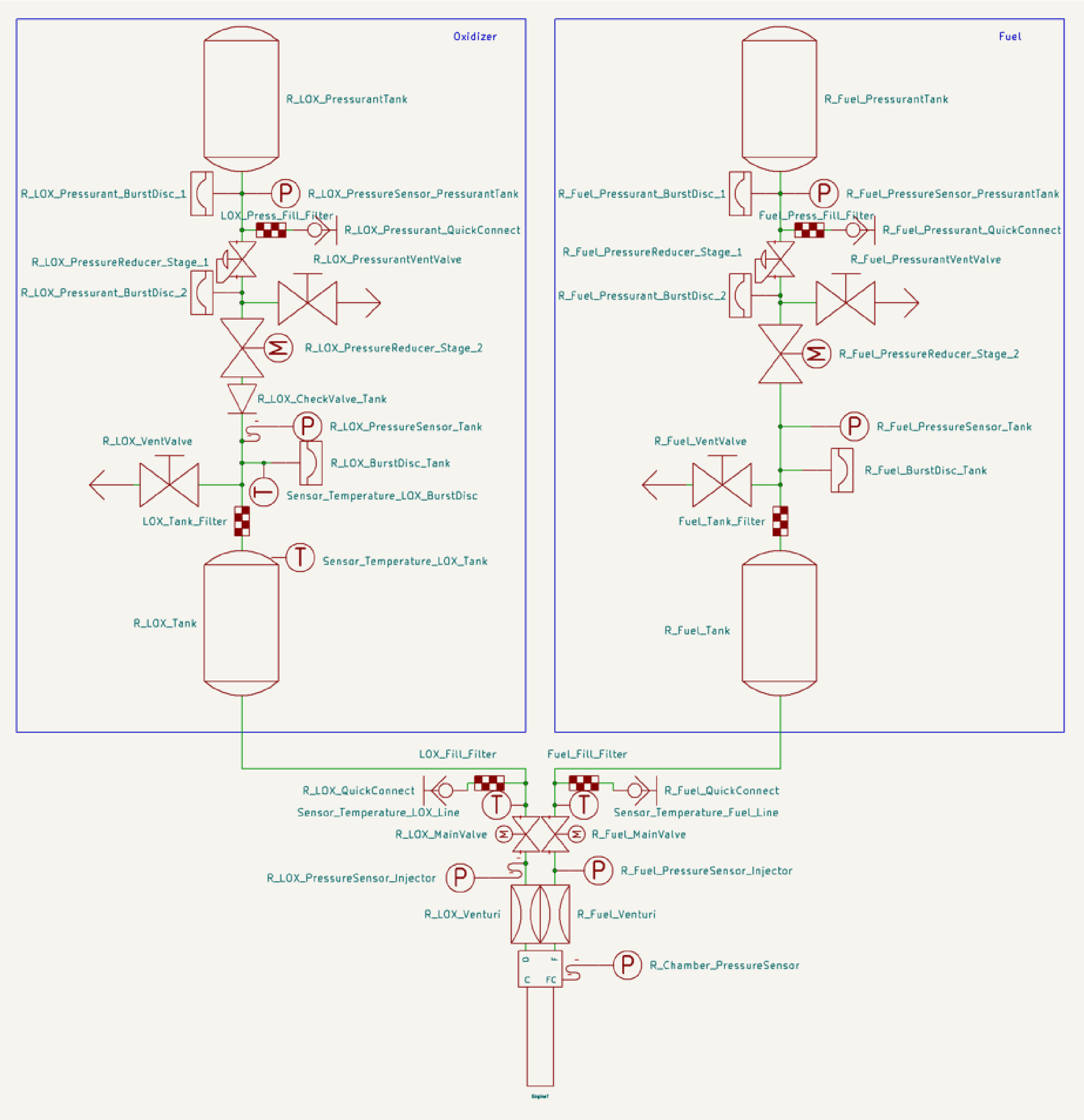


Fig. 2.8: PnID

2.3 Aerostructure:

The aerostructure subsystem consists of nose cone, body tube, fincan, railbuttons and several interfaces between the different subsystems.

For all components, the occurring mechanical loads as well as the interaction of the various subsystems had to be taken into account. Last but not least, the aesthetics of the rocket and its recognizability should also be achieved.

2.3.1 Nose Cone:

The shape of the nose cone was decided by a parametric CFD study (Figure 2.9, for which three common nose cone shapes for our targeted velocity regime are chosen to be compared. These three shapes are the LV-Haack and Von Kármán of the Haack series family as well as the power 1/2 (parabola) shape. The result of this CFD study, comparing the drag of the shapes over several velocities, is that, although all shapes are closely matched in terms of performance, the Von Kármán shape stands out. As the volume of the recovery system can be used more efficiently with an LV Haack shape, it is used and the slightly poorer performance is accepted.

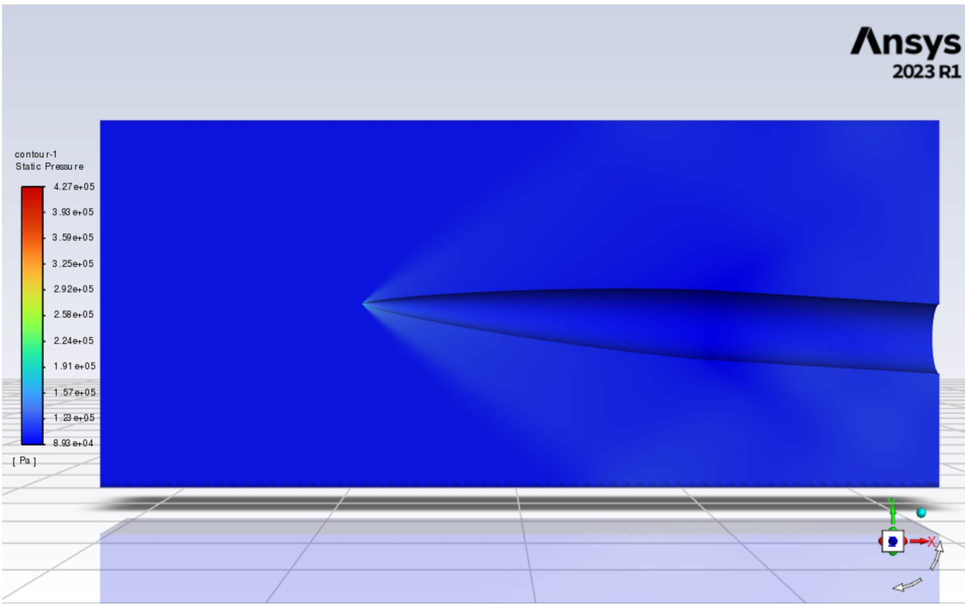


Fig. 2.9: Static pressure CFD study

The 630 mm long nose cone was manufactured from GFRP prepreg, which is transparent to electromagnetic radiation, making it the RF window of the rocket. In order to be able to laminate the same nose cone more frequently, a two-part negative mould was milled in-house from the moulding material Ureol (see Figure 2.10). This enables a cleaner workflow and less post-processing, as the surface of the end product already has a high surface quality.

Curing in an autoclave under vacuum ensures that the individual fiberglass layers are perfectly bonded together. To achieve a perfect surface, any unevenness in the laminated nose cone was coated with resin and then sanded. After cutting to the correct length and drilling the holes for the coupling, the surface is reworked again.

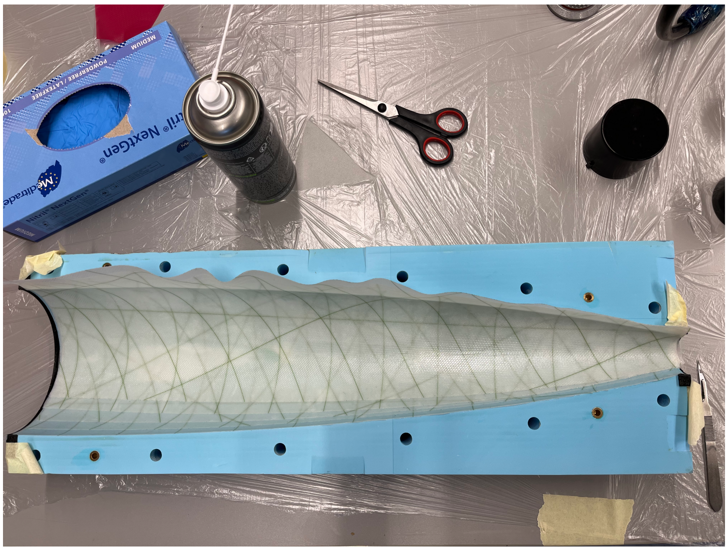


Fig. 2.10: Negative mould during the lay-up process

Compared to previous iterations of the nose cone, which were manufactured using a wet lamination process, this one is much more robust because it has maintained a uniform thickness throughout its entire circumference due to the manufacturing method and because it was hardly sanded afterward.

Since producing a clean tip during the lamination process is difficult, an approximately 75 mm long aluminum cone is turned and screwed into the top of the nose cone. A glued-in aluminum piece holds the cone in place and also holds a steel pin to attach a rope connecting to the recovery system. This allows the nose cone to be attached to the rest of the rocket during recovery.

2.3.2 Body Tube:

The 2750 mm long body tube with an outer diameter of 132.8 mm is laminated using carbon fiber prepreg, because of its lightweight characteristics. As it proves difficult to laminate a tube of this length, a process was developed that ensures a high quality result. A 3000 mm long aluminum laminating core with an outer diameter of 130 mm was used for this purpose.

The core was mounted on rollers to allow for free rotation during the laminating process. An aluminium extrusion profile was attached to the cut-to-size prepreg mat over the entire length, ensuring that the prepreg is evenly tensioned. This counteracts the majority of wrinkles. A straight line is marked on the winding core with the help of a taut cord, on which the mat is placed and flattened with laminating tools to iron out the last small creases. After all layers have been applied, a thickness of 1.4 mm is achieved and the tube is wrapped in shrinkwrap and vacuum bagged. It was then cured in an autoclave, eliminating the last remaining air pockets. After curing, the pipe is coated with a layer of resin which is sanded and polished to minimize surface drag.

Fig. 2.11: Laminating the body tube

In order to guarantee that the tube can withstand the expected bending loads, the normal forces acting on the nose cone and fincan were calculated which result in the maximum bending moment. Additionally, the thrust was also taken into account and a safety factor for the composite material was calculated using the finite element analysis software Ansys 2.12. To ensure that the centering rings can withstand the acceleration forces of the full tanks, a test ring was screwed into a test tube and weighed down with the appropriate weight.

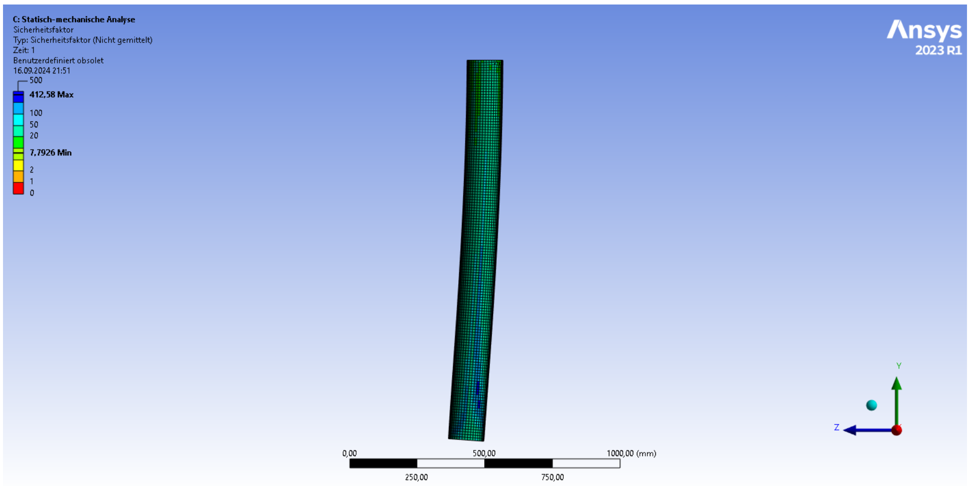


Fig. 2.12: Simulated safety factor

Coupler:

Fincan and body tube are joined using an aluminium coupler ring that provides a tight fit and is held in place via radial screws. This ring is also where the thrust from the engine is transmitted into the airframe and is explained in more detail under section 2.2.5.

The rocket's nose cone and body tube are connected through a separable coupler, which is held in place by a spring steel clamp band. At apogee, once the line keeping the clamp band in tension is severed by one of the burn wires, the coupler separates and the drogue parachute is deployed. A more in depth explanation is found under section 2.4.4.

Umbilical Feedthroughs:

To make fueling, arming and setting up pad-communication convenient, easily accessible connectors and mechanisms are necessary while the rocket is on the launchpad. For this purpose, openings for the connections are provided on the side of the airframe.

Launch Pad Mechanical Interface:

The vehicle is connected to the launch rail using two rail buttons. The upper rail button is made of brass and is mounted with a screw that is also used to hold the oxidizer tank. The location of the upper rail button influences both the stability on the rail as well as the effective length of rail available for stabilization during launch. The bottom rail button is used to support the weight of the vehicle while on the launch pad and to hold it down until successful engine ignition is confirmed. It is screwed to the airframe fincan coupler and further explained under section 2.7.2.

2.3.3 Fincan:

To bring the center of pressure well below the center of gravity and thus ensure sufficient static stability, we opted for four fins with a semi-span of 110 mm and a lightweight carbon fiber construction. The stability margin over time was simulated with OpenRocket and RocketPy as seen in figure 2.13. The fillets between fins and centerpiece are designed rather extensive, so that those areas are resistant enough especially against fin flutter. The center cone follows the same LV-Haack shape as the nose cone. The manufacturing process is exactly the same as for the µHoubolt project, the last liquid-propellant rocket of the TU Wien Space Team.

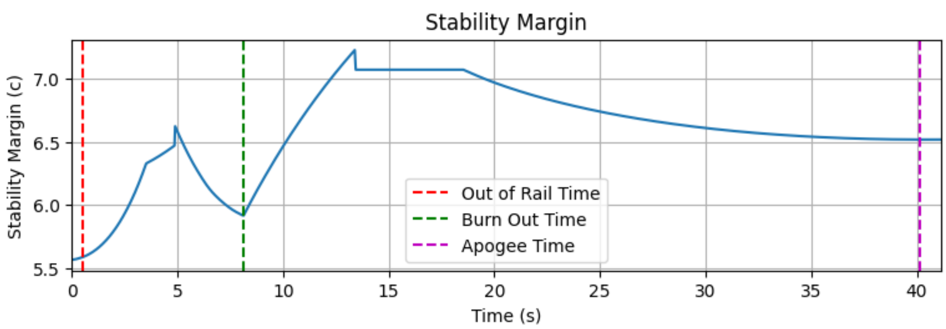


Fig. 2.13: Stability margin (cal) over time (s)

The clipped delta fin shape is based on a modified double wedge cross-section profile that was then adapted so that a positive mould could be 3D-printed in-house. This mould was sanded and gaps were filled with spray filler and treated with several thin layers of coat to seal pores and after that with release agent. Then a four-part negative mould consisting of high-temperature epoxy tooling gelcoat and high-temperature epoxy moulding paste was taken as seen in figure 2.14. This was then used to laminate with pre-preg carbon fiber.

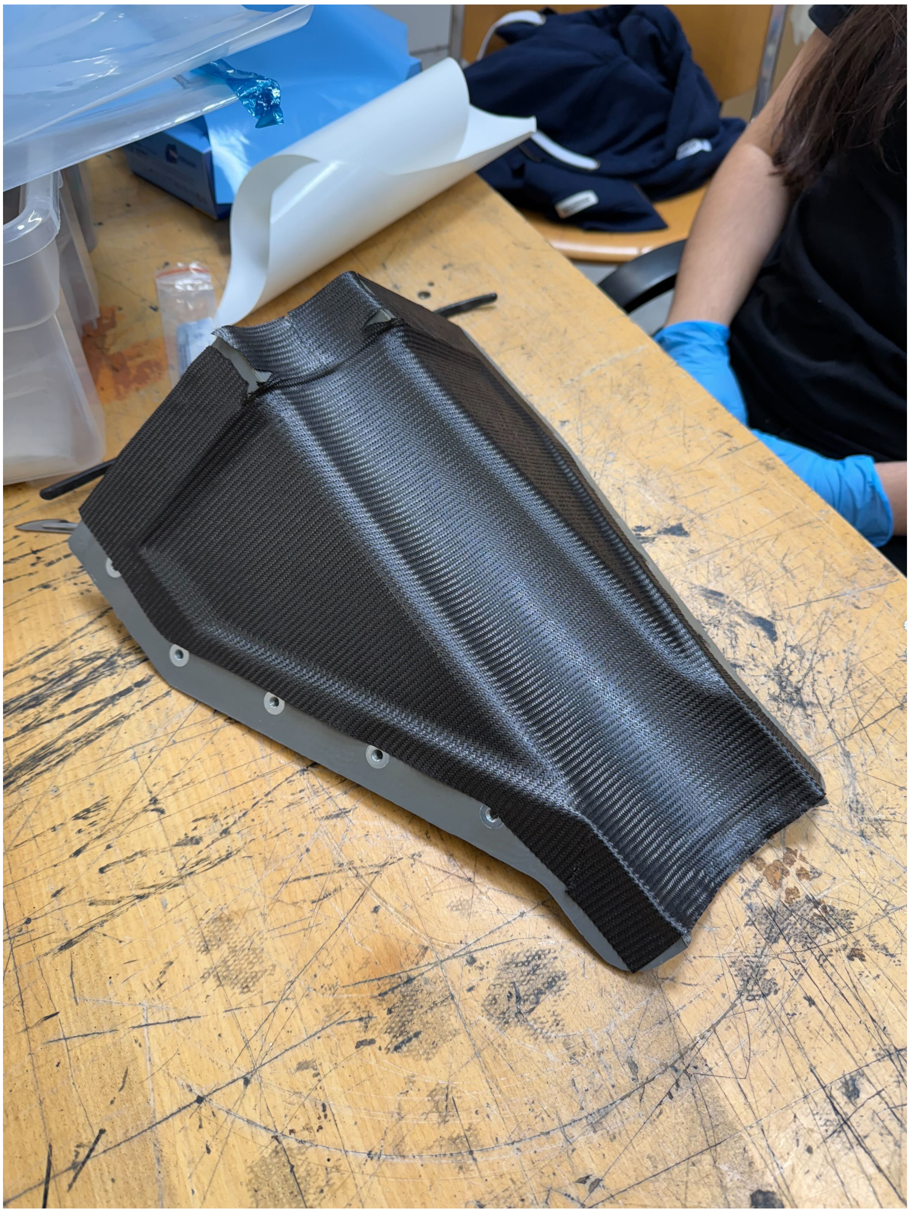


Fig. 2.14: Laminating a fincan segment into our in-house manufactuerd mould

For the fin cores Rohacell, a closed-cell rigid foam, was chosen. Those inlays are both essential for the stiffness of the fins and ensure that enough pressure is exerted on the laminate during the curing process. The boards of Rohacell foam were CNC-milled to the correct form and then placed on the four carbon fiber mats before the negative mould was assembled.

The inside of the fincan was strengthened with another three layers of carbon fiber. After being sealed in a vacuum bag and cured by being gradually heated to 135°C in the autoclave, the fincan was sanded, cut down to the lengh of 280 mm and prepared for painting with a sanded and polished resin layer.

2.3.4 Livery Design and Surface Finish:

As already mentioned, all rocket parts that are exposed to the airflow are coated with a resin layer and then sanded and polished to minimize the surface drag.

To accomplish a flawless look as well as create a surface that mitigates some of the solar heating experienced in the EuRoC launch environment, the nose cone is painted white, because it encases most of the electronics. The decision was made in favor of lacquer and against adhesive foil, since the latter has proven to be both unsightly and less resistant.

On the body tube the team name, the project name, the academic affiliation and the sponsor logos are arranged into a minimalistic design. The fincan features the Team ID and the Austrian flag. Each of them additionally displays a unique but simple graphic pattern of black and white to allow ground-based observers to track and record the launch vehicle's altitude.

To achieve a satisfactory result the whole airframe was sanded and coated with transparent primer. After drying, stencil stickers with cutouts for the markings were applied. The white paint was then sprayed on and allowed to harden. The stickers were then carefully removed and the airframe covered with a clear, glossy two-component clear coat.

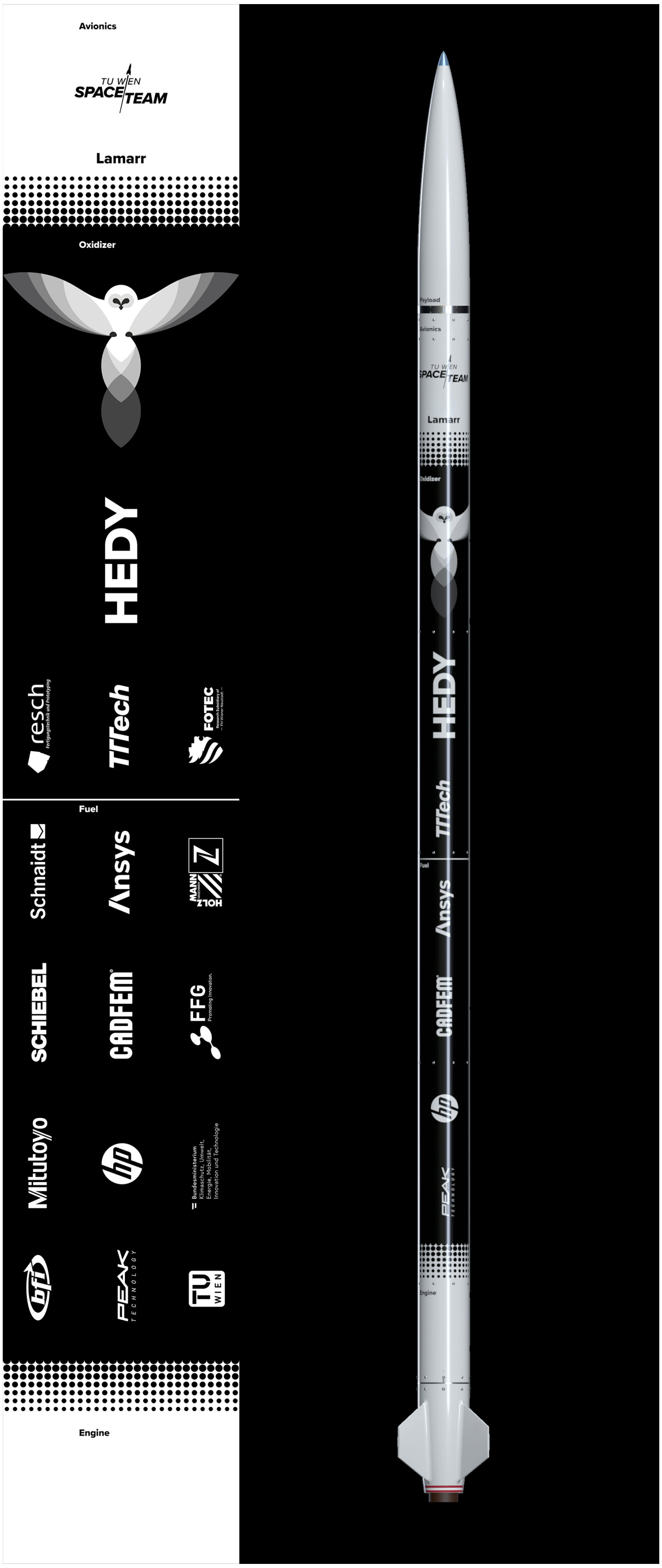


Fig. 2.15: Rocket livery design.

2.4 Recovery:

2.4.1 Recovery Overview:

Our rocket employs a fully redundant two-stage recovery system. Both the initial deployment event and the main deployment event are triggered by nichrome burn wires, which are connected to the pyro channels of the two flight computers, one Altimax G4 Altimeter acting as the main flight computer and a CATS Vega as the backup flight computer.

The rocket's nose cone and body tube are connected through a separable coupler, which is held in place by a spring steel clamp band. At apogee, once the line keeping the clamp band in tension is severed by one of the burn wires, the coupler separates and drogue parachute is deployed.

When the rocket has descended to an altitude of 450 m, the line connecting the drogue parachute to the body tube is cut and the drogue parachute pulls the main parachute out of the rocket and strips off the parachute's deployment bag.

Main and drogue parachute lines have integrated shock absorbers.

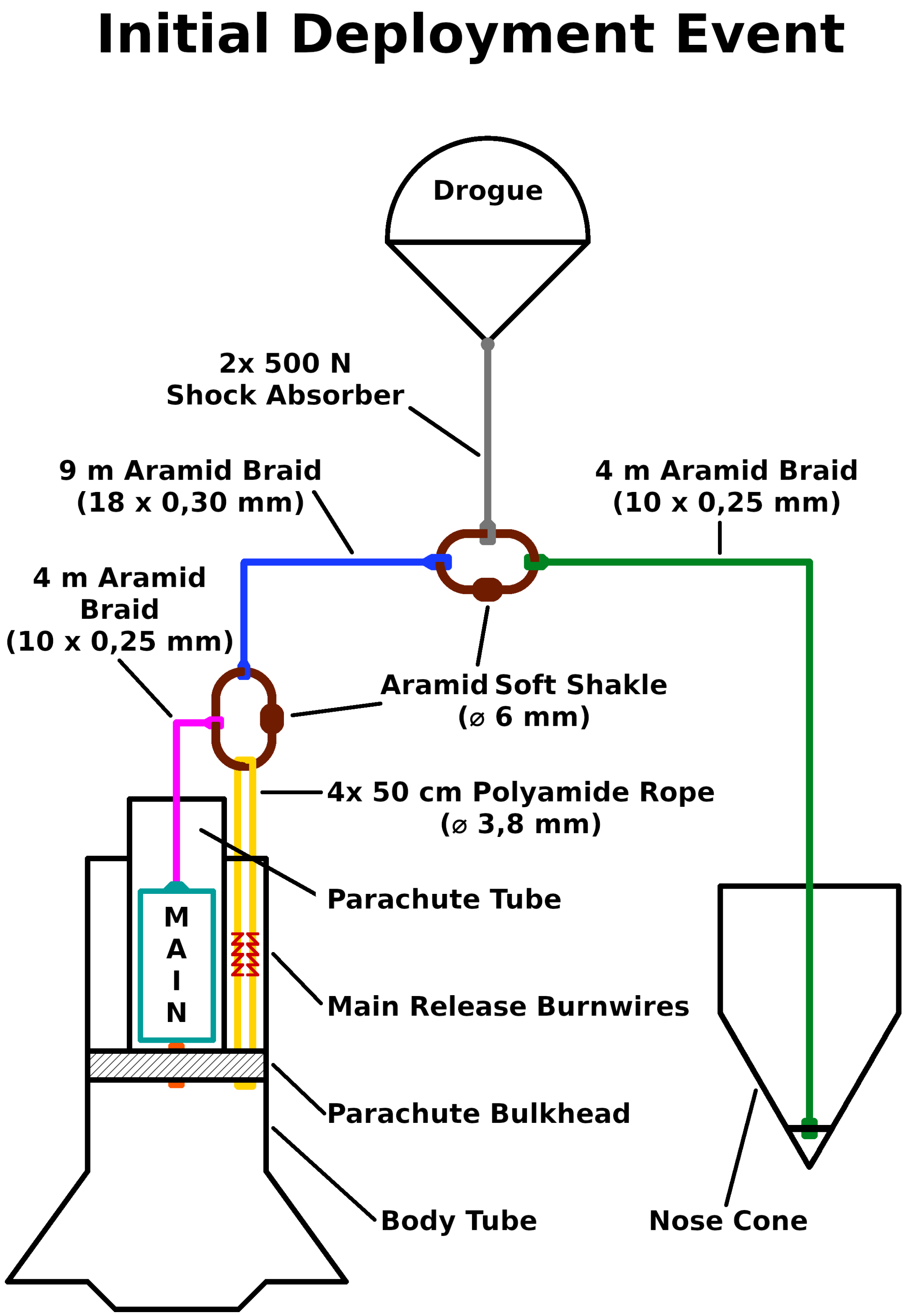


Fig. 2.16: Line diagram after the initial deployment event at apogee

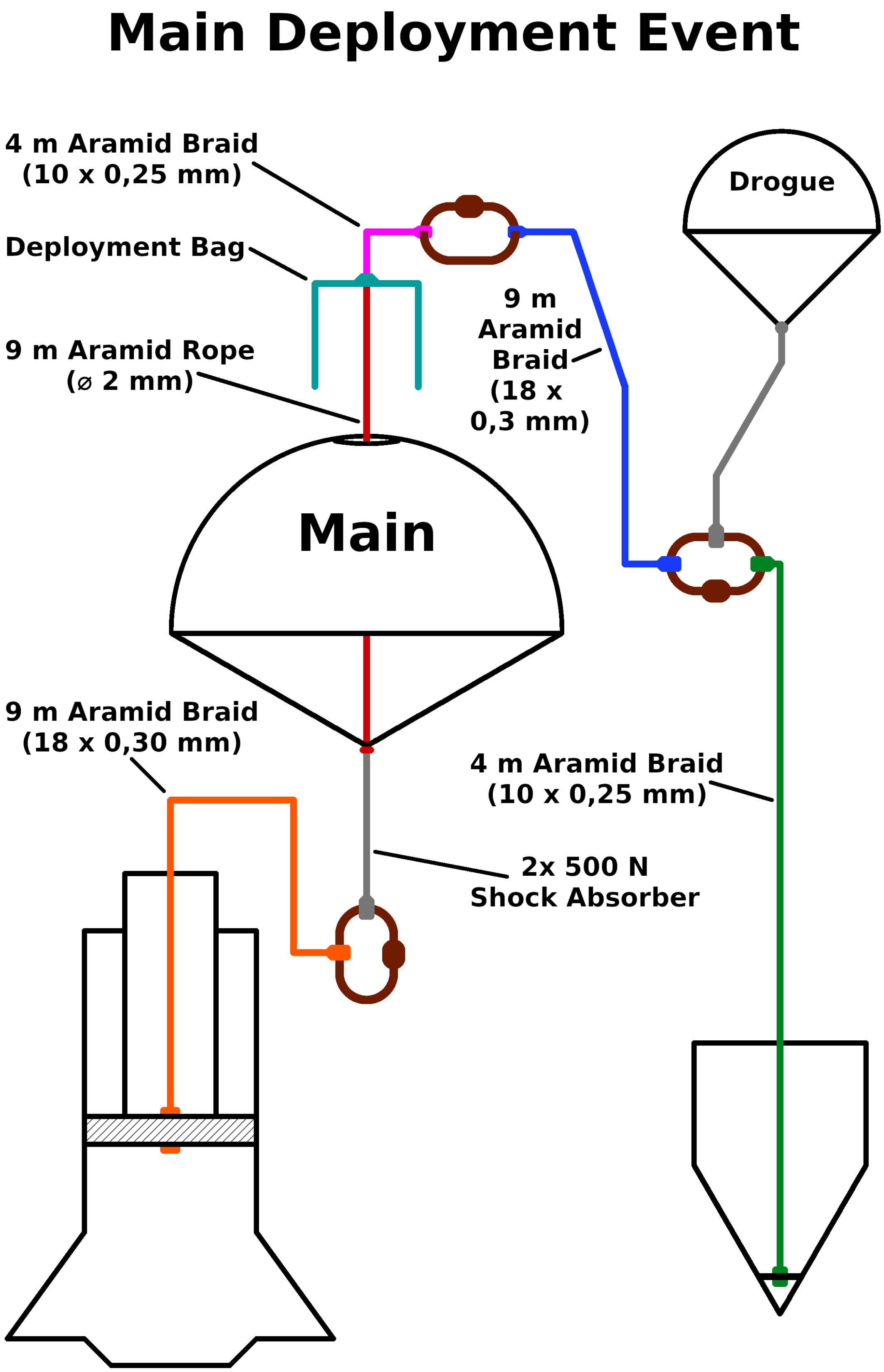


Fig. 2.17: Line diagram after the main deployment event at 450 m altitude

2.4.2 Parachutes:

The drogue and main parachutes are dimensioned such that the initial braking force of both parachutes are comparable. Since the main parachute and drogue parachute are tied to the same hardpoint inside the rocket, it can thus be efficiently designed to withstand both forces with adequate reserves.

Both parachutes are manufactured out of the canopies of decommissioned skydiving parachutes. The individual segments and gores were cut out of the fabric using a soldering iron to minimize fraying and stitched together with regular cotton thread using a sewing machine. The parachute shroud lines are fashioned out of 2 mm thick aramid cords with an individual breaking strength of 2500 N.

For the drogue parachute, a cross design was chosen since it can be manufactured easily and robustly. In addition, cross parachutes have the advantage of mitigating parachute opening shock loads and it can be easily visually distinguished during descent from the main parachute because of its shape. The edge length of the cross parachute is 35 cm and for the purpose of the drag force and terminal velocity calculations the drag coefficient was estimated to be 0.55, with the entire canopy area being used as reference area. To verify these assumptions, three previous rocket flights using cross parachutes were evaluated, with calculated and measured descent velocity matching well. Three shroud lines are sewn to each edge, for a total of twelve lines.

The main parachute is of the annular type, fashioned out of ten gores of alternating red and white parachute fabric for high contrast and visibility. The segments were laid out for a 2.1 m diameter toroidal parachute using the ChuteMaker parachute gore template generator. To calculate the drag force of the parachute, a drag coefficient of 1.8 was assumed for the toroidal geometry of the annular parachute. On each of the 10 seams a shroud line is attached.

Prior to deployment, the main parachute resides in a deployment bag fashioned out of the same tear-resistent fabric used for the canopies.

For each of the parachutes, an expected descent velocity was calculated using the drag equation:

$$F_D = \frac{1}{2} p v^2 C_D A \tag{2.2}$$

The term for the drag force F_D was set to be equal to the gravitational force F_G of the rocket, and the equation was solved for the velocity v. However, in addition to the drag force experienced by the parachute, the influence of the body tube on descent was also taken into account. The drag force experienced by a long cylinder parallel and perpendicular to airflow was calculated and then the air resistance of the body tube at different angles of attack between 0 and 90 degrees was roughly estimated using linear interpolation. For the body tube, a 3 m long cylinder with a diameter of 130 mm was assumed. The air resistance of the fins and nose cone were neglected for this estimation.

As can be seen in figure 2.18, the air resistance of the body has a significant influence on the expected terminal velocity of the rocket, especially when looking at the descent velocity after the initial deployment event. This finding is also in line with the measured descent velocity of past rocket flights undertaken by the TU Wien Space Team.

Using equation 2.2, we also calculated the expected maximum drag forces experienced by the rocket during parachute deployment. For this purpose, different deployment speeds were taken into consideration. For the initial deployment event, because of a large number of variables influencing the horizontal speed of the rocket at apogee, like wind speed and launch rail angle, a wide array of velocities was used as input for the calculations. These results can be seen in figure 2.20.

For the main parachute braking force estimation in figure 2.21, the results of the terminal velocity calculation from figure 2.18 were used.

In conclusion, the behaviour of the body tube and the resulting drag force has a large influence on terminal velocity of the rocket during the initial descent phase, in turn affecting the opening load on the main parachute significantly. That is why, in order to limit main parachute opening loads and provide ample safety margin in case the drogue parachute under-performs, a particularly large cross parachute design was chosen, targeting an initial descent velocity of around 23 m/s.

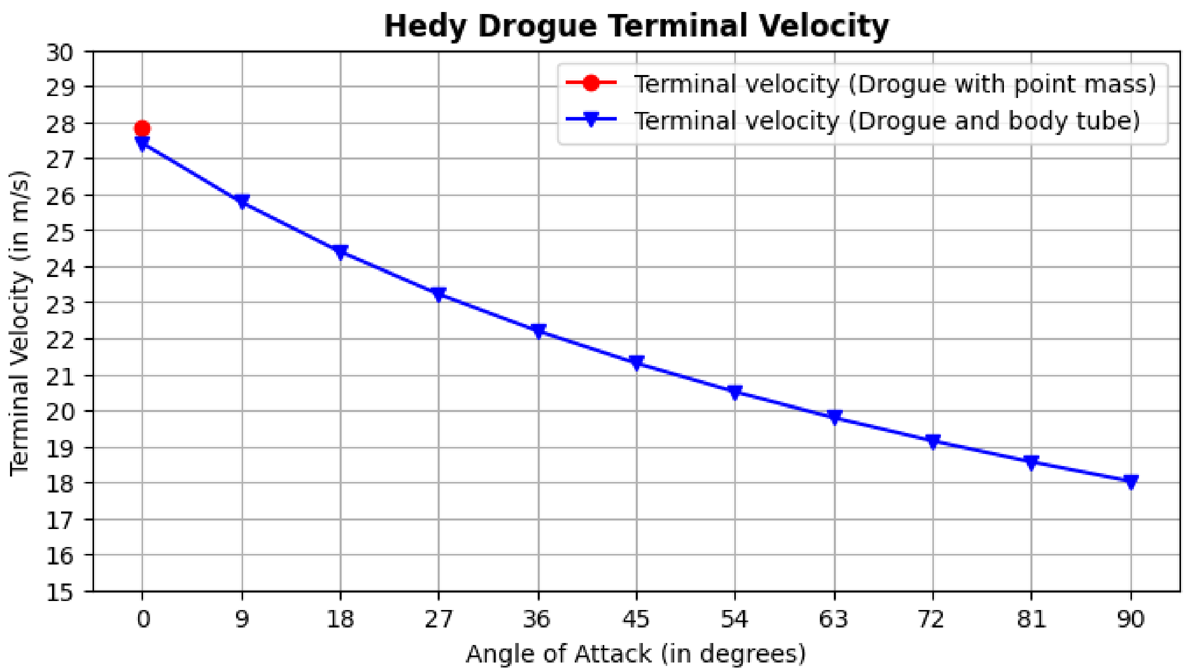


Fig. 2.18: Terminal velocity of the rocket after deploying the drogue parachute, factoring in the air resistance on the body tube at different angles of attack

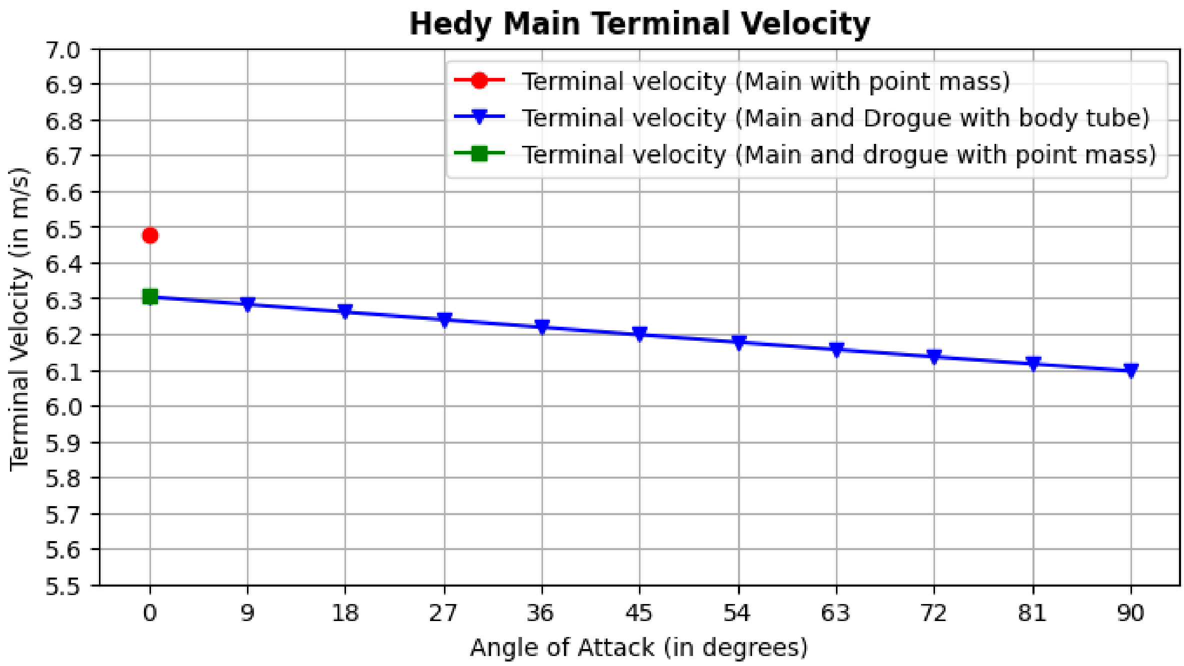


Fig. 2.19: Terminal velocity of the rocket after deploying the main parachute, factoring in the air resistance on the body tube at different angles of attack

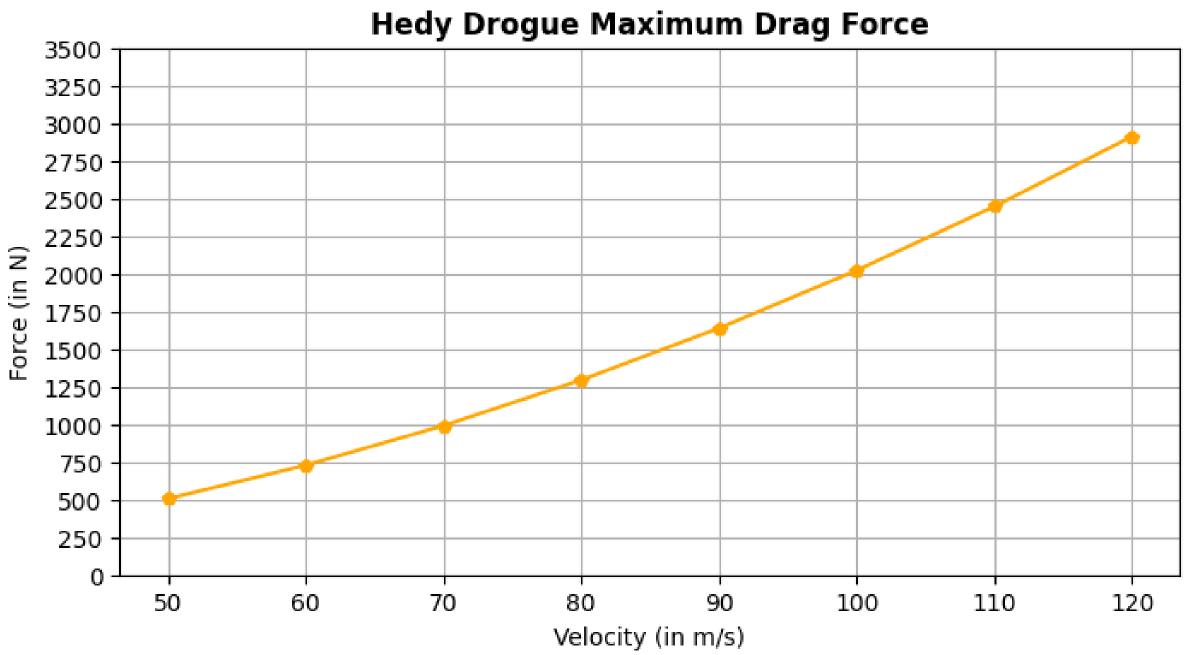


Fig. 2.20: Maximum drag force generated by the drogue parachute at different deployment velocities

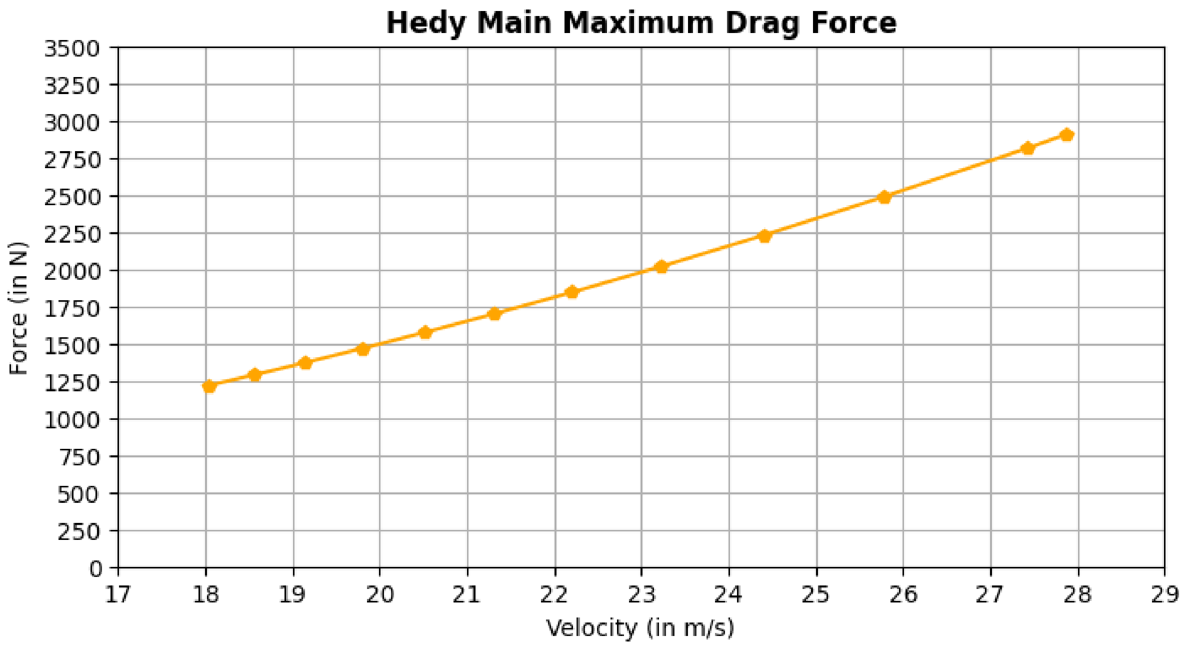


Fig. 2.21: Maximum drag force generated by the main parachute at different drogue terminal velocities

2.4.3 Lines, Links and Shock Absorbers:

A detailed overview of all parachute lines, links and hard points can be seen in the two line diagrams 2.16 and 2.17.

Almost all load bearing parachute lines are fashioned out of braided aramid sleeve manufactured by Siltex. Such aramid braid has been used as parachute line by the TU Wien Space Team for several rocket launches in the past with great results. The aramid braid has the advantages of regular aramid rope like high strength, flame resistance and excellent durability against abrasion while also offering further benefits in handling and processing, such as being well suited for splicing eyes into the ends as well as sewing segments together for the use as shock absorbers. Short segments of aramid braid with spliced eyes have undergone static load tests to verify that they are capable of withstanding at least 5000 N of force.

A short segment of line which connects the drogue parachute to the parachute bulkhead inside the body tube is made out of polymide rope and is cut during the main deployment event, allowing the drogue parachute to pull the main parachute out of the parachute tube. Since aramid is very resistant to high temperatures, it is unsuitable for this task. Instead, 3.8 mm thick polyamide rope with a nominal breaking strength of 2490 N is used. For this purpose, it is tied into a continues loop with a knot and run through the parachute bulkhead on one end and a soft shackle on the other such that 4 lines of rope run parallel from one point to the other. Two nichrome burn wires are placed on two of those lines and cutting the loop at any point results in the entire connection releasing immediately.

In order to determine the breaking strength of a folded polyamide rope loop and to figure out what knot would be most suitable to this purpose, static load tests were conducted and it was found that the loop would always break in one of the two attachment points, well in excess of 5000 N.

To link different elements of parachute line system, in place of the more common steel screw links, soft shackles made out of 6 mm thick aramid rope are used. Since both the CATS Vega's antenna and our own radio antenna are fixed on the parachute tube, these self-made soft shackles offer the advantage of not interfering with the outgoing radio signals from our avionics, improving our chances of maintaining an uninterrupted telemetry link with our rocket during flight.

For this very same reason we decided to forgo the use of steel swivel links in our recovery system, given that none of the hard points the parachute lines are connected to are at risk of being unscrewed by the rocket parts spinning in the air and building up torsion in the lines. The parachute bulk head in the rocket is fixed to the body tube with screws radially, and all lines are tied directly to it and not to a ring nut or eye-bolt. Similarly, the hard point in the nose cone is a GFRP disk that is glued into the forward end of the nose cone with holes in it to tie the parachute lines to the part directly.

Both parachutes are connected to the rocket components through shock absorbers made out of 18 mm diameter Siltex aramid sleeves with a wall thickness of 0.3 mm. The aramid braid is folded lengthwise and stitched along its length with high strength polyester sewing thread. Since our shock absorbers start ripping open at around 500 N and we only want them to activate during the most critical part of the parachute opening shock during the moments of highest load, two absorbers are used in parallel to bring the activation force up to around 1000 N.

2.4.4 Clamp Band Coupler:

During flight, the body tube and nose cone are held together by an aluminium coupler made of two halves which are pressed against each other by plastic clamps. The force acting on the clamps is provided by a spring steel band which is kept in tension by a short loop of Dyneema line with a thickness of 1 mm. During assembly, the line is run through a hole in a hexagonal tensioning pin sitting in a ratchet reliably preventing the mechanism from loosening. Once the line has been tied into a loop with a knot, the tensioning pin is turned until a certain experimentally determined torque has been reached. The lines are slightly deflected by a pair of metal pins with 3 mm diameter onto which ceramic sleeves with 5 mm diameter were glued. Nichrome burn wires are coiled around the ceramic sleeves. This nichrome burn wire has a resistance of 2.4 Ω and when a voltage of 12 V is supplied to them, they quickly heat beyond 1000 °C cutting the Dyneema line retaining the clamp band.

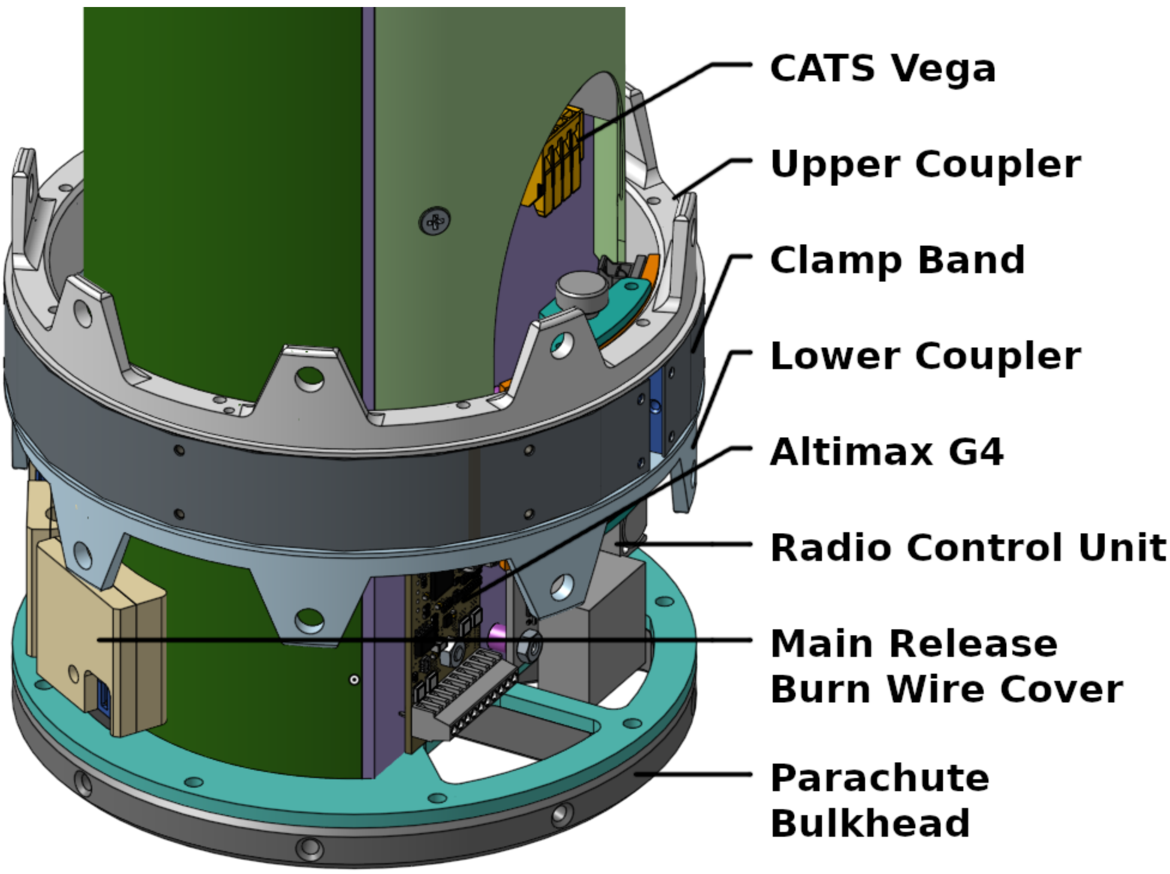


Fig. 2.22: Clamp band coupler and adjacent recovery components

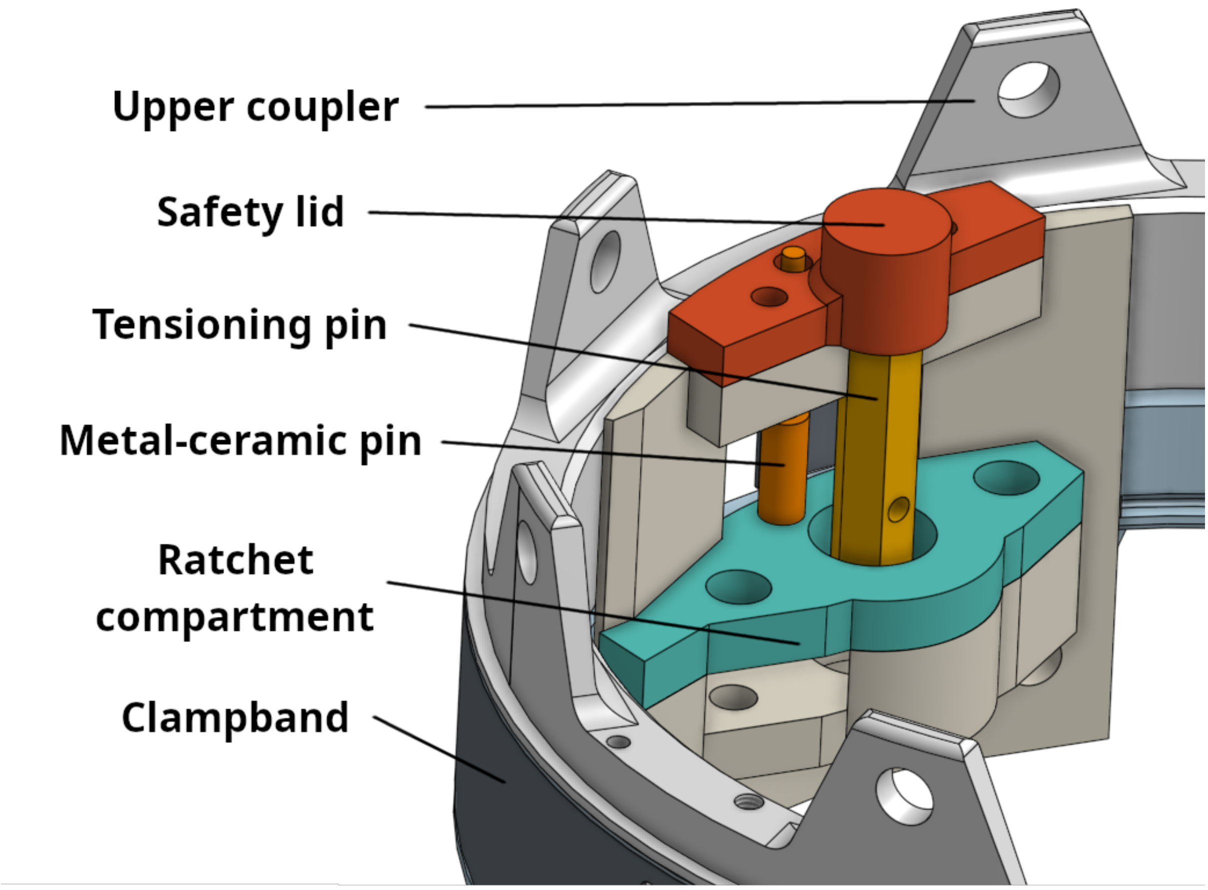


Fig. 2.23: Burn wire mount components

In order to calculate the forces that are expected to act on the coupler during flight, the Barrowman Method was used. The normal force on the nose cone was calculated using the following formula:

$$F_N = \frac{1}{2}\rho v^2 \frac{1}{4}\pi D^2 \alpha (C_{N\alpha})_C \tag{2.3}$$

with ρ being the air density, v the rocket velocity, D the diameter of the rocket, α the effective angle of attack and $(C_{N\alpha})_C$ the slope of the normal force coefficient at $\alpha = 0$.

For our rocket, conservative estimates were made for the flight characteristics, the angle of attack for example was assumed to be 10°. The resulting normal force acting on the nose cone was found to be around 300 N. Using this estimate, static load tests were performed on the clamp band coupler and nose cone, discovering a large number of structural weak points in the assembly which were subsequently reinforced.

In the first prototype, the part holding the tensioning screw was glued to the parachute tube. When the clamp band is put under tension by a force F_C, the tension screw would bear a force of $2F_C$. During our tests, we discovered the possibility of the screw failing. For this reason, the screw mechanism was eventually replaced by a much more reliable ratchet solution together with a new hexagonal tensioning pin. In addition, the force acting on the pin was also acting on the parachute tube, which broke out of its base plate because of the long lever arm magnifying the torque, resulting in the parachute tube and base plate epoxy connection failing. Because of this, the part holding the tension pin was moved from the parachute tube directly to the lower coupler, which can withstand the force of the clamp band without any problem. Finally, the next weakest link was found to be the initially used fishing line tying the ends of the clamp band together, which was replaced by a Dyneema line with 1 mm thickness. This resulted in a longer actuation time, however, the thicker and stronger line proved to be much more reliable in terms of stability to prevent unexpected coupler failure.

Taking the result of the calculation for the normal force on the nose cone, the bending moment M_C acting on the coupler was estimated to be around 150 N m. Using this figure, the force acting on the crowns of the upper and lower coupler, which are used to connect them to the body tube and nose cone respectively, was calculated using the formula:

$$F_{crown} = \frac{M_C}{2D} \tag{2.4}$$

The force F_{crown} was found to be approximately 600 N for the lower coupler, and the crown were subsequently designed with a safety margin of 2, using high strength 6082 aluminium alloy. In addition, static load tests of a crown dummy were performed, and the aluminum part was recorded withstanding in excess of 1100 N of force without deforming.

2.4.5 Recovery Avionics:

Two different flight computers are used in our rocket to trigger the recovery system.

An **Altimax G4 Altimeter** is acting as the main flight computer. It is connected to the same battery packs as the remaining electronics inside the rocket. Two sets of nichrome burn wires are connected to pyro channel 1 and pyro channel 2 respectively, the first one releasing the clamp band and triggering the initial deployment event, and the second one cutting the polyamide rope and releasing the main parachute. The Altimax G4 has been flown in several rockets build by the TU Wien Space Team in the past and has worked reliably so far. It is capable of outputting up to 15 A continuously, but in order to keep the recovery mechanism symmetric between the two flight computers and make it impossible to accidentally mix up the connectors, burn wires with a resistance of 2.4 Ω are used for every one of the line cutters, limiting the current to 5 A when the battery input voltage of 12 V is applied to the pyro channel.

The Altimax is programmed to power pyro channel 1 at apogee and pyro channel 2 during descent at an altitude of 450 m. It supplies each pyro channel for a duration of 3 seconds.

The second flight computer is a **CATS Vega**. Besides recovery, it is also responsible for altitude logging and tracking. As the redundant backup flight computer, it is supplied by its own dedicated 12 V battery pack. In order to be able to supply the burn wires with the necessary current of 5 A, the PTC fuses on each of the two pyro channels are bypassed.

The CATS Vega is programmed to power pyro channel 1 at apogee for 3 seconds, and pyro channel 2 at an altitude of 450 m for a duration of 6 seconds, since the actuation time for the polyamide burn wire is significantly longer than that of the clamp band line cutter.

2.4.6 Recovery Test Flight:

In April of 2024, a rocket powered by a solid propellant motor was launched containing a prototype of the planned recovery system. The rocket has an inside diameter of 130 mm and a nose cone closely matching that of our liquid propellant rocket, allowing us to test a same-scale prototype of the recovery system in flight. The recovery system was fully redundant, with both an Altimax G4 and CATS Vega acting as flight computers on board. In addition, a prototype of the payload was also mounted inside the nose cone.

The rocket flew to an altitude of 600 m and the decoupling mechanism worked flawlessly, with the drogue parachute deploying quickly as planned. When the rocket reached an altitude of 250 m, the main release mechanism triggered, successfully severing the line connecting the drogue parachute to the body tube. However, the drogue parachute did not manage to pull the main parachute out of the parachute tube. During ground tests, we verified that the weight of the test rocket was enough to pull the main parachute out, even though there was some resistance because of the deployment bag being too large and rubbing up against the inside of the parachute tube. However, during flight, the large body tube and fins of the rocket introduced a lot of drag, slowing down the rocket body and reducing the force from the drogue parachute acting on the main parachute. Furthermore, because of the pronounced drag of the fins, the rocket body was not hanging on the drogue vertically but at an incline, further hindering the main parachute from exiting the parachute tube. Both drogue and main parachute lines were fitted out with 300 N shock absorbers. Since the rocket had a low horizontal velocity at apogee and there were no aggressive winds, the drogue parachute shock absorbers did not trigger. Those on the main parachutes line were not triggered because the main parachute did not deploy. While the function of all recovery mechanisms was confirmed, the most important learning from the test flight was to make the deployment bag of the main parachute smaller in circumference, so that, even if the main parachute tries to expand inside the bag, it does not stretch out far enough to rub up against the parachute tube and hinder the deployment of the main parachute in any way.

2.5 Payload:

The payload transported by Hedy will be in cooperation with the Geodesy Institute of the Technical University of Vienna. It will have a form factor of one 4U Picosat with a mass of 1 kg and be non-ejectable.

The idea behind the payload is to validate an SRAD tracking device with the data from a COTS Tracker. The SRAD Tracker has been developed as part of a bachelor's thesis at the Geodesy Institute. Lithium-ion batteries will power both trackers to comply with the EuRoC requirements. A Reperix from Silicdyne will be used for data validation.

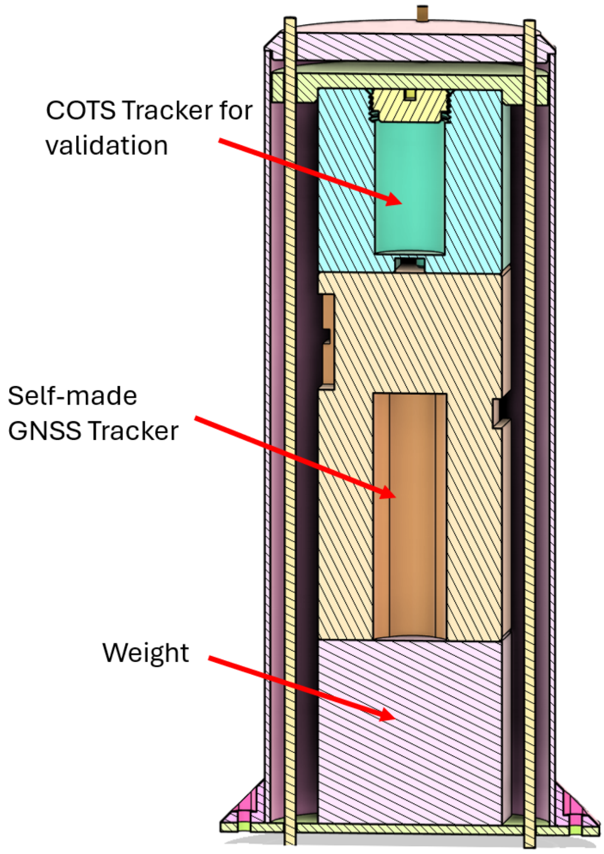


Fig. 2.24: Payload

2.6 Avionics:

Figure 2.25 shows the functional block diagram of the Lamarr avionics. The system is divided into three main sections: the nosecone, the electronics stack, and propulsion control section. This structure ensures a clear separation between parachute deployment electronics, the central power and communication infrastructure, and the subsystem control units.

The following abbreviations are used throughout this chapter:

- **ECU** - Engine Control Unit
- **RCU** - Radio Communication Unit
- **PMU** - Power Management Unit
- **UCI** - Umbilical Cord Interface
- **RBF** - Remove Before FLight (interlock board)

2.6.1 Nosecone

The nosecone contains three independent COTS systems: the Altimax G4, the CATS Vega, and the Reperix. The Altimax G4 and the CATS Vega are exclusively responsible for parachute deployment, ensuring redundancy and independence from the rest of the avionics. The Reperix serves as a dedicated tracking system. Each unit is powered separately: the Altimax G4 is supplied by the backup battery, the CATS Vega is connected to the main battery, and the Reperix relies on its own battery. This separation guarantees that parachute deployment and tracking remain functional under all circumstances.

2.6.2 Electronics Stack

The electronics stack forms the central avionics section and houses the main and backup power systems, the RBF interlock board, the RCU, and two onboard cameras.

The main power source is a 3S3P configuration of 21700 lithium-ion cells, permanently integrated with a PMU. A second, smaller 3S1P battery provides backup power and is also connected to a separate PMU. Both PMUs receive input power from the Umbilical Cord Interface (UCI), which provides a regulated 15 V DC supply from the ground support equipment (GSE). This arrangement allows both batteries to be charged at up to 0.5 A, regardless of whether the RBF pin is inserted or not. During charging, the avionics are supplied directly by the external umbilical power source, ensuring that the batteries are not discharged on the pad. Once umbilical power is disconnected, the PMUs automatically switch to battery operation. The PMUs are designed to supply peak currents of up to 10 A, and each includes two current sensors which provide feedback via a 0-20 mA current loop. These signals can be read by the 0-20 mA input channels of an ECU.

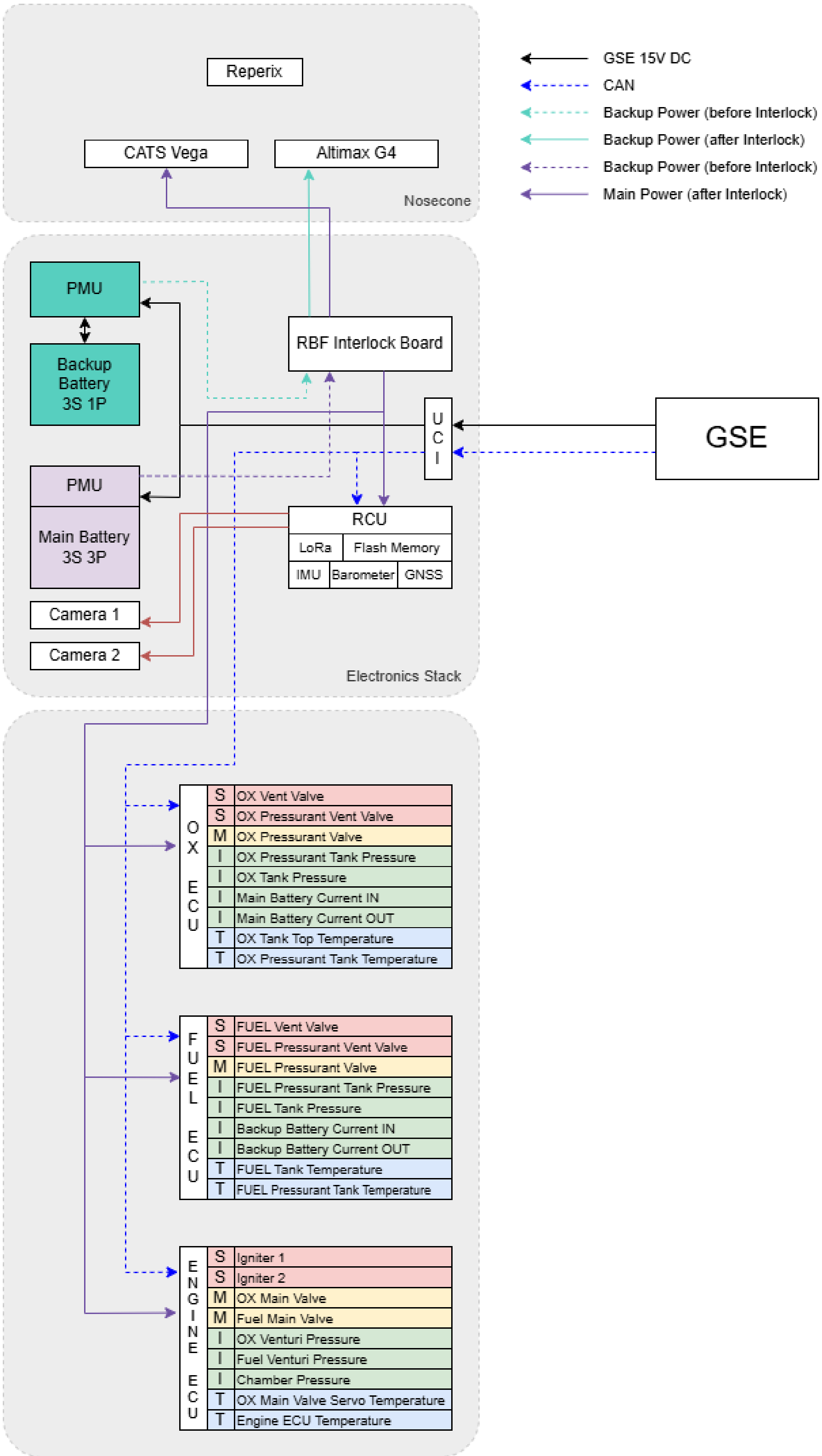


Fig. 2.25: Avionics system blockdiagram

Downstream of the PMUs, both power lines are routed through the RBF interlock board. This board is a critical safety element that sequences the connection of the backup and main power systems to the rest of the rocket. It contains four mechanical limit switches arranged in pairs, as well as MOSFETs for switching higher loads. By gradually inserting or removing the RBF pin, the backup and main systems can be switched on or off in sequence. This procedure allows verification of proper boot-up behaviour of the flight computers before launch.

In addition to the power system, the electronics stack also houses the RCU, which provides the radio downlink for telemetry. The RCU integrates a GNSS receiver, an IMU, and an accelerometer, and is also responsible for switching the two onboard cameras.

2.6.3 Propulsion Control

The third section of the avionics consists of three ECUs: the OX ECU, the Fuel ECU, and the Engine ECU. Each ECU is based on identical hardware and is designed as a standardized, replaceable module. Connections are provided through a PCIe card edge connector, which allows rapid replacement in case of hardware failure. Inside the rocket, breakout boards distribute the ECU channels to solenoids, sensors, and servos through standardised connectors. For ground support equipment, a larger Input Output Board (IOB) is used. This board also relies on an ECU as its controller but fans out all channels to robust M12 connectors, providing greater flexibility and durability during testing and operations on the ground.

Each ECU provides four high-power channels, which can also be configured as igniter outputs and are capable of performing continuity checks. In addition, four 0-20 mA sensor inputs are available, typically used for pressure sensors and current monitoring. Two PT100 sensor inputs are provided for temperature measurements, and two channels are available for controlling motorised servo valves.

Functionally, the OX ECU controls the oxidizer-side valves and sensors, while the Fuel ECU handles the fuel-side equivalents. The Engine ECU coordinates overall rocket operation and takes control of the other ECUs once internal control is active, including managing the ignition sequence.

2.6.4 Wiring and Connectors

Signal and power cabling below and partly within the electronics stack is implemented using Teflon-insulated stranded wire. This type of wiring was selected for its mechanical robustness and resistance to elevated temperatures. All connectors used inside the rocket are automotive-grade, keyed, and locking to ensure reliable operation under vibration and to prevent accidental disconnection. Multiple connector families are deliberately employed to avoid the risk of incorrect mating during assembly and integration. Wires are held in place by zip ties.

2.6.5 Engine Control Unit (ECU)

The Electronics Control Unit (ECU) 2.26 is the standardised control module of the avionics system. Each ECU provides four high-power channels capable of igniter firing and continuity checks, four 0-20 mA sensor inputs for current and pressure measurement, two

PT100 temperature sensor channels, and two servo channels for motorised valves.

The ECU is designed around a PCIe card edge connector, which serves as its sole electrical interface. This allows rapid replacement of the unit in case of hardware failure. Inside the rocket, breakout boards are used to fan out the ECU channels to solenoids, sensors, and servos via standardised keyed connectors. For ground support equipment, a more robust Input Output Board (IOB) is available, which fans out all channels to M12 connectors.

Functionally, three ECUs are used in the rocket: the OX ECU controls oxidiser-side valves and sensors, the Fuel ECU manages the fuel-side equivalents, and the Engine ECU has a dual role. It directly operates the two main motorised valves that regulate the oxidiser and fuel flow into the injector, and it also coordinates the overall operation of the avionics while the rocket is controlled internally.

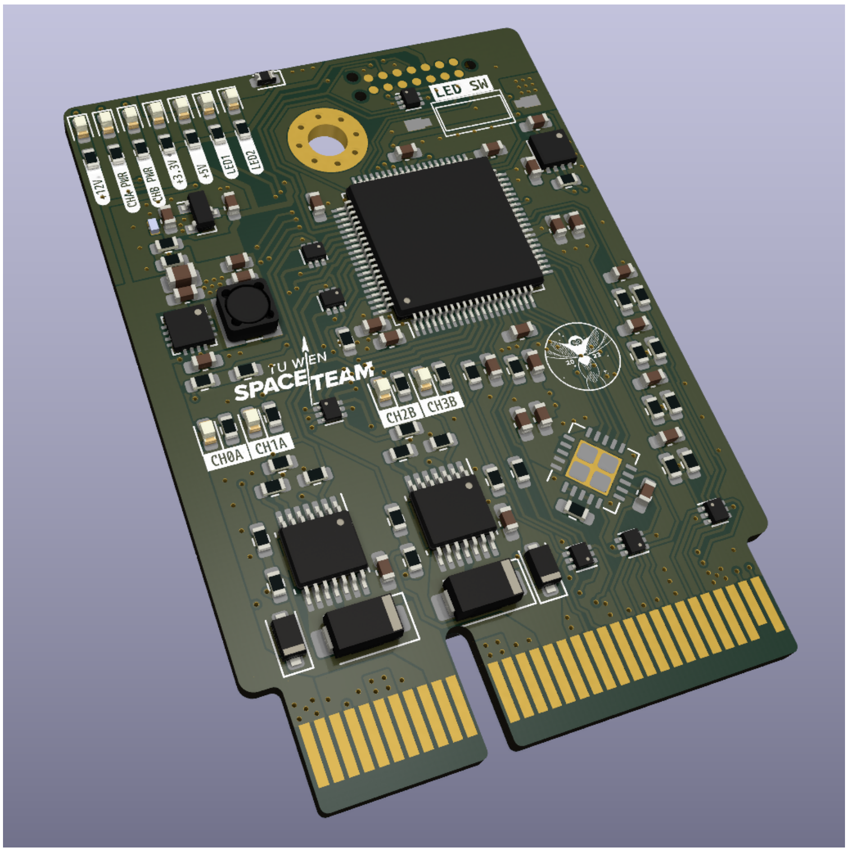


Fig. 2.26: ECU

2.6.6 Radio Communication Unit (RCU)

The Radio Communication Unit (RCU) 2.27 is responsible for telemetry downlink and provides integrated navigation and motion sensing capability. It includes a GNSS receiver, an IMU, and an accelerometer. The RCU also has the ability to switch the two onboard cameras, allowing ground operators to enable or disable camera recording.

The RCU forms the primary communication link between the rocket and the ground segment during flight, ensuring continuous transmission of telemetry and position data. For optimal RF performance, the RCU's antennas are located in the nosecone, as the electronics stack is enclosed by the composite carbon-fibre body tube.

Like the ECUs, the RCU communicates over the common CAN-FD bus, which connects all avionics units to the GSE.

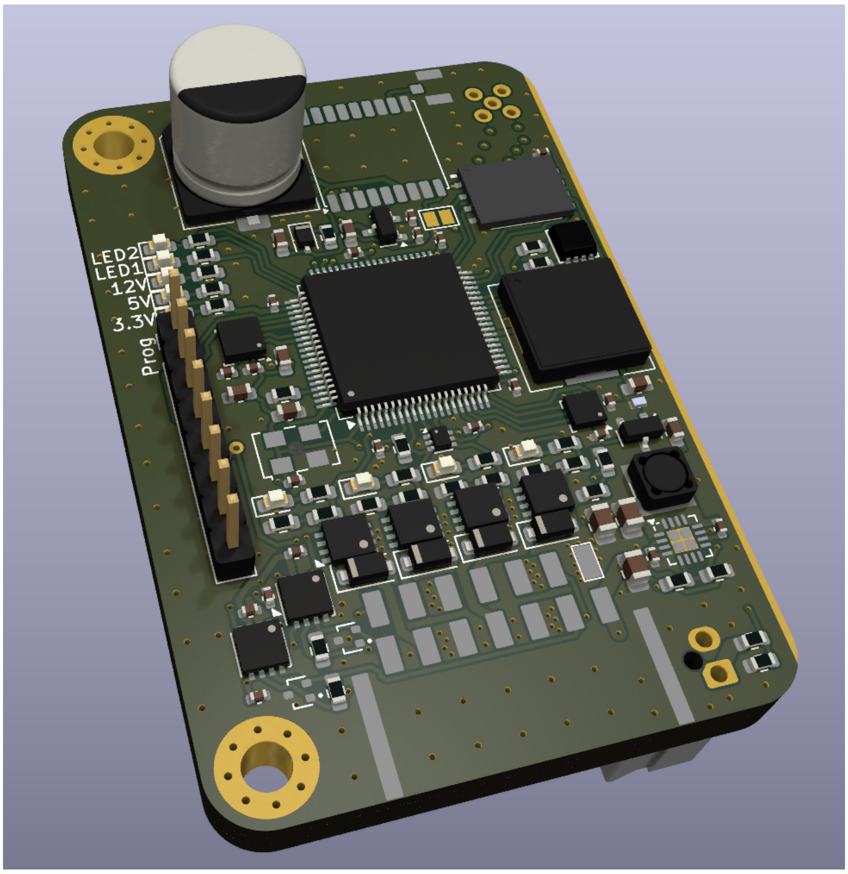


Fig. 2.27: RCU

2.6.7 Power Management Unit (PMU)

The Power Management Unit (PMU) 2.28 is permanently coupled with the main and backup batteries and is responsible for battery charging, switchover, and current monitoring. Each PMU has one power input and one power output, allowing direct inline connection between the batteries and the avionics power bus.

Both PMUs receive input power from the 15 V DC supply of the Umbilical Cord Interface (UCI). While external power is present, the batteries are charged at a maximum current of 0.5 A, and the avionics system is supplied directly by the umbilical connection. When the umbilical is disconnected, the PMUs automatically switch to battery operation. Each PMU is capable of handling peak currents up to 10 A.

For monitoring purposes, each PMU contains two onboard current sensors. Their outputs are provided via a 0–20 mA current loop, which can be measured by the 0–20 mA input channels of an ECU. With these two current values, the current flow into the battery, the current delivered from the battery, and the net current “through” the PMU can be determined, allowing precise monitoring of charging and discharging states.

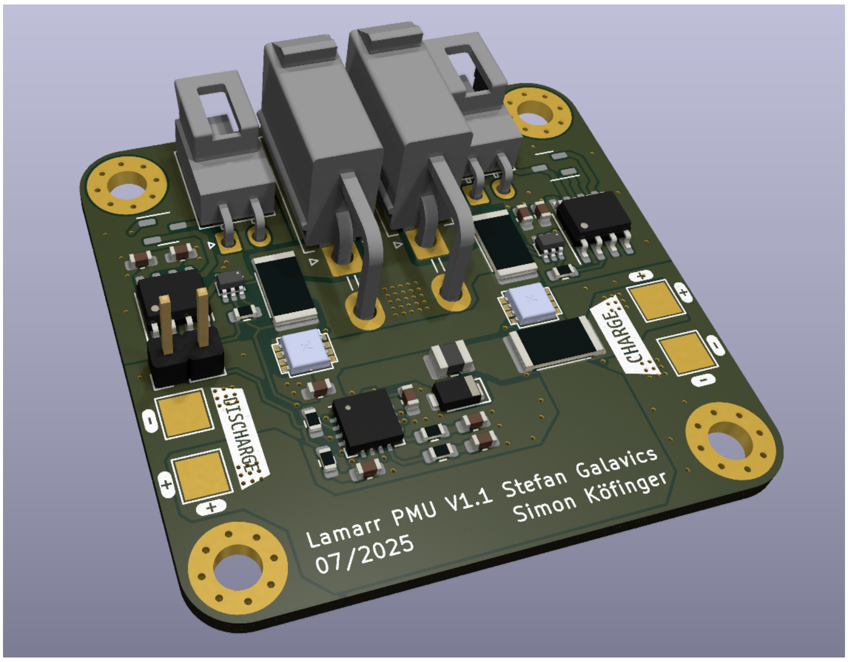


Fig. 2.28: PMU

2.6.8 Umbilical Cord Interface (UCI)

The Umbilical Cord Interface (UCI) 2.30 connects the rocket avionics to the Ground Support Equipment (GSE). It provides regulated 15 V DC power for charging the main and backup batteries and for powering the avionics during pre-launch operations. In addition, the UCI carries the CAN-FD bus, which allows the GSE server to communicate with all avionics units before launch.

The UCI is composed of two parts: the rocket-side interface in the electronics stack and the breakaway part attached to the GSE. The breakaway part is held onto the rocket via corner-mounted magnets, ensuring that the connector can only be attached in the correct orientation. The interface is rated to carry up to 10 A of current, providing robust pad-side operation.

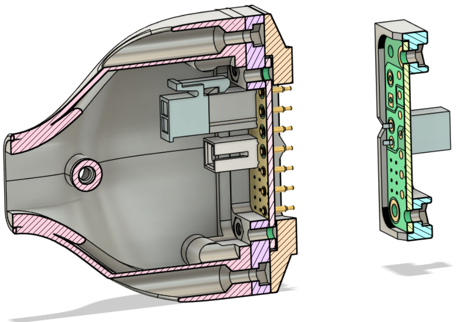


Fig. 2.29: UCI section view

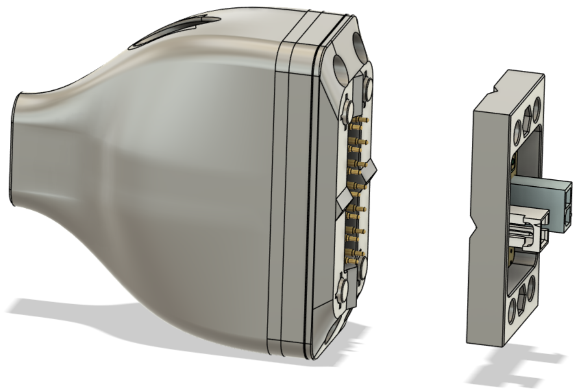


Fig. 2.30: UCI

2.6.9 RBF Interlock Board

The RBF interlock board 2.31 is a critical safety device that ensures controlled and sequenced connection of power to the rocket avionics. It employs four mechanical limit switches arranged in two rows and includes MOSFETs for switching higher current loads. By gradually inserting or removing the RBF pin, the backup and main power systems are switched on or off in sequence. This design allows verification of correct boot-up behaviour of the flight computers before launch.

The interlock board receives power outputs from both PMUs and distributes them to the remainder of the avionics. Its role is central to pre-launch safety and controlled arming of the system.

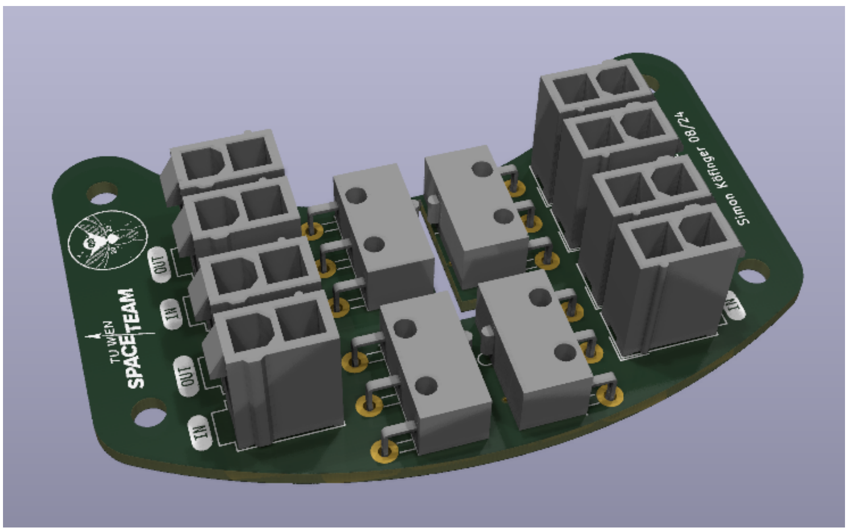


Fig. 2.31: RBF

2.6.10 Ignition Safety Switch

In addition to the avionics units described above, the ignition circuit is equipped with an external safety device referred to as the Ignition Box. This unit allows the pyro ignition voltage from the Engine ECU to the igniter to be interrupted at any time during ground operations. The Ignition Box contains two independent key switches, both of which must be inserted and turned to the "on" position to connect the Engine ECU's pyro output to the igniter. The keys are mechanically interlocked so that they can only be removed in the "off" position, ensuring that the circuit defaults to a safe state whenever the keys are not actively engaged.

This device provides an additional layer of safety by requiring deliberate human action with two keys before ignition is possible, preventing accidental energization of the igniter during integration and pad operations.

2.7 Ground support equipment:

The launching of biliquid rockets poses additional challenges compared to solid motors. Especially the handling of hazardous propellants like liquid oxygen necessitates a system for automatic fuelling of the rocket after all personell has vacated the immediate area surrounding the vehicle. Since biliquid engines generally also have a longer startup time and a lower thrust to weight ratio, a hold-down system is required to ensure a safe engine startup and rail exit velocity.

Due to these reasons, we decided to use our own launch pad instead of adapting an organizer-provided launch rail. This gives us more design freedom, as well as flexibility at the launch site.

2.7.1 Launch Rail:

Our launch rail is based on five FD33-200 triangular aluminium trusses, commonly used in stage construction and rigging. Rigidly mounted to the truss structure are 30x30L aluminium extrusions acting as the launch rail. The rail extends and additional meter from the trusses for a total length of 11 m. The launch rail structure is mounted to the subframe of a trailer for ease of transportation, which also holds the tanking system and electronic infrastructure. For additional stability three guy wires are mounted to the top of the launch rail. They are connected to ballast (sand bags) on the ground. Screw anchors have not worked with the hard and brittle ground at the launch site in the past.

This basic structure has been used as the main launch platform for TU Wien Space Team for a number of years, being used for small rockets built by new team members, recovery test vehicles and our dedicated CanSat rocket. It was also used to launch our previous bi-liquid rocket µHoubolt at EuRoC 2022 as well as numerous static fire tests for this rocket.

2.7.2 Hold-down System:

The hold-down system consists of a lever which locks the rocket in place. A catch, which is moved by a pneumatic cylinder, prevents the lever from rotating out of the way until the command to release the rocket is issued in the launch sequence. The lever is connected to the structure of the launch rail via a load cell that measures the thrust produced by the engine directly. All structural components consist of welded stainless steel bar stock.

The lever interfaces with the rocket at the lower rail button. It consists of a steel insert, which is directly mounted to the thrust structure inside of the rocket, and a polymer aeroshell for reduced aerodynamic drag and low friction in contact with the aluminium launch rail.

Once nominal engine startup is confirmed by both the chamber pressure sensor and the load cell connected to the hold-down system, the rocket is released.

This system is also used during static fire tests on the launch rail. During the GSE setup process before launch it is load tested and the load cell calibrated using a hydraulic jack.

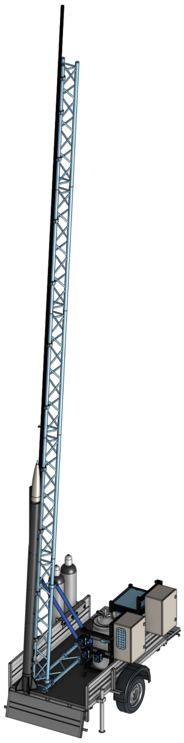


Fig. 2.32: Launch rail and GSE

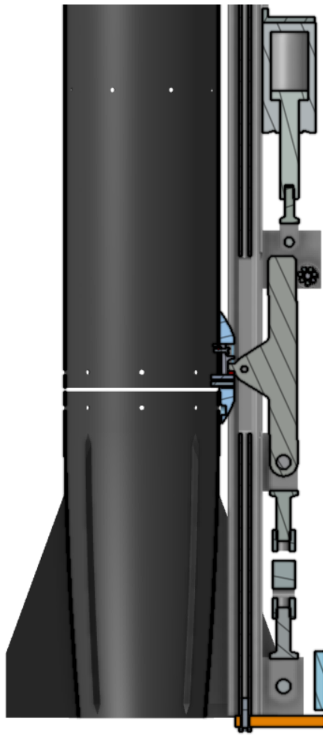


Fig. 2.33: Sectional view of the hold-down engaging with the bottom railbutton

2.7.3 Flame diverter

To protect our launch equipment and prevent damage caused by debris from the ground during engine startup, a flame diverter, constructed from steel box sections, is used to redirect the exhaust plume horizontally away from the trailer.

During static-fire tests a water injection system is used to protect the diverter and to decrease noise. Since the logistics of transporting an IBC-container of water to the launch site seems infeasible, no water injection will be used during the launch. This may destroy the flame diverter, but that is a risk we are willing to take.

2.7.4 Tanking System:

Since the tanking of hazardous substances and high pressure gas are among the most dangerous phases of launching a bi-liquid propellant rocket, we have designed a remote controlled Tanking System for loading liquid oxygen (LOX) and high pressure nitrogen gas (HPN2) into our rocket without human presence necessary.

Ethanol Tanking:

Because our fuel (ethanol) is relatively safe and easy to handle, it is loaded manually as one of the final tasks before we leave the launch area. A container of ethanol with a riser tube is connected to the rocket with a quick-connector to the fill port upstream of the fuel main valve. The container is pressurized with nitrogen at 1.4 bar via a manual valve,

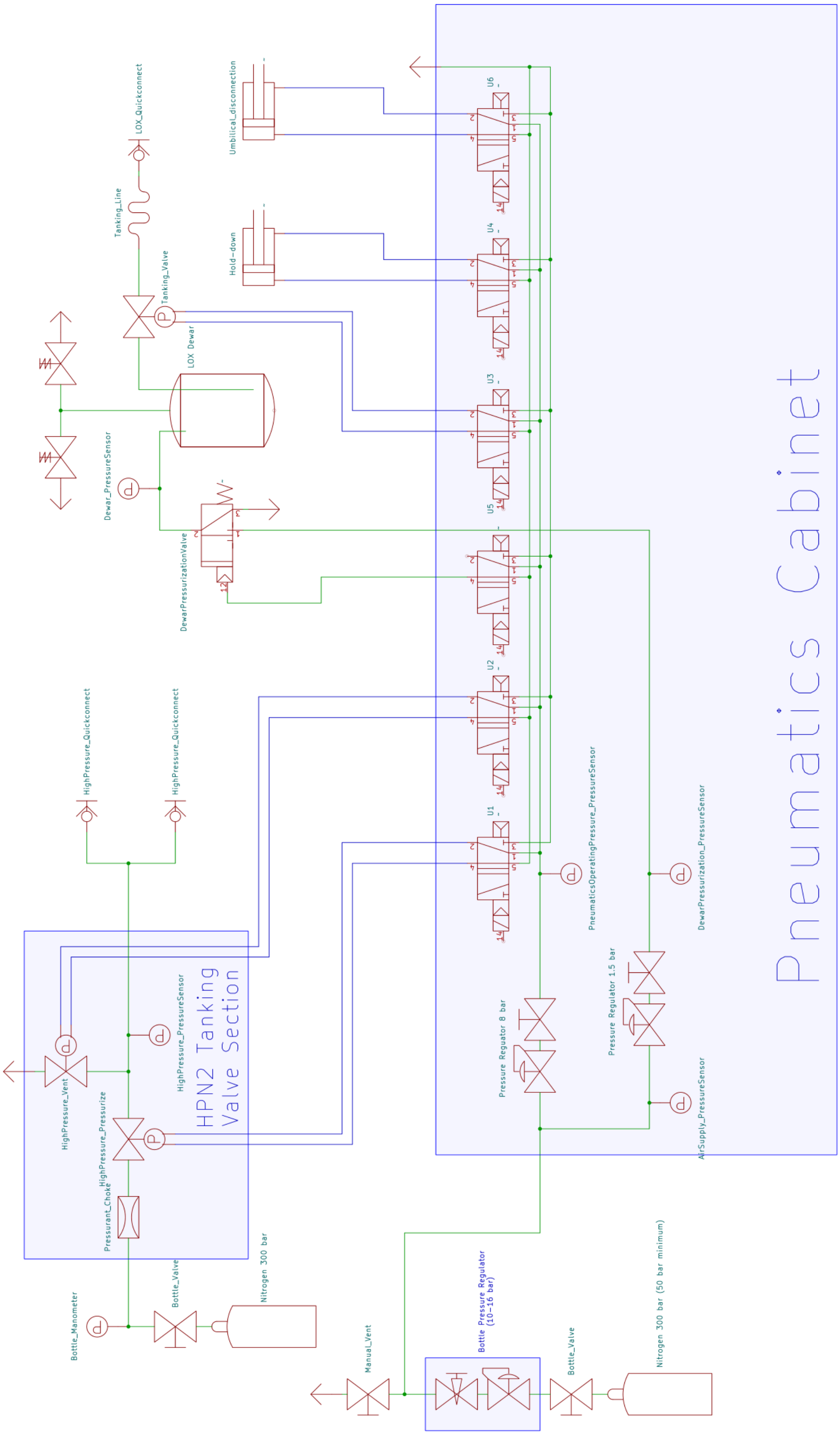


Fig. 2.34: GSE PnID

forcing the fuel to flow into the rocket. The tanking progress is monitored with a scale to ensure a known quantity of ethanol is loaded into the rocket.

The ethanol tanking system has been used in numerous cold-flow and static-fire tests of our system and has evolved into a reliable and easy solution.

Liquid oxygen Tanking System:

Liquid oxygen is tanked into the rocket from our own LOX-dewar, originally designed for medical use. It is pressurized with nitrogen gas at 1.4 bar, forcing liquid oxygen through the tanking line, via a tanking valve, through an SRAD quick-connector into the rocket. The dewar is positioned on top of a load cell to monitor its mass during tanking.

Pressurization is achieved by a mono-stable 3/2 pneumatically actuated valve, connected to its own pressure regulator inside the pneumatics cabinet. There the tanking pressure, and by extension the tanking speed, can be adjusted. A pneumatically actuated valve was chosen over a solenoid valve, due to its better performance at low pressures and relative simplicity (two moving parts, including the spring). This ensures that the dewar is always vented to the atmosphere by default and never fully enclosed. Two redundant pressure relief valves on the dewar further prevent an uncontrolled buildup of pressure.

The LOX tanking valve is a stainless steel Swagelok ball valve, modified with LOX compatible seals and bushings. The exact valve has been used in our engine test stand and has performed reliably. A stainless steel hose is used to connect to our SRAD LOX-connector inside the rocket. The LOX piping is insulated with rubber foam insulation material commonly used in the HVAC industry.

This method of LOX tanking is the same as the one used during every hotfire test the team has conducted and has proven to be very reliable and controllable. Tanking is fast and mainly limited by the venting rate of the vent valve inside the rocket.

High pressure nitrogen Tanking System:

The pressure-fed system of our rocket requires nitrogen gas at 300 bar for pressurizing the tanks. For tanking, a 300 bar nitrogen bottle is connected to the tanking system without a pressure regulator. Because of the danger posed by this highly compressed gas, the pressurant is also loaded remotely.

The nitrogen bottle is connected to the tanking system via a flexible hose with a pressure gauge at the bottle connector. An adjustable choke allows for regulating the tanking speed, as a pressure spike could damage the COPV tanks inside the rocket. After the choke, a ball valve interrupts the flow of nitrogen into the rocket, while a second valve after that is used to vent the tanking system before disconnecting. A pressure sensor monitors the pressure inside the tanking system.

Attached to the valve section at the quick disconnect is a flexible hose leading to the retraction arm. A T-fitting splits the flow to two quick disconnects, which are connected to the fill ports of the pressure regulators inside the rocket.

All components of the pressurant tanking system are used in either hydraulic systems or high-pressure airguns. The pressurant tanking system has been used for many cold-flow and static-fire tests and has worked as designed.

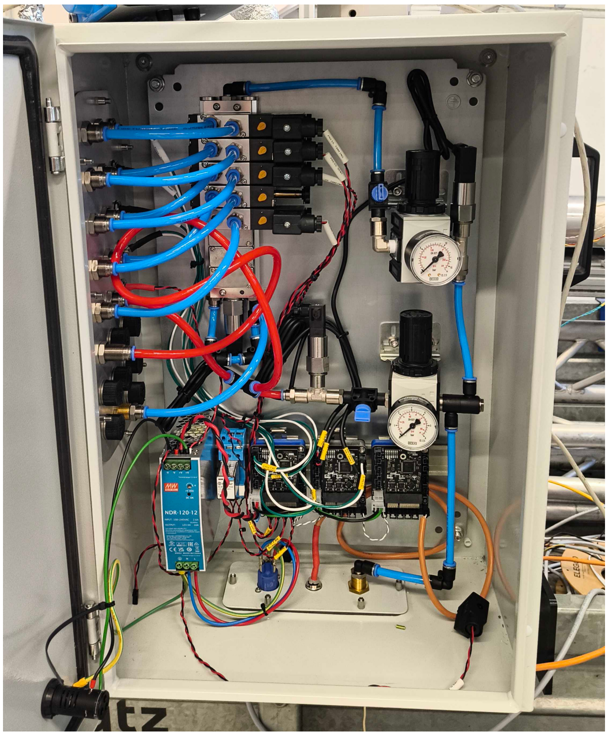


Fig. 2.35: Inside of the pneumatics cabinet

Pneumatic System:

For actuating the ball valves of both the LOX and pressurant tanking systems, pneumatic actuators are used. They have proven to be more reliable and powerful than electronic servo motors. Because other actions benefit from this power density and reliability, the pneumatic system has been expanded to the hold-down, dewar pressurization and decoupling subsystems.

Our pneumatic system is fed by a dedicated nitrogen bottle. The pressure is first reduced to 12 bar by the bottle pressure regulator connected to the pneumatics cabinet by a hose. Inside the cabinet a second pressure regulator further reduces the pressure to the pneumatics working pressure of 8 bar. This two-stage system is used, because we have found bottle pressure regulators to be unreliable at holding their set point at such relatively low pressures during changes in temperature. Since the maximum inlet pressure of the pneumatic pressure regulators are 16 bar, the supply pressure can vary by ± 4 bar without issue. All pressures inside the pneumatics system are also monitored by pressure sensors.

The pneumatics cabinet further contains the solenoid valves controlling all pneumatic actuators, and a second pressure regulator for providing lower pressure nitrogen for dewar pressurization during tanking. All actuators also provide feedback of their position using limit switches.

Disconnection and Umbilical Retraction:

For pressurant tanking, quick-connectors used in paintball or PCP-air guns are used. After tanking, they are disconnected and removed from the rocket by pneumatic cylinders pushing against the ouside of the airframe.

Since we could not source a COTS quick-connect which satisfied our requirements of LOX-compatibility, low mass and bidirectional flow when connected, we opted for a SRAD approach. Our LOX quick-disconnect consists of a check valve inside the rocket and a counterpart with an electromagnet. The counterpart has a protrusion which holds open the check valve when the two parts are connected. This allows for bidirectional flow which is important in case of an abort after LOX-tanking.

All tanking connectors are held in place by retraction arms constructed primarily from aluminium extrusions. After tanking is completed and the connctors are disconnected, the arm is moved back by a geared DC motor. This minimizes the risk of damage to the rocket and connectors during liftoff.

For electrical power and CAN-Bus connection an electrical umbilical is connected to the rocket with pogo-pins and magnets. It is not retracted together with the filling hoses, but is ripped off by the rocket during ascend.

2.7.5 Power and Communication:

Electrical power at the launch site is provided by EuRoC and is backed up with our own UPS. The UPS is monitored by the server and provides enough backup power to safely shut down the GSE and rocket in the event of a power interruption.

For controlling the rocket and GSE via CAN-bus a server is located in an enclosure on the trailer. The server cabinet also includes networking infrastructure and the UPS. Mission Control is connected to the server via a pair of parabolic antennas using a WiFi link. Multiple IP-camera feeds are also transmitted through this link.

3 Mission concept of operation:

3.1 Rocket lifecycle during EuRoC:

1. Rocket gets presented at the exhibition.
2. On the day before the launch, the rocket gets assembled, the recovery section is prepared, and the electronics are checked.
3. On the launch day we bring the rocket to the launch site and start going through the launch day checklists.
4. After landing, we recover the rocket and return it to the launch site.
5. After inspection of the rocket, we bring it back to the exhibition area.

3.2 Launch Procedure:

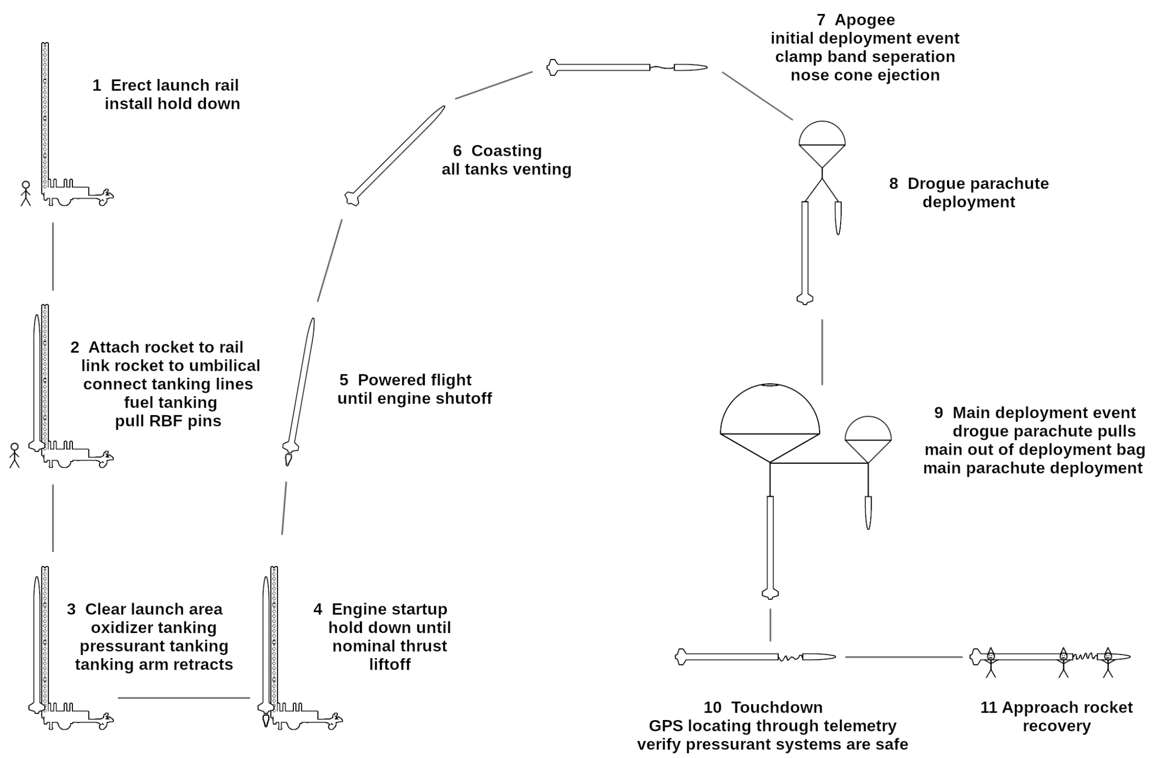


Fig. 3.1: Concept of Operation

3.2.1 Mission Control Setup:

1. Connecting directed radio link and Raspberry Pi with LoRa shield to server.
2. Powering on server, Mission Control PC and monitors.
3. Connecting Mission Control PC to server via LAN.
4. Opening Mission Control Web-Application on Web-Browser.
5. Connecting igniter safety box to the electrical cabinet
6. Rollout the 30 m long cable to connect the igniter safety box to the two stage keybox

3.2.2 Launch Pad Setup:

1. Assembling tanking system.
2. Installing nitrogen bottles.
3. Testing pneumatic system.
4. Connecting GSE to directed radio link.
5. Sliding rocket onto launch rail with hold-down system.
6. Testing umbilical disconnection and retraction.
7. Connecting oxidizer, pressurant and electrical umbilicals.
8. Pulling RBF pin to power on avionics.
9. Checking sensors and actuators, verifying movement and calibration, via Mission Control.

3.2.3 Fuel Loading:

1. Closing fuel main valve.
2. Attaching the quick-connector to the fuel fill port.
3. Filling the tanking vessel with predefined amount of ethanol.
4. Raising the tanking vessel to above the height of the fuel tank.
5. Waiting for all ethanol to drain into the rocket.
6. Covering the rocket's fuel inlet section.

3.2.4 Final Pad preps:

1. Opening pressurant bottle and checking for leaks.
2. Connecting igniters after checking for zero potential at electrical connections.
3. Staring pad cameras.
4. Mission and pyrotechnics lead are leaving the rocket area
5. Mission and pyrotechnics put there two keys into the key box and arm the igniters with a minimum distance of 25 m

From this point onwards the rest of the preparations until launch can be done completely remotely.

3.2.5 Oxidizer Loading:

Pressure and temperature data is closely monitored throughout the whole process.

1. Closing oxidizer main valve.
2. Opening LOX vent valve.
3. Taring LOX dewar scale and hold-down load cell.
4. Opening LOX fill valve.
5. Pressurizing dewar to start tanking.
6. Closely monitoring dewar and rocket weight.
7. As soon as target LOX amount is tanked into rocket, close LOX tanking valve.
8. Depressurize dewar.

3.2.6 Pressurant Loading:

1. Closing pressurant venting valve.
2. Opening pressurant tanking valve.
3. Waiting for stable pressurization.
4. Closing pressurant tanking valve.
5. Opening pressurant vent valve.

3.2.7 Disconnection and Retraction:

1. Disconnecting LOX disconnect.
2. Activating umbilical retract of pressurant and oxidizer tanking lines and verifying clean separation.

3.2.8 Internal Countdown and Launch:

1. The propellant tanks are pre pressurized to the operating pressure via an external sequence.
2. All system parameters are manually checked to be within range.
3. After Go/NoGo, the rockets internal control is activated via Mission Control .
4. The rocket start internal countdown, activates the igniters, and actuates all necessary valves.
5. The rocket checks for proper engine performance after ignition. This is evaluated by chamber pressure and thrust force on hold-down
6. If proper engine performance is detected by the rocket, it sends a signal to the Launch Pad to release the holddown.
7. Lift-Off is achieved once the electrical umbilical that is magnetically held in place gets disconnected by the rocket moving out of reach.

Until lift-off there is still a possibility for manual abort from Mission Control. Beginning with lift-off and the electrical umbilical disconnecting the rocket is monitoring itself and no manual abort is possible. The rocket is now in powered ascent phase.

The entire engine burn duration is about 9.2 s long, 8.1 s after hold down is released. After this time the main valves are closed and we have achieved MECO (Main Engine Cut Off).

From then on, the rocket is in unpowered ascent until apogee is detected and recovery is triggered.

3.2.9 Recovery:

1. Opening fuel main valve for remaining fuel unloading.
2. Separation of the nose cone from the body tube at apogee.
3. Drogue chute release at apogee.
4. Main chute release 450 m altitude. Backup Altimax triggers at 450 m.
5. Recovering the rocket after landing.

3.2.10 GSE Security:

1. Stopping all cameras.
2. Closing the nitrogen bottles.
3. Vent pressurant tanking system by opening the pressurant tanking valve.
4. Vent pneumatics system by opening the manual venting valve.

3.3 Simulation:

3.3.1 3D-figure of the flight trajectory:

The 3D-trajectories were obtained by running a RocketPy simulation with the data of our rocket. The RocketPy Version used is Version 1.10.0. The thrust measurements are taken from one of our static fire tests. The rail departure velocity required by EuRoC can be achieved using these thrust measurements. The trajectory showin in 3.3 shows the trajectory as simulated in a standardized environment without wind. In the trajectory shown in 3.2 the flight is simulated with predicted winds.

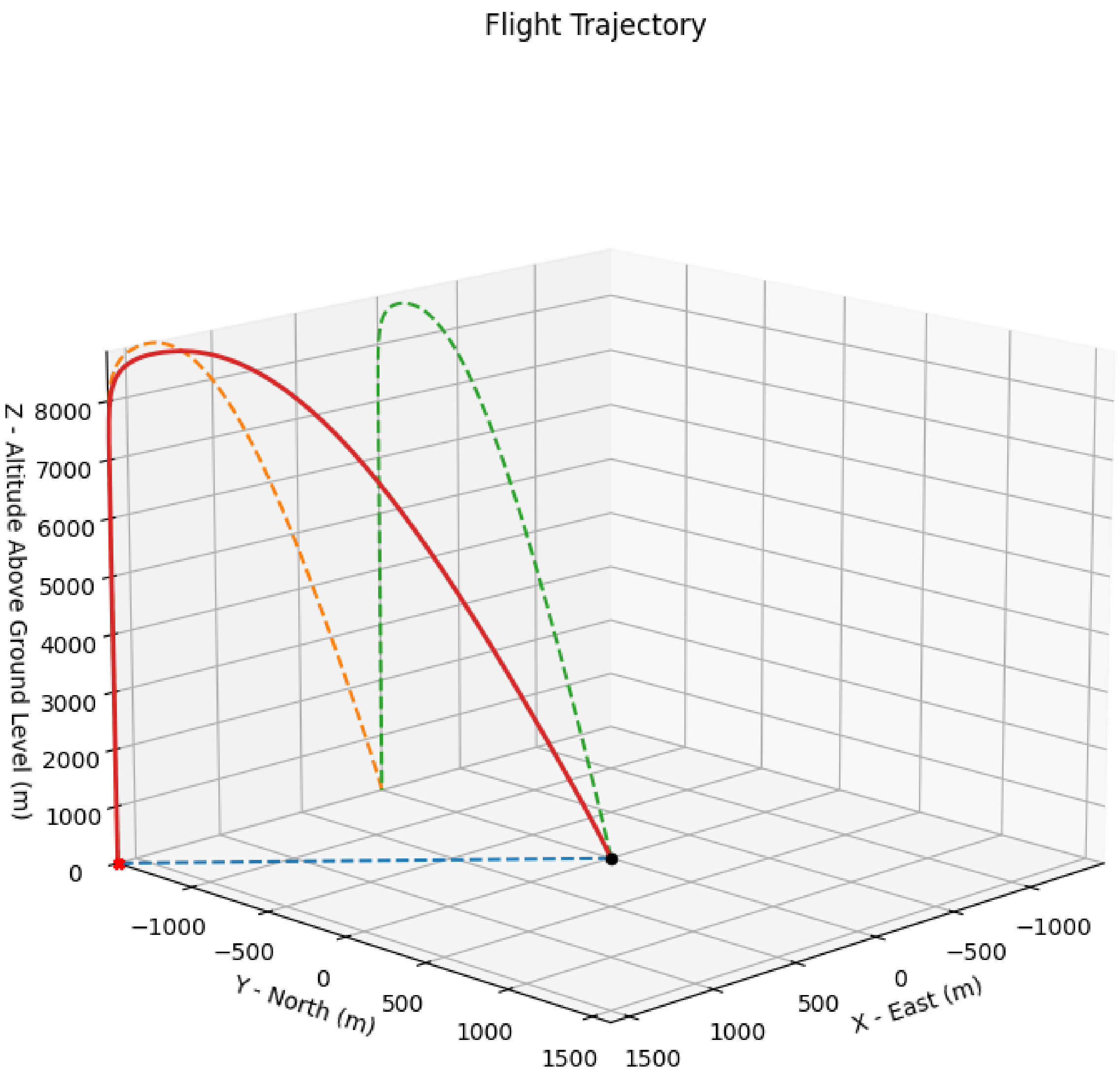


Fig. 3.2: 3D-trajectory without wind

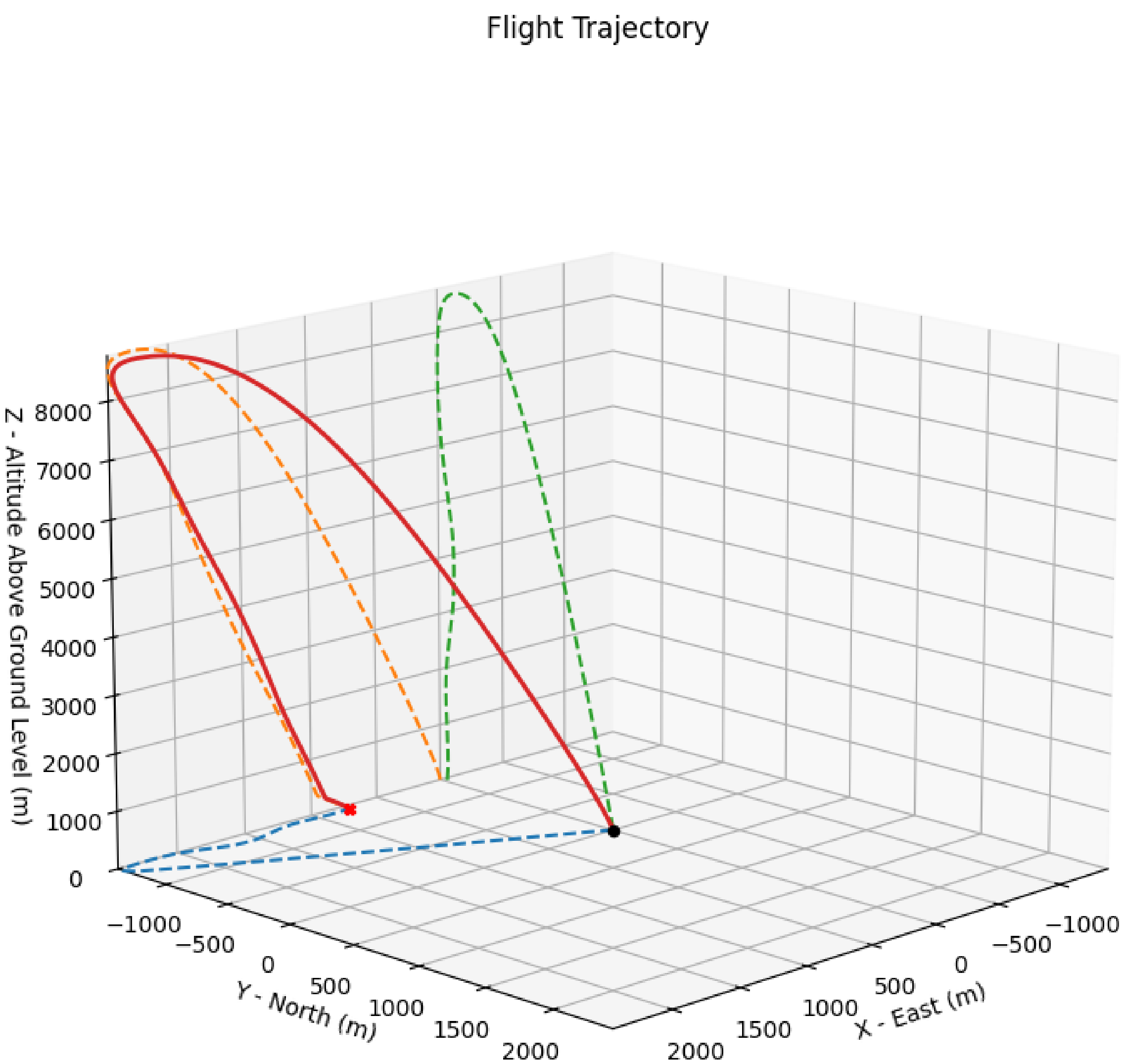


Fig. 3.3: 3D-trajectory with predicted winds

4 Conclusion and Outlook:

Project Lamarr and its Rocket Hedy embody the TU Wien Space Team's 6 year tradition of developing liquid-propelled rockets. Leveraging years of expertise from previous projects, Lamarr represents a leap forward, incorporating numerous advancements over its predecessors.

One of the project's key achievements lies in its ambitious scope. It was a challenge to determine which of the many innovative ideas to prioritize in order to meet deadlines, and which to defer for future exploration. A notable change was the transition from nitrous oxide to liquid oxygen as the oxidizer, requiring not only new infrastructure but also a steep learning curve for the team.

Ongoing challenges include managing time to complete and thoroughly test all systems, as well as ensuring proper documentation to pass on vital knowledge to future team members. As is common in volunteer-based teams, we face limitations in manpower, particularly during university exam periods. Addressing this issue may involve rethinking the recruitment process for upcoming projects.

The students now leading Project Lamarr began with little knowledge, but through dedication and experience, have grown into experts who will pass their insights to the next generation. This continuous transfer of knowledge will enable future Space Team members to further refine and expand the team's capabilities. In addition to technical knowledge, the experience to work on hands-on practical project of the caliber of a space project is invaluable for life as well as for their careers.

After several problems and being unable to launch at last year's EuRoC, the main focus was to improve the reliability of the already existing hardware and undergo an extensive testing campaign. Based on that approach, we were able to make the next step and decided to participate in the L9 category.

A Appendix

A.1 System Data:

Mass (Dry)	16 200 g
Fuel Mass	3656 g
Oxidizer Mass	4550 g
Pressurant Mass	243 g
Mass (Wet)	24 894 g
Tank Volume (Fuel)	5200 mL
Tank Volume (Ox)	5200 mL
Length	3707 mm
Diameter (Body)	132.8 mm
Diameter (Nozzle)	75 mm
Pressurant Pressure	300 bar
Oxidizer Pressure	30 bar
Fuel Pressure	30 bar
Nominal Thrust	2000 N
Combustion Chamber Pressure	15 bar
Burn Duration	9.2 s (Including 1.1s Holddown)
Total Impulse	18 400 N s
Max Speed	564 m s^{-1} (Mach 1.66)
Apogee	9 km
Descent Rate (Drogue)	29 m s^{-1}
Descent Rate (Main)	6 m s^{-1}
Altitude Main Chute Deployment	Altimax G4: 450 m, Backup CATS Vega: 450 m
RF (LoRa) Frequency	868 MHz

Tab. A.1: General System Data

A.2 Detailed test reports:

A.2.1 Ground test demonstration of recovery system:

Main Release Test

Date / Time	2024-07-28
Participants	Lutfi Celik, Joscha Henkenjohann
Testing purpose	To evaluate the performance of the new Burnwire PCB and the Main Release housing, including the effectiveness of the heating wire installation and the overall assembly of the housing.
Changes	Version 1
Doc. Ref.	

Preparations:

The new Burnwire PCB and Main Release housing were assembled.

The heating wire was installed in the clamp, and the housing was constructed without additional insulation.

Tests were conducted to assess the performance of the heating wire and the housing's ability to withstand heat.

Test Execution:

The heating wire was attached to the PCB and tested under operational conditions.

Observations included the performance of the heating wire and the integrity of the housing during operation.

The clamp and housing were subjected to repeated testing to evaluate their durability.

Results:

The heating wire was securely mounted in the clamp, and contact was satisfactory.

The Main Release housing assembled easily; however, during tests, the outputs of the clamps showed signs of scorching.

The plastic of the housing began to melt slightly, and the wire embedded into the plastic, which complicated repeated testing.

Videos of tests with 0.3 mm Nichrome wire and 3.8 mm Paracord were reviewed. The cutting speed of the wire appeared adequate.

The heating wire pieces were cut to a 2.5 Ohm resistance, and the performance was generally acceptable.

Learnings:

The absence of additional insulation in the housing led to melting of the plastic and impaired the heating wire's performance.

There was insufficient space in the housing for Basalt band or PTFE insulation. A plan to use a layer of aluminum tape followed by Kapton tape for insulation was proposed.

Further testing with improved insulation materials is necessary to prevent plastic melting and ensure consistent performance.

Attachments:

Main Release Test

Date / Time	2024-04-16
Participants	Lutfi Celik, Alexander Berger, Stefan Kuttenreich
Testing purpose	To evaluate the performance of the main parachute trigger mechanism under varying tensile forces and to determine if knots in the nylon loop affect its maximum load-bearing capacity.
Changes	Version 1
Doc. Ref.	

Preparations:

Nylon loops with various knots were prepared.

Each loop was equipped with a 2.4 Ω Nichrome heating wire encased in a suitable housing.

The setup included a new lever system designed to safely apply larger tensile forces than achievable with weights alone.

A laboratory power supply was used to provide consistent voltage to the heating wires.

The test involved applying 2500 N tensile force to the nylon loops before activating the heating wire.

Test Execution:

Each nylon loop was subjected to a 2500 N tensile force for several seconds.

The tensile force was then reduced to approximately 240 N (equivalent to the rocket's weight).

The heating wire was energized to cut the nylon loop.

Tests were performed with Nichrome wires of 0.2 mm and 0.3 mm diameters to assess performance differences.

Results:

In the initial tests using the 0.2 mm diameter heating wire, the trigger mechanism failed. The wire burned out before cutting through the nylon loop, despite a short period of current flow.

Subsequent tests with a 0.3 mm diameter heating wire, which has over twice the tensile strength and less than half the specific resistance of the 0.2 mm wire, were successful. In these tests, the wire effectively cut through the nylon loop within approximately 2 seconds after the 2500 N pre-load.

The nylon loops withstood a maximum tensile force of approximately 6000 N. This indicates a safety factor of more than 2 for the 3.8 mm thick nylon ropes against the expected braking force of 2500 N.

Observations revealed that failures occurred where the ropes contacted the screw links, not at the knots, indicating that the knots did not weaken the loop significantly.

Learnings:

The 0.3 mm diameter Nichrome wire is effective for cutting the nylon loop after high tensile loading, suggesting it should be used for reliable operation.

The knots in the nylon loops did not represent a significant failure point; rather, the loops failed at contact points with the screw links.

The current design and concept are robust, and the safety factor for the nylon loops is satisfactory for the application.

Attachments:

Main Release Test

Date / Time	2023-12-29
Participants	Lutfi Celik, Victor Prack
Testing purpose	Evaluate an alternative main parachute release mechanism using nylon loops and heating wires for severing, focusing on actuation time and strength under parachute shock conditions.
Changes	Version 1
Doc. Ref.	

Preparations:

Nylon loops sewn and prepared for load testing.

Heating wires installed to cut the nylon loops and simulate parachute deployment. Multiple heating wire configurations were tested (wrapped through and around the loops).

Tested under controlled loads, aiming for consistent actuation times under various load conditions (240 N and simulated parachute shock with 1800 N).

Test Execution:

1. **Baseline Test:**
    - Under 240 N, nylon loop severed successfully in ~1 second using 0.2 mm heating wire.
    - No damage to supporting structures, with proper load handling.
2. **Simulated Parachute Shock:**
    - Initial attempts to simulate parachute shock using a drop test were unsuccessful due to inconsistent results from suspension dynamics.
    - Nylon loops pre-loaded with 1800 N (180 kg weight) to simulate shock conditions.

    - First test saw both 0.2 mm heating wires fail due to stress transfer from the elastic nylon loop, causing breakage at the insertion points.
3. **Revised Approach:**
    - Heating wire was wrapped around the loop instead of inserted through it, with no structural failures under 1800 N.
    - Further tests with 0.5 mm heating wire showed robustness but had slow release times (>10 seconds) due to lower heat output (10 W).
4. **Final Test:**
    - Reverted to 0.2 mm heating wire with a wrapped configuration, achieving a ~2 second release time at 40 W.

Results:

Nylon loop release under 240 N was reliable with actuation times around 1 second.

The wrapped configuration of the heating wire under 1800 N load was successful without structural damage.

Increasing wire thickness (0.5 mm) decreased performance due to lower heating power.

The 0.2 mm wire delivered acceptable results with ~2 second actuation time when optimized for robustness.

Learnings:

Wire insertion through the nylon loop introduces stress points and leads to wire failure under high loads. Wrapping around the loop solves this issue.

For future tests, 0.3 mm heating wire could provide a balance between robustness and heating power, potentially improving performance under high loads.

Precise measurement of parachute shock forces is necessary for further validation.

Main Release Static Load Test

Date / Time	2024-03-04
Participants	Lutfi Celik, Dominic Wipplinger, Alexander Berger
Testing purpose	To evaluate the performance of the new lever system for tensile load tests of recovery components and to assess the effectiveness of different knots and materials in terms of tensile strength.lore ipsum
Changes	Version 1
Doc. Ref.	

Preparations:

- The lever system was completed, constructed from a 170 cm long steel profile with an approximate 1:8 leverage ratio.
- The pivot point was a solid aluminum half-cylinder, and the base fixing point was a 5 mm thick L-steel profile mounted under the leg of the welding table.
- M6 ring nuts were used as anchor points for the ropes.
- Initial tests used 3.8 mm Paracord nylon ropes to check the setup's functionality and performance.

Test execution:

- The lever system was loaded with a theoretical tensile force of up to 2500 N, equivalent to the nominal braking force of parachutes.
- Breaking tests were conducted with 3.8 mm Paracord to determine the tensile strength and the effect of various knots.
- Observations included the behavior of the nylon cord under load and the stability of knots used in the tests.

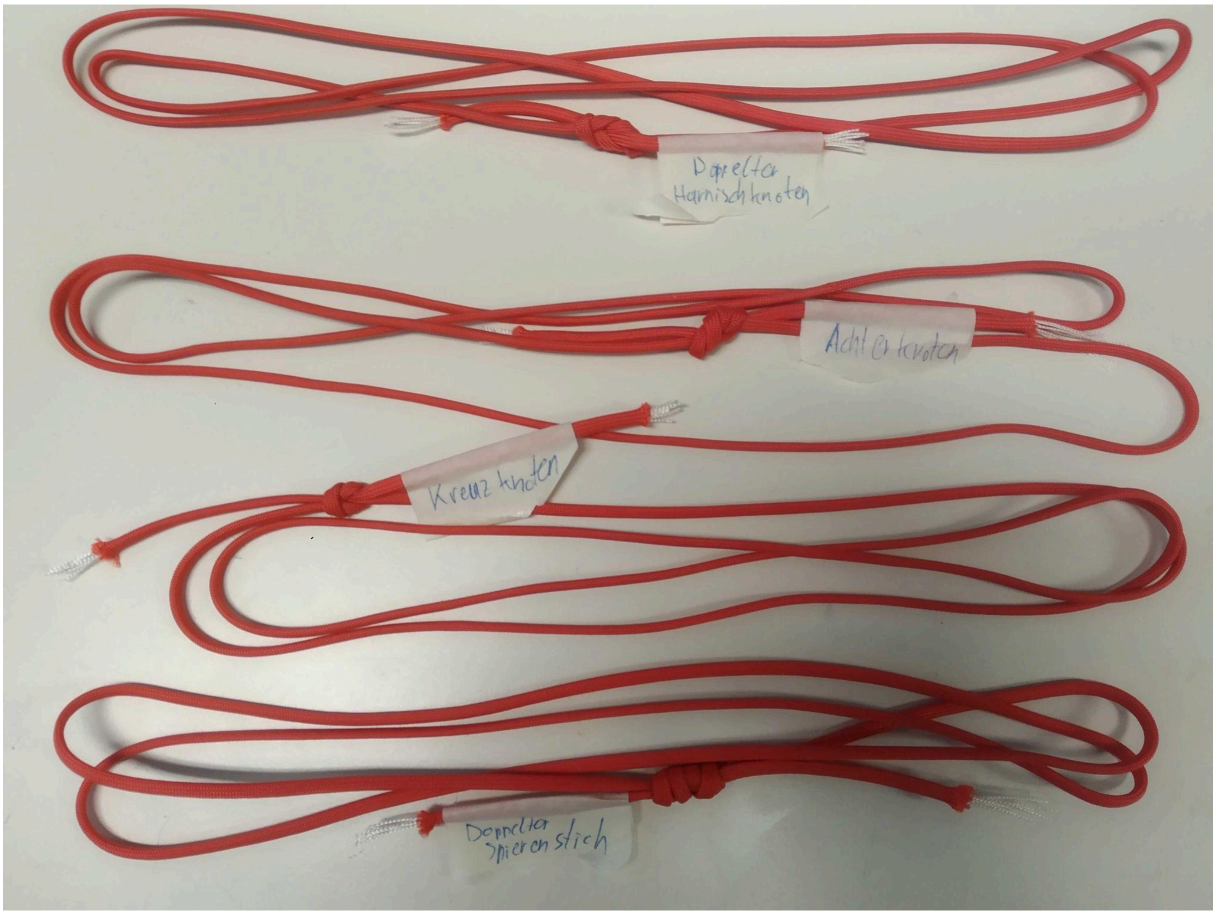
Results:

- The nylon Paracord exhibited significant elongation under load, which caused it to reach the end of the usable range of the lever.
- Knots used to secure the nylon rope to the screw links frequently shifted, impacting test consistency.
- The Paracord broke at a tensile force of 1320 N, which is below the nominal breaking strength of 2490 N.
- Observations indicated that the breakage occurred at the knot site, suggesting that knot placement and design may have affected the results.
- Subsequent tests using Aramid cord showed improved performance, with reduced elongation and more stable knot behavior compared to nylon.

Learnings:

- The significant elongation of nylon Paracord under load was a critical issue, suggesting that alternative materials such as Aramid may offer better performance for tensile tests.
- The shift and failure of knots were problematic; however, the knot type and the condition of the cord were both factors in the observed failures.
- The Aramid cord demonstrated better performance with less elongation and improved knot stability, indicating it as a preferable choice for future tests.

Attachments:


Doppelter Harnischknoten
Achterknoten
Kreuzknoten
Doppelter Spierenstich

Clamp Band Test

Date / Time	2024-02-18
Participants	Lutfi Celik, Niklas Stephan, Ying Mei
Testing purpose	Evaluate the impact of using different core materials and wrapping patterns on the clampband release mechanism's actuation time and structural integrity.
Changes	Version 1
Doc. Ref.	

Preparations:

- Two prototypes using magnesia rods were tested, focusing on thermal resistance and mechanical durability.
- The new clampband design and modifications to the coupler were prepared to eliminate unnecessary flat areas from the previous screw connection.
- Two different wrapping patterns were prepared for testing aerodynamic performance and actuation time.

Test execution:

- Magnesia rods repeatedly broke during transport, assembly, and clampband tensioning. Subsequently, aluminum oxide rods were ordered for future tests.
- The new continuous spring steel clampband functioned well during tensioning and release.
- The first wrapping pattern allowed an actuation time of <1 second, with the right side consistently below 0.5 seconds. However, the clampband didn't lie flush with the coupler.
- The second wrapping pattern improved the aerodynamic alignment but led to slower actuation times (>1 second) on both sides due to increased distance between the nylon thread and heating coil.

Results:

- Magnesia rods are not durable enough for this application; aluminum oxide rods will be tested next.
- The new spring steel clampband and clamp designs performed well under tension.
- The second wrapping pattern resulted in unacceptable delays in actuation time due to the larger distance between the nylon thread and heating coils.

Learnings:

- Using aluminum oxide rods may solve the fragility issue observed with magnesia.
- Aerodynamic improvements must be balanced with maintaining a fast actuation time, as excessive spacing reduces performance.
- Further development of the heating wire holder is needed to reduce thread spacing while preserving durability.

Attachments:

Clamp Band Test

Date / Time	2024-01-23
Participants	Lutfi Celik, Niklas Stephan, Ying Mei
Testing purpose	Evaluate the actuation time and structural improvements of the clampband release mechanism with integrated pulley pin.
Changes	Version 1
Doc. Ref.	

Preparations:

- Two new prototypes of the heating wire holder were designed and printed, both with integrated pulley pins.
- Differences in spacing between screw, heating wire coil, and pulley pin were tested to improve thread insertion.

Test Execution:

- Conducted tests on both versions:
  - The first version had increased spacing (~1mm) to ease nylon thread threading.
  - The second version had tighter spacing to maintain optimal actuation time.
- Additional tests were performed with a 0.1 mm diameter heating wire found by Florian, but it broke multiple times during setup and burned out immediately upon activation.
- An alternative wrapping method was tested to improve aerodynamic properties of the tensioned clampband.

Results:

- The first version, with increased spacing, caused a significant delay in actuation time.
- The second version, with tighter spacing, maintained an actuation time of <0.5 seconds on the side without the pin, while the side with the pin remained slower.
- The 0.1 mm heating wire proved too fragile and unsuitable for this application.
- The aerodynamic test did not yield conclusive results on actuation time.

Learnings:

- The distance between the pulley pin and the heating coil needs further reduction to improve the actuation time on the pinned side.
- The 0.1 mm wire is not durable enough for use in this mechanism.
- Aerodynamic modifications require further investigation to determine their effects on performance.
-

Attachments:

Clamp Band Test

Date / Time	2024-01-07
Participants	Lutfi Celik, Niklas Stephan, Ying Mei
Testing purpose	Test steel pin version of the clamp band Endurance test to check if clamp band is influenced by remaining armed for a long time
Changes	Version 1
Doc. Ref.	

Preparations:

- Setup of the clampband release mechanism with a steel pin used as a pulley to adjust the path of the nylon thread.
- The clampband was tensioned, and all components were checked to ensure proper configuration for testing.

Test Execution:

- Conducted two tests with the steel pin pulley in place to measure actuation time on both sides of the mechanism.
- The system was subjected to repeated tensioning to observe the effects on the steel pin.
- A long-term durability test was performed by leaving the clampband tensioned overnight before triggering the release mechanism the following day.

Results:

Both sides of the mechanism achieved a consistent actuation time of approximately 0.3 seconds, successfully meeting the goal of a sub-0.5 second release.

- The steel pin was torn out of the plastic after repeated tensioning, indicating a new weak point in the design.
- In the durability test, the clampband maintained tension overnight and still triggered successfully with <0.5 seconds actuation time.

Learnings:

- The steel pin design requires further reinforcement to avoid failures after repeated tensioning.
- Improvements are needed to enhance both the robustness and ergonomic usability of the heating wire holder to simplify nylon threading.

Attachments:

Clamp Band Test

Date / Time	2024-01-01
Participants	Lutfi Celik
Testing purpose	To address the asymmetrical release times observed during previous tests, where the release on one side was faster than the other. To explore design modifications, such as different screw sizes and support structures, to improve balance in release performance.
Changes	Version 1
Doc. Ref.	

Preparations:

1. **Asymmetrical Release Observation:**
    - During testing on 2024-01-01, it was observed that the release times between the left and right sides were not identical. Specifically, the right side of the system released under 0.5 seconds, while the left side took approximately twice as long.
    - Upon further inspection, the nylon thread was found to be winding asymmetrically through the screw during tensioning, meaning the sections of the thread to be severed by the heating coils were closer to one side than the other. This discrepancy directly contributed to the difference in release times.
2. **Potential Solution:**
    - It was hypothesized that switching to a smaller M3 screw instead of the current M4 screw might help correct this asymmetry. However, the benefit would only marginally shift the thread by approximately 0.5 mm, not enough to fully resolve the problem. Furthermore, the smaller screw would require finer threading (around 1 mm diameter), which could make the threading process more difficult and potentially weaken the screw.

3D Printing of Heating Wire Holders:

1. **Different Printing Orientations:**
    - Various orientations were tested for 3D printing the heating wire holders. Printing the holder flat required extra support material, which had to be removed and sanded down after the print was complete. However, this approach resulted in more structurally sound overhangs that securely anchored the GFK cores in place.
    - A downside to this method was that it placed the weakest axis of the 3D print in the direction of the greatest tensile force during testing, making the holder vulnerable to breakage under load.

Execution:

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1. **Steel Pin as a Guide:**
    - a new test was conducted where a steel pin was embedded into the plastic as a makeshift pulley to guide the nylon thread closer to the left side. This modification aimed to balance the distance between the heating coils and the nylon thread on both sides, thus improving release symmetry.
    - Concerns were raised about the potential for the pin to be pulled out of the plastic under tension, but the initial setup held during the test.
    - Threading the nylon through the pin proved to be more cumbersome, but it was concluded that slight changes in the part's geometry could alleviate this issue.
2. **Proof of Concept:**
    - The release time with the steel pin was still not ideal, but the test served as a proof of concept, indicating that further refinement in the design could potentially solve the asymmetry problem.

Results:

The use of a steel pin successfully brought the nylon thread closer to the left side, improving the balance between the release times. Although the pin held during this test, the threading process was more difficult, suggesting a need for geometric adjustments to the part design.

Learnings

- Conduct further tests with an improved steel pin guide design to determine the impact on release times and ease of assembly.
- Revisit the design of the 3D-printed heating wire holder to optimize print orientation and material strength.
- Explore alternative methods of adjusting the nylon thread path to achieve symmetric release times.

Attachments:

Clamp Band Test

Date / Time	2023-12-29
Participants	Lutfi Celik
Testing purpose	To test the latest iteration of the clampband release mechanism. To assess improvements in ease of assembly, durability, and heating performance. To continue optimizing the release time to below 0.5 seconds.
Changes	Version 1
Doc. Ref.	

Test execution:

1. New Tension Screw Fabrication:
   - A new tension screw had to be fabricated since the previous M4 screw was too short for the new holder.
   - The process involved carefully grinding down the screw head with a Dremel, centering the drill points, and chamfering the holes to prevent thread damage during tensioning.
   - The threading was filed down around the holes to avoid damage to the nylon thread, and the holes were brought closer together to reflect the positioning in the tensioning blocks, allowing the nylon threads to be more easily severed.
2. GFK Core Fabrication for Heating Coil:
   - GFK (fiberglass) cores for the heating coil were cut and shaped using a bandsaw and sander.
   - These cores were fragile and became brittle after just a few tests due to heat exposure. As a result, a larger batch of small GFK rods was planned for production using a CNC machine.

    - For shaping, an electric screwdriver was used to hold the rods, allowing sanding to create near-cylindrical cores. Although the process was unconventional, it worked well with Matthias Rier's advice to use a stationary drill for more precision.
3. Heater Wire Mount Redesign:
    - The new holder for the heating wire offered several advantages, including moving the heater cables away from the aluminum coupler to avoid short circuits and making the wire length adjustable to optimize heating performance.
    - This design reduced the chance of short circuits and ensured safer operation by eliminating the risk of the wire contacting the coupler. Additionally, insulating tape was added for extra safety.
    - The adjustable wire length allows for tuning the resistance to match the flight computer's power output, maximizing heating efficiency.
4. Threading Configuration:
    - The threads no longer cross over the heating element, reducing the risk of the nylon thread pulling or damaging the heating wire mid-flight.
    - This design also permits more holes in the tensioning blocks and screw, which may become necessary if higher axial forces are encountered during flight. Statically loading tests will confirm if additional connections are required.

Results:

- Assembly Improvements:
  The new tension screw and modifications to the nylon threading significantly improved ease of assembly and durability. The thread was less prone to accidental cuts or damage during tensioning.
- Heating Coil Durability:
  While the current GFK cores showed some fragility after repeated use, the prototype demonstrated that the design could support high-power heating elements. Further tests with GFK rods and potential exploration of carbon fiber (CFK) cores are planned to enhance durability.

- Release Time:
  The new setup reduced the release time to under 0.5 seconds at 45 Watts, a significant improvement over previous iterations. There remains a slight gap between the heating coil and the nylon threads, which could further be minimized to achieve even faster release times.

Learnings:

1. **GFK Core Durability:**
   Current GFK cores are not as heat-resistant as anticipated. Potential solutions include switching to CFK rods or modifying the core fabrication process to improve thermal tolerance.
2. **Holder Redesign:**
   The current gap between the heating coil and the nylon threads should be reduced to increase the efficiency of the cutting process. This could further shorten the release time.
3. **Material Consideration:**
   The team will explore using CFK rods to improve manufacturing uniformity and reduce fabrication time. However, further investigation is needed into the potential risk of short circuits due to CFK’s conductivity.

Clamp Band Test

Date / Time	2023-12-18
Participants	Lutfi Celik
Testing purpose	To confirm whether friction between the nylon thread and the tensioning blocks/screws is the primary cause of long release times. To evaluate alternative configurations for the nylon threading and the heating element to reduce the release time to below 1 second.
Changes	Version 1
Doc. Ref.	

Test execution:

1. Simplified NiChrome Heating Wire Setup:
    - The first test aimed to verify the hypothesis that friction from the nylon thread contributes to the long release time. A NiChrome heating wire was used, with the nylon thread only fastened on the top side at the tensioning blocks and screw.
    - As expected, the release time was significantly reduced, measuring under 0.5 seconds. However, the tension force from the clampband caused the knot in the nylon thread to come undone. To counter this, the knot had to be made considerably larger in this configuration.
2. Crossed Nylon Thread Configuration (Suggested by Georg Mikula):
    - In the second test, the nylon threads were crossed (steps 4-5 and 10-11 from the diagram were reversed). This modification aimed to bring the threads closer to the heating element and improve the cutting efficiency.
    - A short piece of NiChrome heating wire with 1 Ohm resistance was used as the heating element. The setup was recorded with a

high-speed camera and a digital stopwatch to improve time measurement accuracy.
    - The crossed-thread setup worked exceptionally well. Using the slow-motion footage, it was observed that the heating wire severed the first nylon thread after 0.2 seconds and the second after 0.8 seconds. This brought the total release time to under 1 second, meeting the team's performance goal.
3. Repeat Test:
    - The test was repeated to verify the results, yielding a cutting time of 0.3 seconds for the first thread and again 0.8 seconds for the second thread.

Results:

- Simplified Setup (Thread on Top Only):
  The test confirmed that friction between the nylon thread and the tensioning blocks/screws significantly delayed the release. Reducing the friction by removing the bottom thread attachment shortened the release time to under 0.5 seconds, but larger knots were required to prevent the thread from slipping.
- Crossed-Thread Configuration:
  This configuration performed excellently, with a total release time of under 1 second, meeting the team’s objectives. High-speed footage confirmed that the heating element cut through both nylon threads in sequence.

Learnings:

1. Heating Element Holder Redesign:
   The next step is to redesign the holder for the heating wire to accommodate a heating coil. This could further reduce the release time

to below 0.5 seconds, as the coil design is more efficient for cutting both threads quickly.

2. Robustness and Reliability Enhancements:
The current configuration should be optimized for increased durability and reliability in various flight conditions. This includes refining the thread tensioning mechanism to ensure consistent results without requiring oversized knots or extra modifications.

Next Steps:

- Redesign the heating wire holder to support a NiChrome heating coil and repeat the tests to improve the release time further.
- Continue testing to ensure the reliability of the crossed-thread configuration and fine-tune the setup for real-world application in the rocket's release mechanism.

Clamp Band Test

Date / Time	2023-12-11
Participants	Lutfi Celik
Testing purpose	To evaluate the performance of the new prototype for the clampband tensioning and release system. To test different heating elements (NiChrome wire, electrical resistors) for cutting the nylon thread that holds the clampband.
Changes	Version 1
Doc. Ref.	

Preparation:

The assembly process was significantly improved, with easier fitting of cable lugs and M2 screws into the holder. However, insulating tape was still required on the coupler to prevent electrical shorts between the screw heads and the poles of the heating wire due to the aluminum coupler.

Test execution:

1. NiChrome Heating Wire:
    - A test using NiChrome heating wire was conducted first. Unfortunately, the release time remained long at approximately 4 seconds, as the power dissipated in the short, low-resistance wire was insufficient, and the contact between the thread and the wire was poor.
2. Electrical Resistors:
    - Next, electrical resistors with a rated power of 0.5 W were tested to determine if they could effectively cut the nylon thread.

    - The system operates at a supply voltage of 12 V and a maximum current of 5 A, providing up to 60 W of power. The goal was to maximize heating power to sever the nylon thread as quickly as possible.
    - However, resistors burned out almost immediately at this power level. Through a series of tests, the team determined that the resistors could withstand a maximum power of only 10 W for the desired duration, which was far below the system's potential capacity.
    - The tests showed a significant decrease in cutting time as heating power increased.
    - Despite the power limitation, resistors operating at 10 W were able to sever a nylon thread wrapped around them in less than one second.
3. Final Test in Recovery Prototype:
    - One of these resistors was installed in the recovery prototype to determine the actual release time. Due to limited power and poor contact between the resistor and the nylon thread, the cutting time was again approximately 3 seconds, which is still too slow for practical use.

Results:

- NiChrome Wire: The NiChrome wire was ineffective due to insufficient power dissipation and poor thermal contact with the nylon thread, resulting in slow release times (~4 seconds).
- Electrical Resistors: Resistors rated for 0.5 W were capable of cutting the nylon thread when operating at up to 10 W, but they were still not optimal. The cutting time could be improved, but achieving higher power levels without burning out the resistors remains a challenge.

Learnings:

1. Increase Power:

    - Use resistors with a higher rated power, though these may be more expensive and bulky, potentially making them difficult to fit between the coupler and parachute tube.
    - Alternatively, a longer NiChrome wire could be used. However, this would require a spool with a non-conductive, heat-resistant core to prevent deformation or short circuits during flight.
    - A thinner heating wire could also be used, but the thinnest wire currently available is already fragile and prone to breaking under tension, so a thinner wire would likely exacerbate these issues.
2. Improve Thermal Contact:
    - Tests showed that 10 W of power is sufficient to cut the nylon thread quickly, provided there is good thermal contact between the heating element and the thread.
    - Using thermal paste, as suggested by Niklas Stephan, could improve the heat transfer. However, the paste may liquefy under high acceleration during flight, so further testing is needed to evaluate this risk.
3. Mechanical Enhancements:
    - Georg Mikula suggested a design improvement where the nylon thread is stretched against the resistor, improving the thermal contact and cutting speed.
    - Using multiple resistors in parallel could increase the total power delivered to the thread, reducing the cutting time further.

Next Steps:

- Test higher-rated resistors and longer NiChrome wires in a controlled environment to evaluate their performance and durability under flight-like conditions.
- Investigate the use of thermal paste or other methods to improve thermal contact without adding unnecessary complexity or failure points.

Clampband Load Test

Date / Time	2024-04-07
Participants	Lutfi Celik, Dominic Wipplinger
Testing purpose	To evaluate the load-bearing capacity of the Clampband coupler and determine the relationship between the number of loops in the Clampband and its tensile strength.
Changes	Version 1
Doc. Ref.	

Preparations:

- The Clampband was tensioned and connected to the nosecone.
- An aluminum profile was attached with brackets to the holder, positioned 30 cm from the coupler.
- Increasing weights were applied until the Clampband failed.
- Tests were conducted with varying numbers of loops through the Clampband and the tensioning screw.

Test execution:

- The Clampband was subjected to increasing loads using weights until it ripped.
- The experiment was repeated with different numbers of loops to assess their effect on the tensile strength.
- Challenges included accurately measuring the pre-tension force required for the Clampband, which affected reproducibility and assembly during flights. Digital torque sensors were used but were insufficient due to high friction forces of securing nuts.

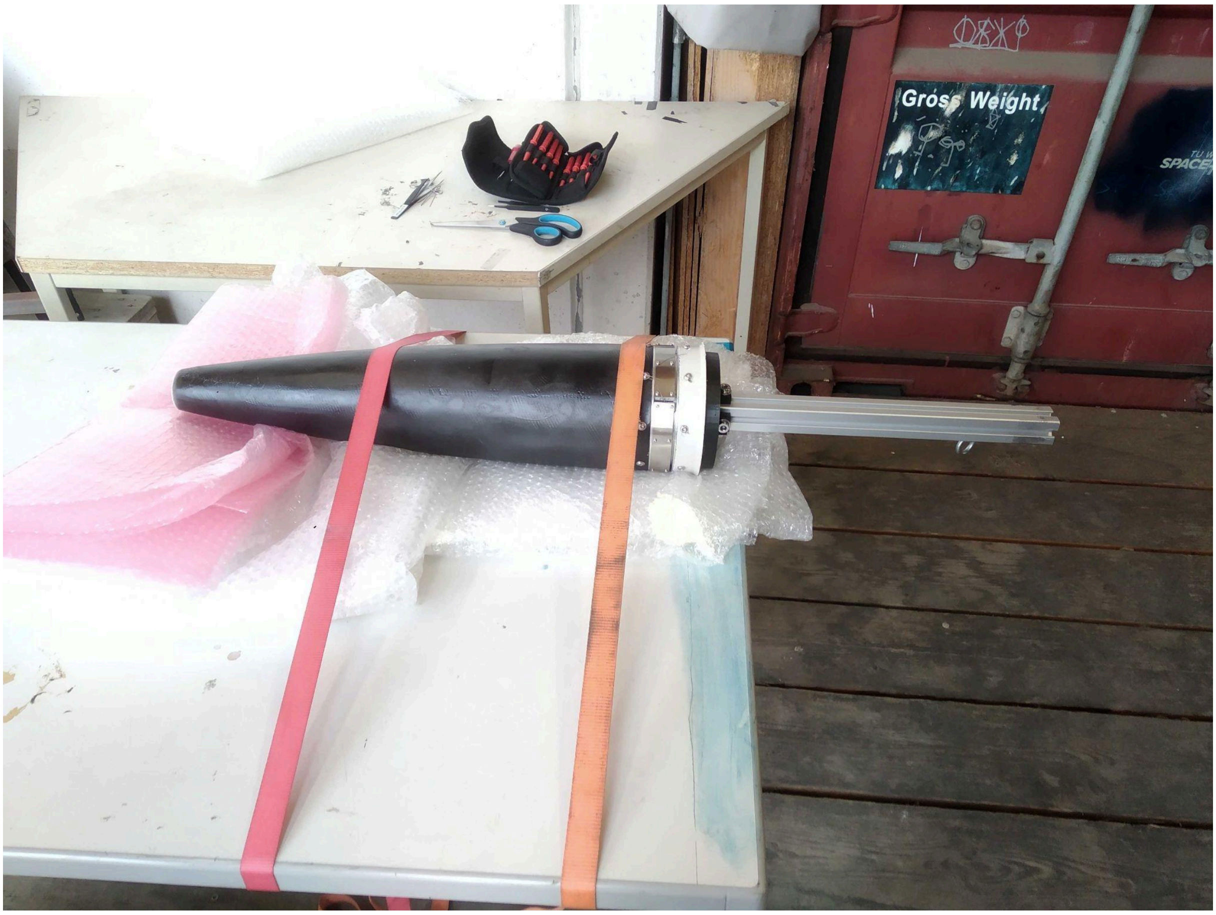
Results:

- The average breaking forces for different configurations were as follows:
  - Single thread, one loop: 105 N
  - Single thread, two loops: 140 N
  - Double thread, one loop: 165 N
- It was observed that the breaking strength did not follow a simple linear relationship with the number of loops.
- A significant issue was the difficulty in determining the pre-tension force, which impacted both the reproducibility of tests and the assembly process.
- Calculations showed that for the Starboat, with a maximum speed of 150 m/s and a nose length of 60 cm, an aerodynamic load of ~100 N is expected, which is manageable with two loops and a safety factor of ~1.5.
- For the Hedy, which requires the coupler to withstand up to 600 N of horizontal force, the system must be made significantly more robust. The current 0.2 mm fishing line is too thin, and thicker threads would be needed, though this would increase the release time.
- An important observation was that failure occurred at the knot with the double thread configuration. Attempts to use a knot with theoretically lower reduction in tensile strength did not affect the breaking strength of the Clampband.

Learnings:

- The breaking strength of the Clampband does not linearly correlate with the number of loops in the thread.
- Accurate measurement of pre-tension is challenging, affecting test consistency and assembly.
- The Clampband needs to be more robust for applications requiring higher forces, and using thicker threads could improve performance.
- Knot failure was significant, and while alternative knot designs were tested, they did not improve the tensile strength.

Attachments:


Gross Weight

Shock Absorber Test

Date / Time	2024-09-03
Participants	Lutfi Celik, Eric Drößiger, Stefan Kuttenreich, Victor Prack
Testing purpose	Determine load at which shock absorber prototype triggers
Changes	Version 1
Doc. Ref.	

Preparations:

Extra strong yarn used for both **upper thread and under thread.**

1. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with extra strong thread
2. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with extra strong thread
3. 20 cm absorber made out 10 mm wide aramid braid, 20 lines of parallel stitches with extra strong thread
4. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with extra strong thread

---

Test execution:

1 - 4 : Weight was added to the shock absorber until it started ripping open

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Results:

1. Opened at 520 N

2. Opened at 445 N

3. Opened at 550 N

4. Opened at 650 N

Learnings:

Attachments:

Shock Absorber Test

Date / Time	2024-08-28
Participants	Lutfi Celik, Eric Drößiger, Stefan Kuttenreich, Victor Prack
Testing purpose	Determine load at which shock absorber prototype triggers, determine absorbed energy
Changes	Version 1
Doc. Ref.	

Preparations:

1. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with extra strong thread
2. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with extra strong thread
3. 20 cm absorber made out 10 mm wide aramid braid, 32 lines of parallel stitches with extra strong thread
4. 20 cm absorber made out 10 mm wide aramid braid, 32 lines of parallel stitches with extra strong thread
5. 40 cm absorber made out 10 mm wide aramid braid, 18 lines of parallel stitches with extra strong thread

Test execution:

1 - 4 : Weight was added to the shock absorber until it started ripping open

5: Drop test with 9 kg weight from a height of 20 cm to determine absorbed energy

Results:

1. Opened at 295 N
2. Opened at 300 N
3. Opened at 520 N
4. Opened at 415 N
5. 1,8 cm of absorber left

Learnings:

Attachments:

Shock Absorber Test

Date / Time	2024-08-19
Participants	Lutfi Celik, Eric Drößiger, Stefan Kuttenreich, Victor Prack
Testing purpose	Determine load at which shock absorber prototype triggers
Changes	Version 1
Doc. Ref.	

Preparations:

1. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with regular thread
2. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with regular thread
3. 20 cm absorber made out 10 mm wide aramid braid, 16 lines of parallel stitches with regular thread
4. 20 cm absorber made out 10 mm wide aramid braid, 32 lines of parallel stitches with thin thread

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Test execution:

Weight was added to the shock absorber until it started ripping open

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Results:

1. Opened at 150 N
2. Opened at 150 N
3. Opened at 135 N
4. Opened at 280 N

Learnings:

Attachments:

A.2.2 Flight test demonstration of recovery system:

Recovery Test Flight

Date / Time	2024-04-21
Participants	Recovery Team
Testing purpose	Verify function of all recovery components during a test flight
Changes	Version 1
Doc. Ref.	

Attachments:

Compo nent	Description	Worked well	Worked poorly	Suggestions for improvement	To do
CATS Vega	Back-up flight computer, but takes over official EuRoC altitude determination and is responsible for GNSS positioning after landing using the ground station. Has telemetry	Programmable as desired, telemetry worked, drogue and main triggers worked, flight data was recorded, state estimation was good, no problems with barometric altitude determination	No GNSS reception, flight computer crashes upon landing	Dielectric waveguide via GPS opening to improve the signal, extendable CATS Vega?	

Altimax G4	Main flight computer, no telemetry or GPS positioning, very reliable. Limited programmability	Drogue and main trigger worked, flight data was recorded, no problems with barometric altitude determination	Not programmable exactly as desired, Pyro Channels are always energized for exactly 3 seconds	Adjust the resistance of the Altimax Burnwire as it can convey more current. But then the two mechanisms are no longer symmetrical and false infection becomes possible	
RBF pin and switch	Mechanism to turn on flight computers shortly before takeoff	Plugging in and pulling out is easy, installation with pins plugged in is possible to prevent false triggering	From the outside you can't tell whether pins are pulled before you connect the screws to the heads! Position not perfect, further away from the rail would be better. Switches tripped when landing because they were sensitive to shock	It is better to use switches with a higher rating and immediately attach pin extensions when assembling so that it is clear whether the pins have been pulled or not	
Aluminum bulkhead	Transfers the entire braking force of the parachutes to the airframe. Stop point for all recovery components. CNC milled.	Radial holes and threads are excellently manufactured with a dividing head. Has endured drogue braking stress without any problems	Chamfers were only made on the top, the bottom had to be chamfered manually.		Breaking tests
Parachute tube holder	Connects the GRP parachute tube to the aluminum bulkhead. ABS 3D printing	Worked problem-free during the flight	Broken several times during stress testing. Possibly integrate with the aluminum bulkhead and make it together as a single part made of aluminum for increased strength		
Parachute tube	1.5 mm thick, 89 mm outer diameter GRP pipe. Serves as a holding point for the antennas and houses parachutes and lines inside.	Drilling of the mounting holes is possible without tearing them out, steps on the upper side to pass through lines, gluing the antenna holder	The main parachute got stuck at the mouth of the tube when the rocket was in horizontal flight	If necessary, round off the parachute tube mouth, for example with a funnel/trumpet-shaped attachment to prevent it from	

		and burnwire holder without any problems		jamming Make openings for lines in the payload holder, not in the parachute tube	
Centerin g ring	Stabilizes the parachute tube against horizontal loads at the level of the lower coupler, ABS 3D printing	Installation possible without collision. Survived the flight unscathed	Questionable strength, large recesses necessary to enable installation, glue point with lower coupler torn off several times	Integrate with lower coupler and manufacture together from aluminum.	Made of GRP and screwed on
Lower coupler	Lower half of the aluminum coupler, which is held together by the clamp band.	Positive connection with the other coupler half. No concerns about strength.	Inaccurate drill holes made installation and removal difficult. Pressing in the insert nuts is complex. Holes too close to the edge.	Production of the drill holes in the future with a dividing head or with 4-axis CNC. Integrating the centering ring.	Determine crown height, measure nose cone, ask Reinhard
Upper Coupler	Upper half of the aluminum coupler, which is held together by the clamp band.	Positive connection with the other coupler half. No concerns about strength.	Inaccurate drill holes made installation and removal difficult. Pressing in the insert nuts is complex. Edges of coupler collided with antenna and blocked nose release. Holes too close to the edge. Attaching the rubber hoses is problematic.	Production of the drill holes in the future with a dividing head or with 4-axis CNC. Additional chamfering on the inner edges to make it easier for the nose to become uneven	Determine crown height, measure nose cone, ask Reinhard
Payload holder	Fixes the payload (form factor 2x CanSat) on the parachute tube, connected to the upper coupler via rubber hoses, which act as the nose ejection mechanism.	Payload firmly anchored, easy access to charging socket and RBF pin.	Tightening is difficult, straps are not particularly tear-resistant and wear and tear is problematic. No way to load payload via Umblical.	Push pins to connect payload with rest of avionics to Umblical. Recesses for lines to pass through.	Pogo pins for Umblica, let WerndlExplorer know about the Umblica connection

Payload	Double Cansat from WerndlExplorer with barometer, IMU and camera. Has its own RBF pin and USB-C charging socket.	Installation problem-free, simply pull the RBF pin, measurement data recorded successfully, good camera recording thanks to LEDs.	RBF can only be pulled before installing the nose, therefore not possible on the rail.	Loading push pins required for loading via Umblical.	
Antenna holder	Fixation point for the CATS Vega dipole antenna. Protects this from the upper coupler when ejecting the nose	Successfully guides the coupler and nose over the antenna without getting stuck.	Very high. Design only possible on one side as the diameter would be too large on opposite sides.	If necessary, move it within the parachute tube	
Antenna	Homemade dipole antenna for the CATS Vega, 2.4 GHz frequency	Continuous telemetry during test flight, range test up to 2 km. Similar properties to the original Moxon antenna	Too big due to SMA connector, problems ejecting the nose.	Strip coaxial cables and turn them inside out as an alternative design for a dipole antenna.	Peter ask about path antenna, or dipole antenna coaxial cable, or WLAN antenna
Main Release Burnwire	Cuts the paracord piece, allowing the main parachute to be pulled out through the braking parachute.	Easy installation, no collision with body tube. Worked on the test flight. No burning or melting of the holder.	Unfavorable design of the connection cables. Connecting brackets to parachute tubes is difficult, but necessary to prevent cable breakage	Adjust the shape of the parachute tube and glue it tightly, use JST connectors, guide the paracord better at the centering ring so that no large deflection is possible	
Main release lines	Paracord rope knotted together, which is attached to the bulkhead and the soft shackle	Withstood the load, installation was easy, triggering worked without any problems			
Clamp band	Holds the two coupler halves together during flight. Tied with a nylon thread.	Installation is reasonably possible	Nylon thread weak point of the coupler during stress tests. Clamping bends the clamp band ends outwards	Use thicker thread for clamp band, make clamping blocks flatter, place opening on the opposite side.	Do not tie the ends of the clamp band thread together, but loop them and connect them with the clamp band

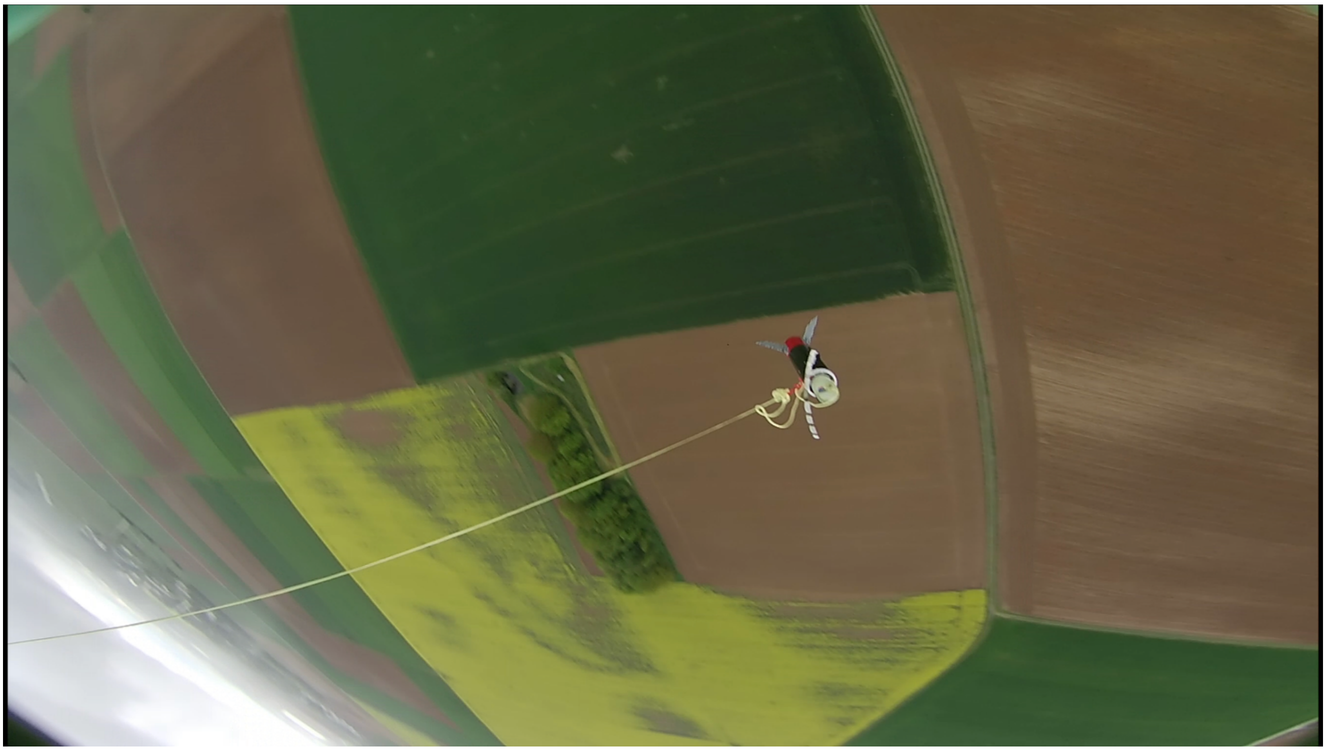
			when opening, which rubs against the launch rail. Position of the opening at the worst point, better opposite the rail		Order thicker Dyneema rope
Clampband burnwire holder	Holds the burnwire for the clampband release mechanism and the tension screw, which is used to wind and pre-tension the clampband.	Clamping is easy, the mother retainer did its job well	Threading the thread is problematic, tensioning cannot be repeated with the same pre-tensioning force, m4 screw with radial hole is a major weak point, installing the burnwire is complex, short circuits in the first tests are a repeated problem	Glue the burnwire holder with a coupler instead of a parachute ear, install the burnwire firmly and not replace it as it is no longer necessary, use PSB as a power supply and connection point, change the geometry and make it slimmer for the centering ring, use JST connector for installation	
Camera plate	GRP plate under the bulkhead, which serves as the lid of the avionics housing and the fixation point for the black RunCam.				
Black RunCam	Camera that films vertically upwards through the bulkhead into the parachute tube. The battery pack is shared with the CATS Vega.		No recording because it was too dark and no main ejection	LEDs to illuminate the interior of the rocket	

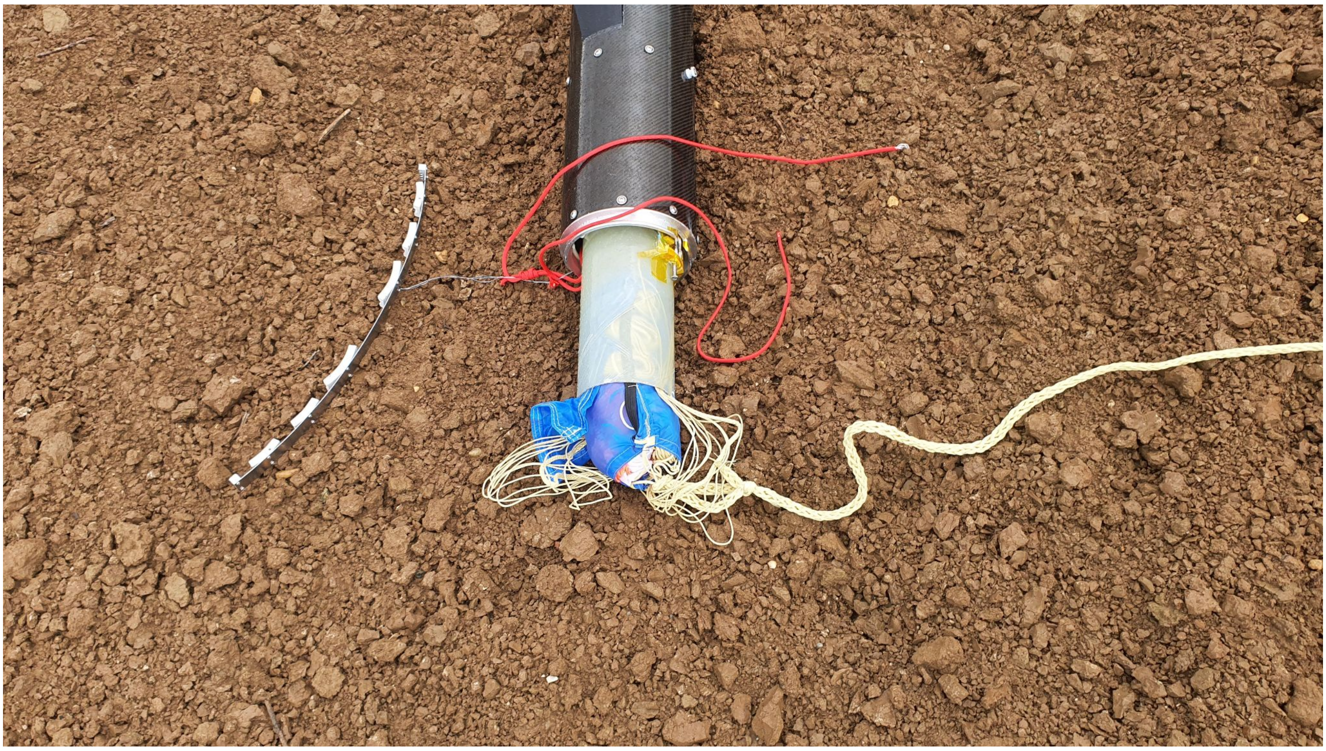
Swivel	Fixed under each of the parachutes to prevent the rocket's lines from twisting.	Tests and flight survived well#			
Soft shackle	Alternative to screw links, made from aramid rope.	Tests and flight survived well	Fastening with shrink tubing is difficult, opening requires cutting open the shrink tubing	20cm length for safety	
Screw links	Connection link of various lines, 3 mm thick	Tests and flight survived well			
Drogue chute	Cross parachute, which serves as a braking parachute and pulls the main parachute out of the parachute tube.	The higher lift compared to the rocket's tail unit ensured horizontal flight of the rocket body after ejection.	Level flight detrimental to main parachute ejection	Possibly larger drug chute for a better flight attitude of the rocket, alternatively a heavier rocket with a center of gravity further back and/or a smaller tail unit.	
Main chute	Main parachute, which slows the rocket to the targeted landing speed. Stored in a deployment bag.				
Deploy ment bag	Self-sewn deployment bag made of parachute fabric, which houses the main parachute. With anchor points for the parachute shroud lines	Stowing the main in the deployment bag is complex, but possible, lines are securely but easily detachable with rubber bands	The deployment bag got stuck on the parachute tube mouth or the pulling force on the rope at ~45° to the mouth was not sufficient to pull it out. Tabs to cover the lines too small.	Smaller diameter relative to the parachute tube, longer shock cord	

Shock absorber	Sewn 10 mm aramid tubes, which are intended to absorb the parachute shock.	Parallel design of the shock absorbers is a good way to increase the limit of the force that triggers it		Step-shaped design, which triggers at ever higher forces.	
Aramid lines	Various lines made of aramid, and rocket parts with parachutes and to connect them together. Some with split eyes, some with knots.	Spliced eyes worked well and were easy to prepare, bowline knots on all lines that cannot be spliced are a good alternative			

Attachments:


LBL





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A.2.3 Electronics thermal testing:

The onboard electronics were consistently tested during all Cold Flow and Hot Fire campaigns. Throughout all test events, the electronics were continuously monitored for thermal behavior. No thermal or humidity-related issues were observed, even during tests conducted in rainy conditions.
All electronic components, including the PCBs, are specially coated to ensure environmental protection. Furthermore, all connectors were greased to prevent moisture ingress and ensure reliable operation.
The electronics demonstrated stable and robust performance across all environmental conditions encountered during testing.

LN2 Endurance Test and Cold Flow

Date / Time	2025-02-08 / 18:30
Participants	• Lutfi Celik (Mission Control) • Raffael Rott (Mission Control Assistant) • Matthias Rier (Mission Supervisor) • Johannes Eschner (Mission Lead) • Matthias Ogris (Mission Lead Assistant) • Oliver Balint (Documentation)
Testing purpose	• Cryogenic endurance test • Leak check under cryogenic conditions • Test solenoid valve performance during leak checks • Perform LN2 cold flow under cryo conditions
Module	Propulsion/Avionics
Component	Ox System and electronics

Preparations:

- Propulsion system mounted on rocket crane
- Checklist Version 1.2 completed (points 1–2) for safe test environment

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Results:

- System checks (3):
  - Ox pressurant valve gave no feedback at PI >100% (known issue)
  - Fuel main valve unexpectedly open
- Final Test Preparations (4): nominal
- Ox system leak check (5): nominal
- Pressurant filling (6): nominal
- Pre-press ox system (7):
  - Aborted → burst disc under pressure regulator failed during sequence
  - Burst disc replaced, test resumed
- Second pre-press attempt: aborted → ox pressurant vent valve opened at 32 bar

- Old pre-press sequence used (slow fill, 20 bar target): stable at 20.4 bar, vent valve stayed closed
- Ox system depressurizing (8): nominal
- Endurance phase (9):
  - LN2 tanking completed, light condensation observed on ox tank bottom
  - System check (10): nominal
- Pressurant filling (11): nominal to 257 bar
- Pressurize ox system (13):
  - First run terminated → ox vent valve opened at 29 bar → recalibrated
  - Second run → sequence failed to regulate pressure; vent valve slightly leaking; recalibrated again
  - Third run → insufficient gas in pressurant tank, stopped at 33 bar
  - LN2 topped off without dumping
  - Fourth run aborted → ox vent valve opened at 34 bar → recalibrated again
  - Fifth run nominal → 37 bar reached, pressure dropped to 31 bar within 2 min (likely tanking line leaks)
- Cold flow: executed nominally after endurance phase
- Test end: ~250 g of ice accumulated on rocket
- Post-test: systems depressurized, safety gear stowed

Discussion insights (post-test analysis):

- Thermal data:
  - Burst disc remained above +4 °C throughout
  - Ox tank at ~–140 °C during fill
  - Ox servo: +30 °C to +2 °C
  - Fuel manifold: min –6 °C
  - ECU: min 1–2 °C
  - Fuel venturi: –11.4 °C
  - Ox venturi: 0 °C
  - Chamber pressure sensor: –0.6 °C
- Cold cable routing in engine bay caused minor shifts (~0.1 bar) in pressure sensors
- Current draw before first test ~1 A (idle state, tank filled)
- Tanking: 20:02–20:12 → 10 min for 3 kg LN2; boil-off of 3 kg over ~70 min (≈40 g/min loss rate)
- Ox tank pressure during fill: ~1.2 bar
- Warm pressurization test: burst disc failed instantly; ox pressurant valve did not fully close (stayed at 8%)
- Cold pressurization test: solenoid valve stuck open

- Cold flow repeated after endurance → executed nominally
- Data review:
  - LN2 losses consistent with earlier tests (~3.7 kg in ~90 min)
  - Insulation improvements reduced visible vapor/smoking
  - Pressurization limited by vent valve leakage and PI controller instability
  - Future work: check valve pressure drop may reduce effective mass flow; requires modification

Summary of observations:

- Insulation of ox tank, lines, and chamber pressure sensor worked effectively
- Thermal decoupling successful
- Burst disc failure occurred during warm press test → confirmed weak point under pressure
- Ox vent valve unreliable under cryo conditions; requires design improvement
- Ox tanking lines showed leaks; must be rebuilt
- Cold flow demonstrated stable system operation, though pressurization sequence needs further tuning

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Learnings:

- Ox system can be pressurized, but leaks persist
- Diffuser design improved ox tank pressurization behavior
- Burst disc and ox vent valve must be redesigned for reliability under cryo conditions
- PI controller calibration needed to stabilize pressurization
- Camera setup must be optimized to avoid oversized video files

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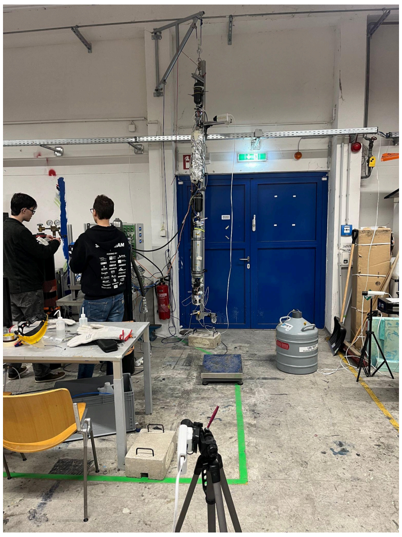
Attachments:

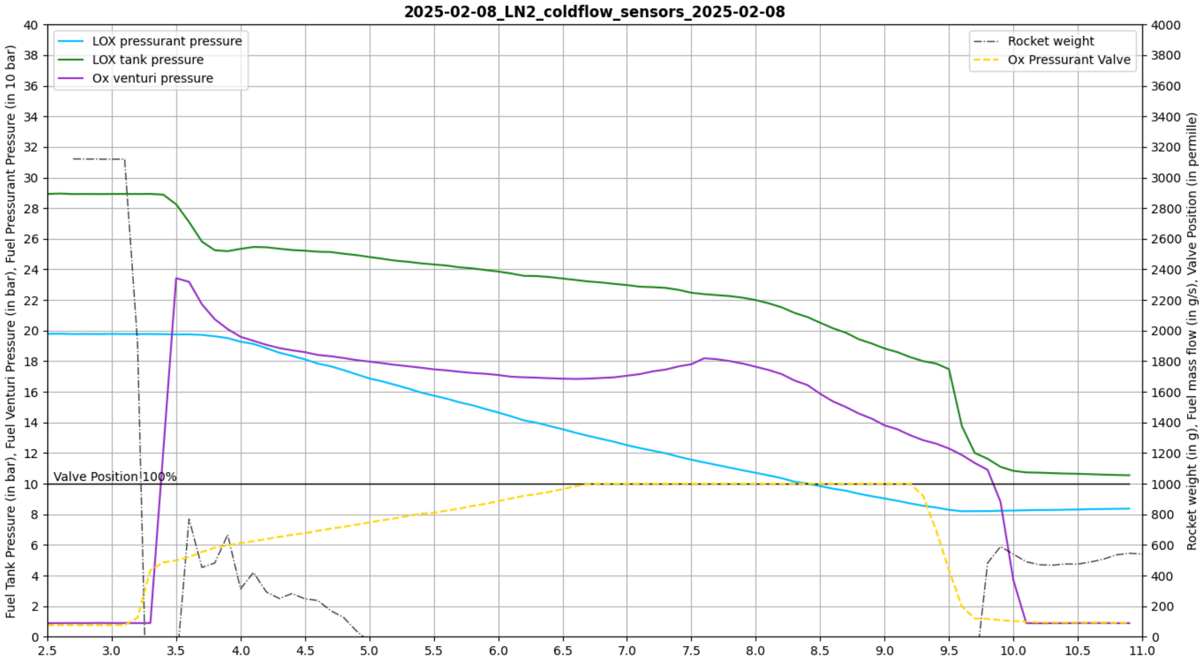
- Attachment 1: Test setup photo



- Attachment 2: Burst disc (failed component)

- Attachment 3: Vent adjustment during LN2 tanking

• Attachment 4: Coldflow data



Signatures:

A.2.4 Combustion chamber pressure:

Test Report

Date / Time	2024-09-17
Participants	Matthias Rier
Testing purpose	Pressure testing the flight burning chamber casing for operating pressure
Changes	Version 1
Doc. Ref.	

Preparations:

The chamber casing is plugged downstream with a piece of phenolic resin-cotton where a FKM o-ring is mounted. An injector is mounted upstream with additional o-rings due to different sealing geometries between casing and injector. To the injector is added an adapter with the fitting for the hydrostatic testing machine. All other holes in the injector are plugged with filler plugs.

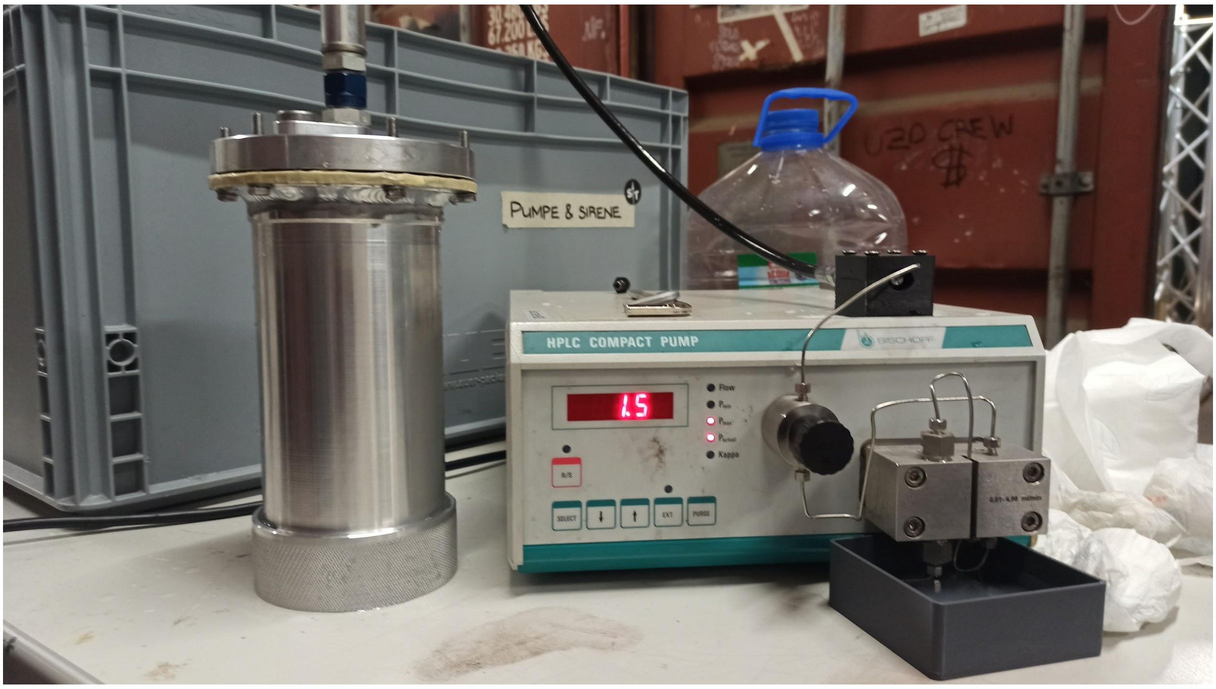


Test execution:

The phenolic plug is fitted with the o-ring, which is lubricated with vaseline and then put in the casing at the downstream end. It is pushed in until the o-ring is inside the chamber. The rest of the plug is pushed in when the retainer nut is screwed on. The fitting for the pressure sensor and the ox main line are removed from the injector and on the fuel main line fitting an adapter with the filling port for the pressure testing machine is mounted. The whole casing and injector is filled with water until it overflows out of the other ports of the injector. Now these ports are plugged with filler plugs. The hose for the pressure testing machine is also filled with water and gets connected to the filling port on the injector. The other side ist now connected with the pressure testing machine.

First test:

The pressure testing machine is switched on with a target pressure of 15 bar which matches the operating pressure of the rocket engine. After reaching the target the pressure is held for one minute with no leaks detected. After one minute the pressure was reduced to ambient pressure.



Second Test:

The pressure testing machine is switched on again, this time with a target pressure of 23 bar. This pressure is approximately 1.5 times the operating pressure of the rocket engine. After the desired pressure is reached, it is held for one minute. After successfully holding the pressure for one minute the pressure was slowly reduced to ambient pressure.

Results:

The chamber casing successfully completed two hydrostatic pressure proofing tests, where one target pressure was set to the operating pressure of the rocket engine and the other target pressure was 1.5 times the operating pressure. Both pressures were held for the time of one minute.

Learnings:

The chamber casing fits adequately on the injector and the sealing is capable of holding more pressure than the operating pressure of the rocket engine. The casing withstands a prolonged time with 1.5 times more pressure than the operating pressure. The threaded retainer nut also is able to contain the increased pressure for an extended period of time and showed no sign of deformation after the test. After the test the retainer nut was able to be unscrewed with a reasonable amount of force which was the same before pressure testing was performed

---

Attachments:

-

Signatures:

Test Report

Date / Time	2025-08-07
Participants	Matthias Rier, Oliver Balint, Fabio Winkler
Testing purpose	Pressure testing the flight burning chamber casing for operating pressure
Changes	Version 1
Doc. Ref.	

Preparations:

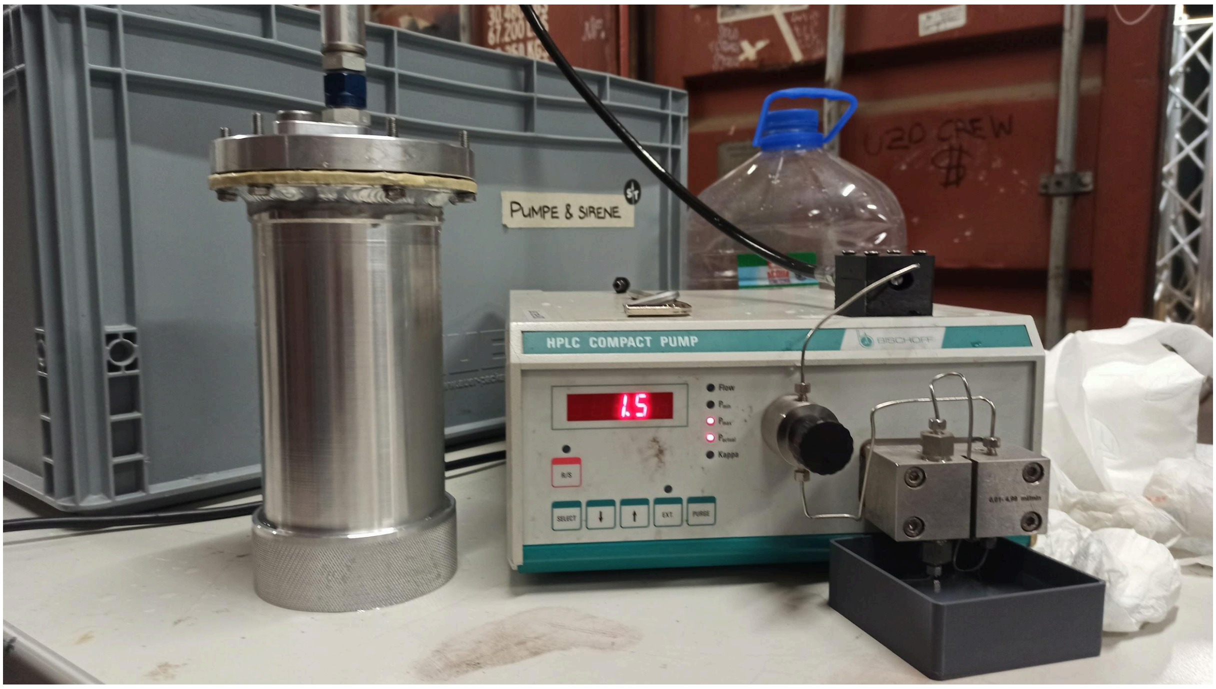
The chamber casing is plugged downstream with a piece of phenolic resin-cotton where a FKM o-ring is mounted. An injector is mounted upstream. To the injector is added an adapter with the fitting for the hydrostatic testing machine. All other holes in the injector are plugged with filler plugs.

Test execution:

The phenolic plug is fitted with the o-ring, which is lubricated with vaseline and then put in the casing at the downstream end. It is pushed in until the o-ring is inside the chamber. The rest of the plug is pushed in when the retainer nut is screwed on. The fitting for the pressure sensor and the ox main line are removed from the injector and on the fuel main line fitting an adapter with the filling port for the pressure testing machine is mounted. The whole casing and injector is filled with water until it overflows out of the other ports of the injector. Now these ports are plugged with filler plugs. The hose for the pressure testing machine is also filled with water and gets connected to the filling port on the injector. The other side ist now connected with the pressure testing machine.

First test:

The pressure testing machine is switched on with a target pressure of 15 bar which matches the operating pressure of the rocket engine. After reaching the target the pressure is held for one minute with no leaks detected. After one minute the pressure was reduced to ambient pressure.



Second Test:

The pressure testing machine is switched on again, this time with a target pressure of 23 bar. This pressure is approximately 1.5 times the operating pressure of the rocket engine. After the desired pressure is reached, it is held for one minute. After successfully holding the pressure for one minute the pressure was slowly reduced to ambient pressure.

Results:

The chamber casing successfully completed two hydrostatic pressure proofing tests, where one target pressure was set to the operating pressure of the rocket engine and the other target pressure was 1.5 times the operating pressure. Both pressures were held for the time of one minute.

Learnings:

The chamber casing fits adequately on the injector and the sealing is capable of holding more pressure than the operating pressure of the rocket engine. The casing withstands a prolonged time with 1.5 times more pressure than the operating pressure. The threaded retainer nut also is able to contain the increased pressure for an extended period of time and showed no sign of deformation after the test. After the test the retainer nut was able to be unscrewed with a reasonable amount of force which was the same before pressure testing was performed

Signatures:

A.2.5 Static Hotfire:

Test Report

Test Type	Hotfire Test
Date / Time	01.06.2024
Participants	Liquids team
Module	Propulsion
Component	Engine

Testing purpose:

- Verifying the engine's functionality.
- Comparing the engine's actual performance to theoretical models.
- Verifying the functionality of custom-designed propulsion components.
- Gaining information about the thrust chamber's ablation.

Preparation:

- Followed standard checklists.

Test execution:

Test Sequence:

- t=-2: Initiate igniter.
- t=0: LOX main valve 100% open.
- t=0.5: Fuel main valve 100% open.
- t=6: Close main valves.

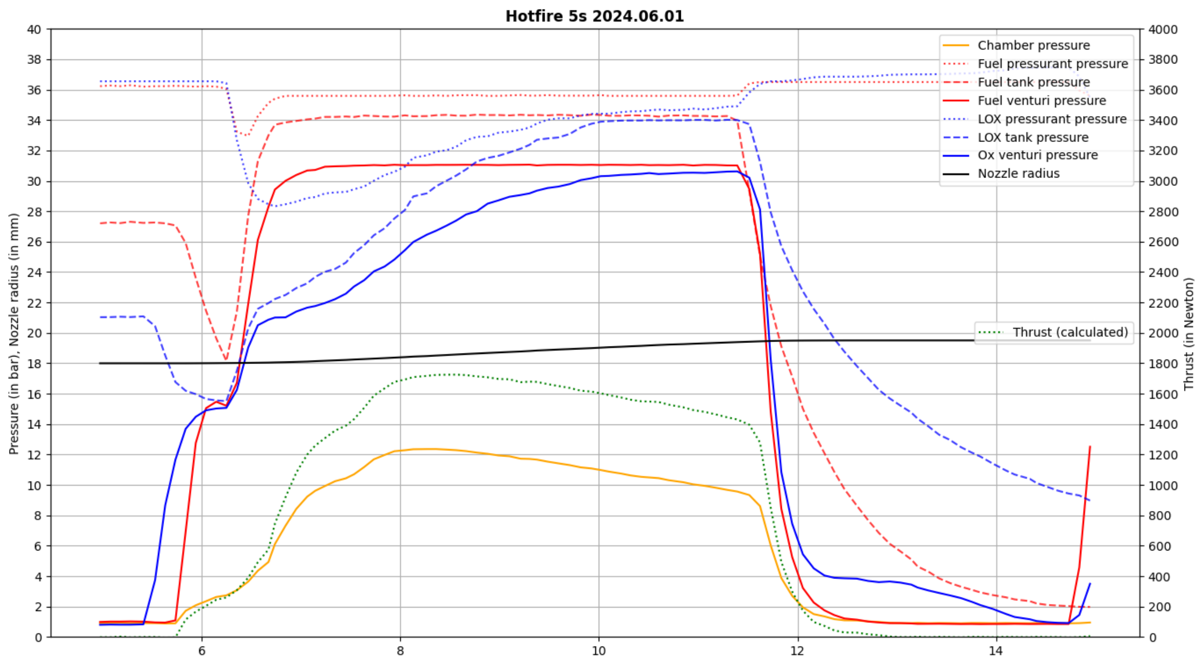
Results:

- Achieved 12.5 bar peak chamber pressure.
- Thrust sensor failed during the test.
- Pintle injector performed successfully.
- Lower-than-expected thrust chamber ablation; phenolic liner used with 8mm wall thickness, approximately 1mm ablated.
- Engine weight reduced from 3566g to 3440g post-test.

Learnings:

- Thrust chamber ablation is less severe than anticipated; phenolic liner might be optimized for future tests.
- The importance of activating the sound suppression system during testing, with potential integration into the test sequence.
- Identified a leak in the oxidizer tanking valve, which will be addressed before the next test.
- Mitigation of trapped LOX between the main and safety valve via a burst disk, pending venting adjustments.
- Thrust back-calculation based on chamber pressure, estimated at 1.86 kN (expected).
- Venturi modifications planned for the next hotfire test.
- Validation of the pintle injector for flight use.

Attachments:



Signatures:

Test Report

Test Type	Hotfire Test Series (3 Tests)
Date / Time	13.07.2024
Participants	Liquids team
Module	Propulsion
Component	Engine

Testing purpose:

- Evaluate the LOX mass flow and its impact on engine performance.
- Analyze impact of LOX preheating and autogenous pressurization
- Assess the relationship between nozzle ablation, chamber pressure, and thrust.

Preparation:

- Followed standard checklists.

Results:

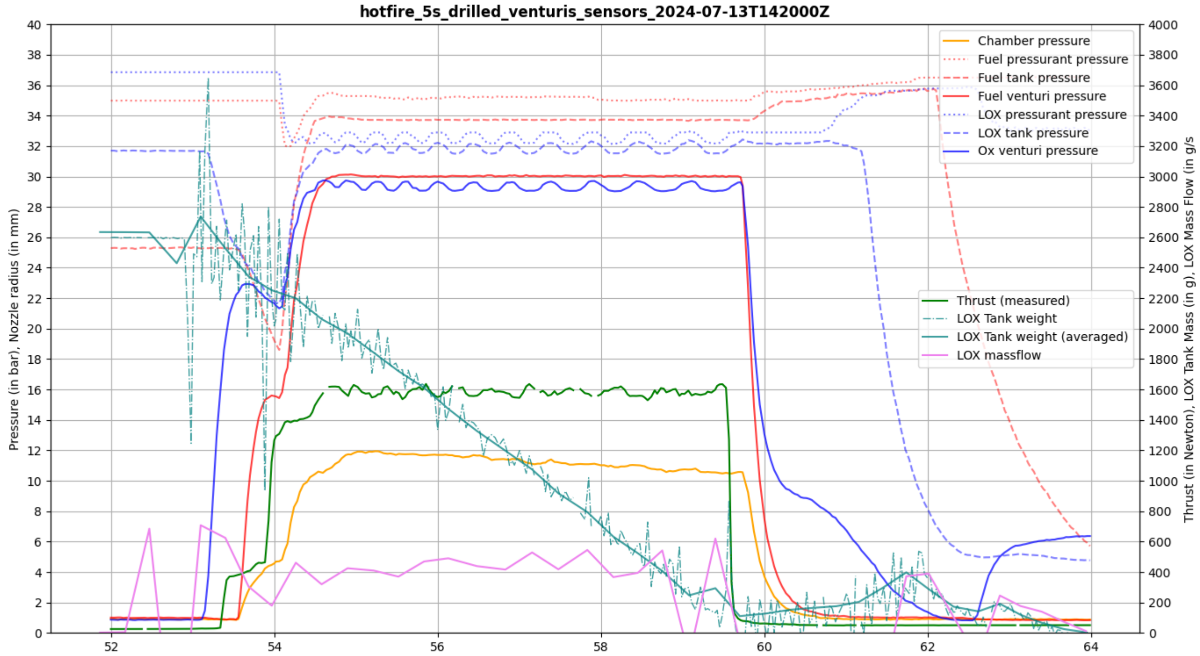
- LOX mass flow was below the required 600 g/s.
- Significant pressure oscillations in LOX tank and Venturi, leading to combustion instability.
- LOX Venturi pressure start-up behavior improved in tests 1 and 2, with immediate regulation to 30 bar.
- Notable nozzle ablation observed, particularly in tests 2 and 3 (throat diameter measurements: 39.86 mm, 46 mm, 46.07 mm).
- Discrepancy of more than 10% between calculated and measured thrust in tests 2 and 3.
- Increased time delay between chamber pressure and thrust measurement compared to the previous test on 03.06.2024 (approx. 0.1 seconds).

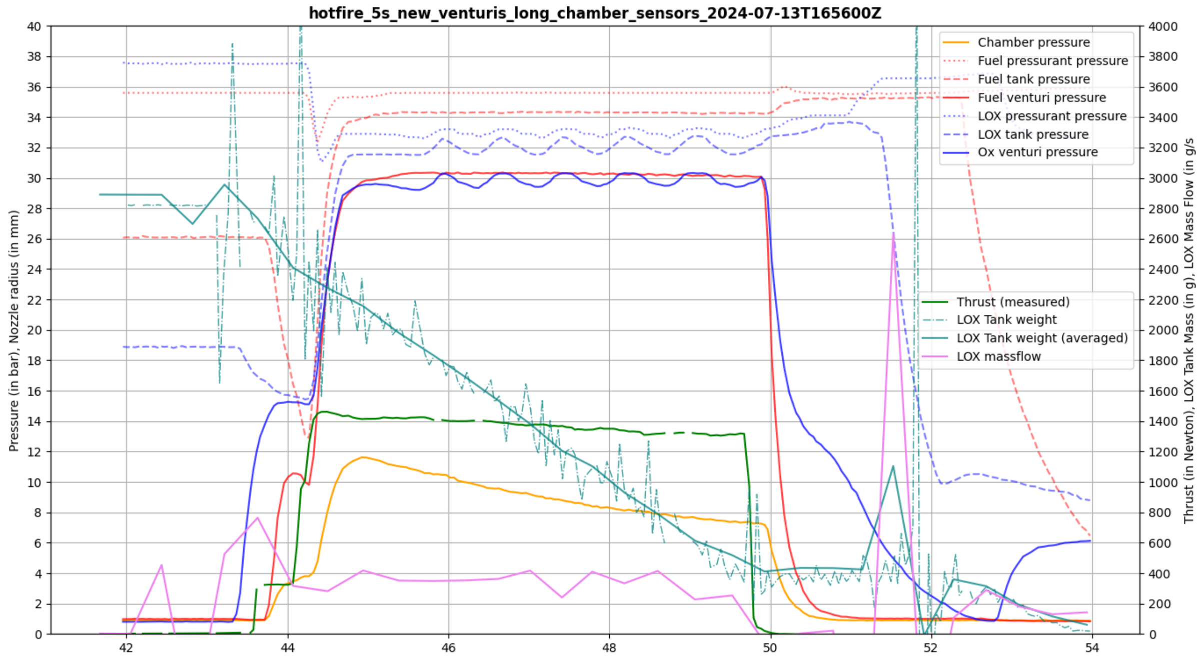
Learnings:

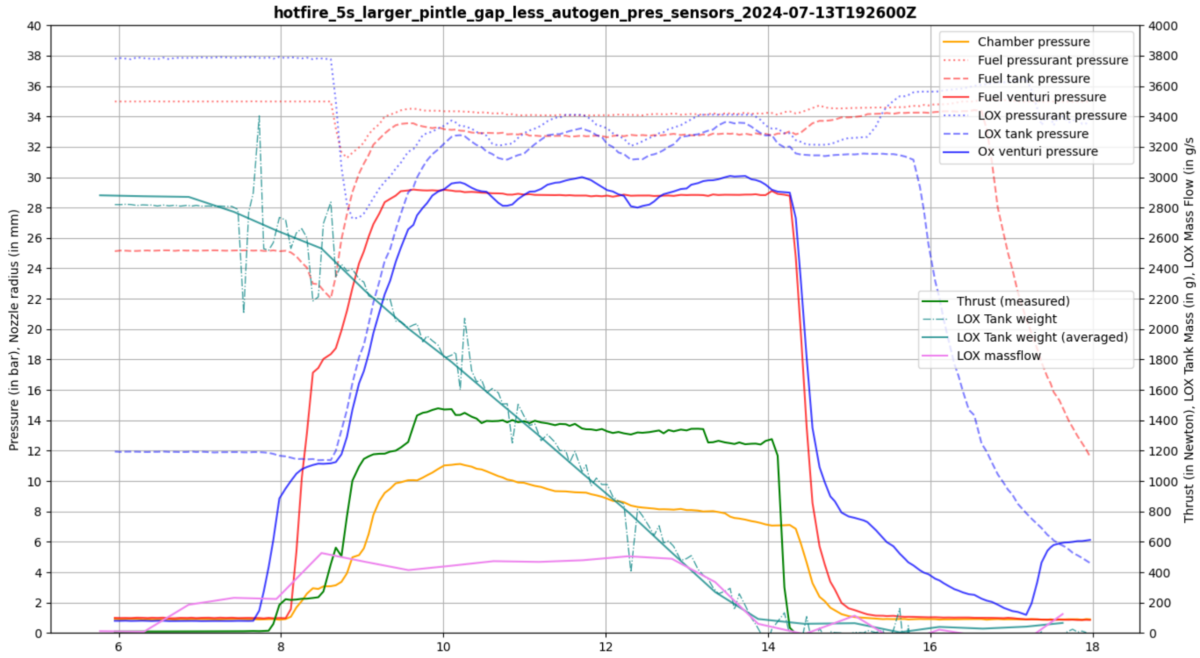
- LOX mass flow rate needs improvement to meet the required specifications.

- Pressure oscillations may be linked to insufficient pre-chilling and issues with the LOX safety valve or diffuser.
- Nozzle ablation requires further investigation, with a focus on the correlation between ablation, chamber pressure, and thrust.
- The start-up sequence for LOX pressure control has been successfully optimized.

Attachments:






hotfire_5s_larger_pintle_gap_less_autogen_pres_sensors_2024-07-13T192600Z
Pressure (in bar), Nozzle radius (in mm)
Thrust (in Newton), LOX Tank Mass (in g), LOX Mass Flow (in g/s
Chamber pressure
Fuel pressurant pressure
Fuel tank pressure
Fuel venturi pressure
LOX pressurant pressure
LOX tank pressure
Ox venturi pressure
Thrust (measured)
LOX Tank weight
LOX Tank weight (averaged)
LOX massflow

Signatures:

Test Report

Test Type	Hotfire Test
Date / Time	05.08.2024
Participants	Liquids team
Module	Propulsion
Component	Engine

Testing purpose:

- Measure and analyze mass flow rates of ethanol and liquid oxygen (LOX) during engine operation.
- Evaluate engine thrust and stability of the LOX system.
- Compare different methods of calculating mass flow rates.

Preparation:

- Followed standard checklists.
- Set up for both the Tank Weight Method and Venturi Method for mass flow calculations.

Results:

- **Ethanol Mass Flow:** Calculated mass flow rate was 600 g/s, significantly higher than the design value of 465 g/s, indicating a possible discrepancy in the discharge coefficient for ethanol.
- **LOX System Stability:** Oscillations in the LOX pressure were largely eliminated, and the system response was stable.
- **Mass Flow Agreement:** The mass flow rates calculated using the Venturi Method and Tank Weight Method were in good agreement during steady-state conditions at full thrust.
- **Thrust vs. Chamber Pressure:** The thrust decrease was less than expected based on the chamber pressure drop, likely due to nozzle ablation increasing the throat diameter, leading to higher thrust at a given chamber pressure.

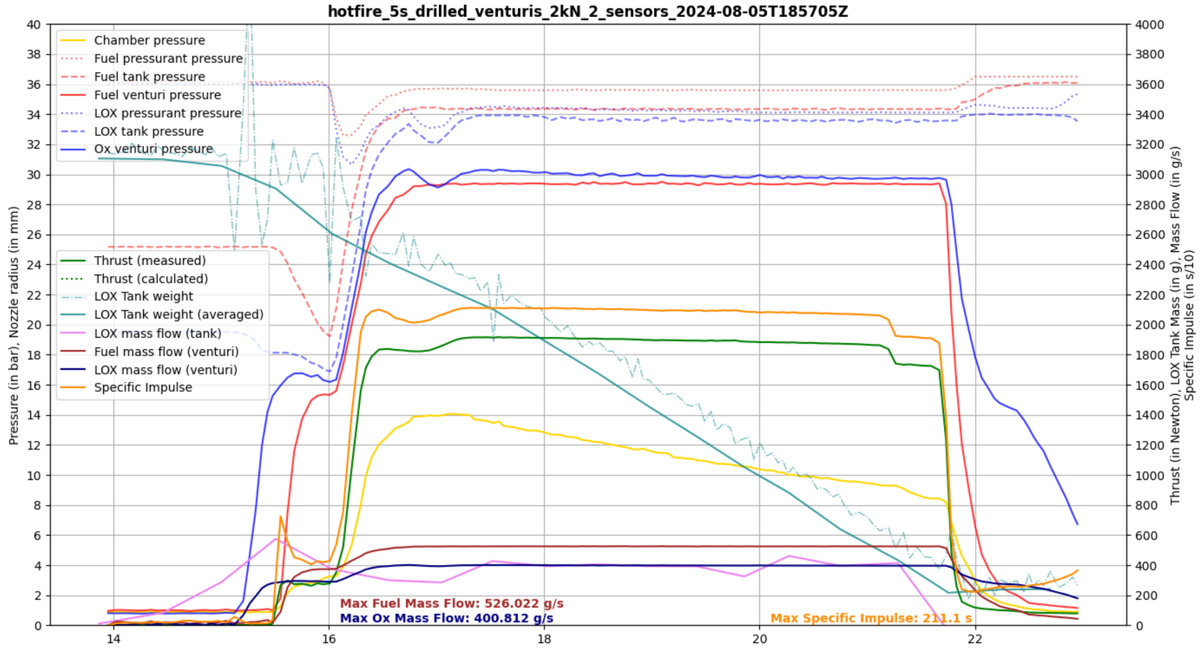
Discussion:

- The initial dip in oxidizer pressures at the start of the test might indicate the LOX system nearly began oscillating again, potentially due to line warming post-prechill.
- Venturi method calculations were under review for potential errors related to different partial pressures not being accounted for.
- The ethanol mass flow discrepancy suggests a need to revisit the discharge coefficient's dependency on fluid type.

Conclusion and Future Work:

- **Specific Impulse:** Calculated specific impulse based on mass flow rates, with further analysis planned.
- **Further Analysis:** The team will back-calculate ethanol and LOX mass flow rates from previous tests to ensure consistency and refine specific impulse data.
- **Planned Improvements:** Upcoming tests will focus on optimizing the pressurization system, with continued refinement of engine performance as a secondary goal.

Attachments:



Signatures:

Test Report

Test Type	Hotfire Test
Date / Time	04.09.2024
Participants	Liquids team
Module	Propulsion
Component	Engine

Testing purpose:

- Evaluate the performance of both the fuel and oxidizer systems, focusing on mass flow measurements.
- Validate the automatic fuel pre-pressurization system, which is analogous to the final setup in the rocket.

Preparation:

- Followed standard checklists.
- Installed a weighting system for the fuel side for more accurate measurement of fuel mass flow.

Results:

- **Ethanol Mass Flow:** The ethanol flow rate, though not ideal due to pre-pressurization, was deemed nearly sufficient for the duration of the test. However, the issue with the pre-pressurization system affected the accuracy of the flow regulation.
- **System Stability:** The ethanol pressurization system failed, potentially due to the power supply being insufficient when multiple solenoid valves were engaged simultaneously during the test. Previous cold flow tests had shown nominal performance with this system, but the increased demand during the hotfire test may have overloaded the power supply.
- **Thrust:** Even though the fuel system did not behave as planned, the engine still delivered around 160 kg of thrust which would be deemed sufficient for a flight.

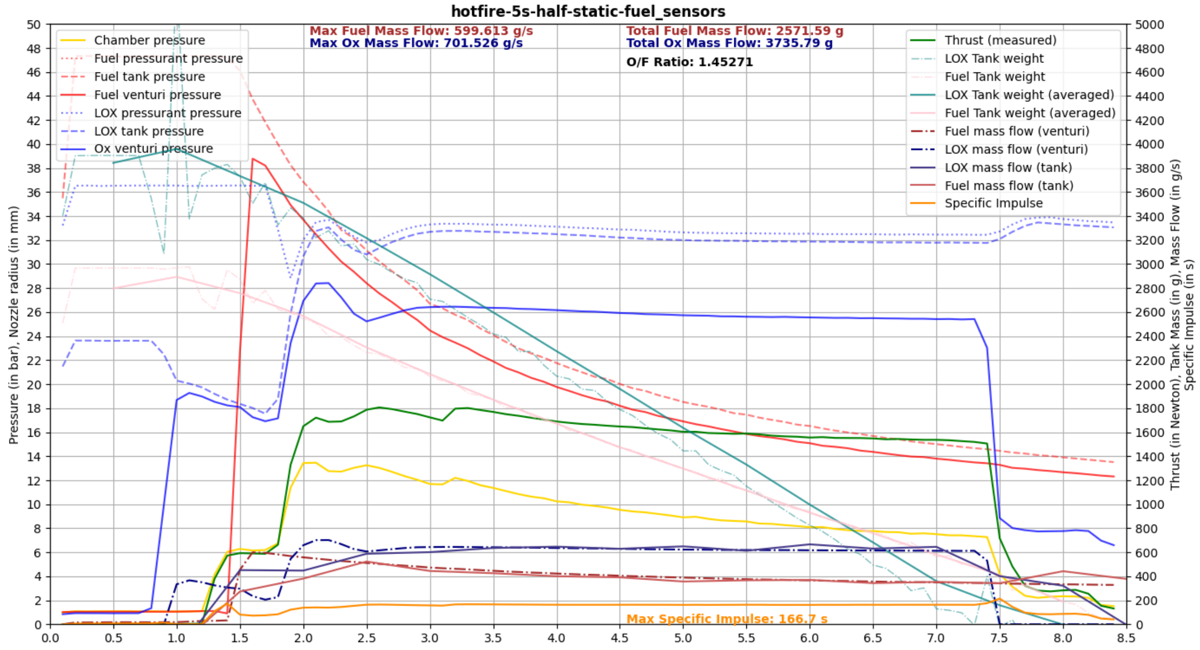
Discussion:

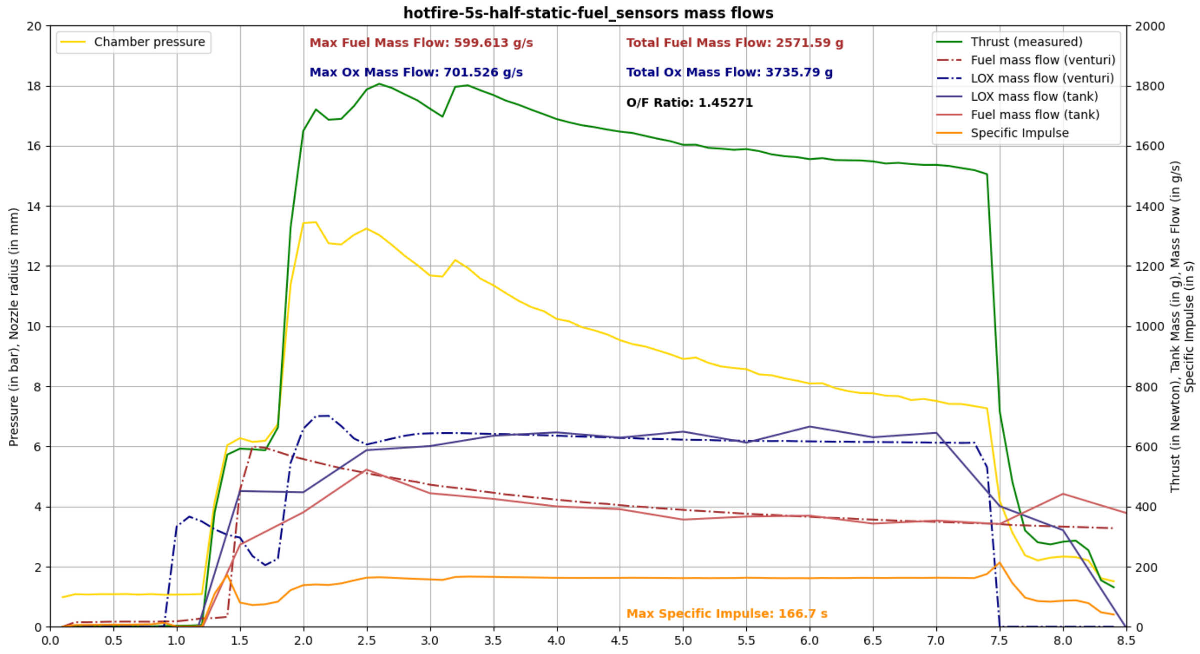
- The automatic pressure regulation system for the ethanol tank failed, leading to manual pre-pressurization.
- Initial tank pressures were not nominal, particularly for ethanol, which reached almost 50 bar instead of the intended 30 bar.
- Ethanol was fed through the pre-pressurized gas volume due to the failure of the solenoid valve responsible for pressurization.
- Both the LOX and ethanol tanks were equipped with weight sensors, allowing precise mass flow calculations during the test.

Learnings:

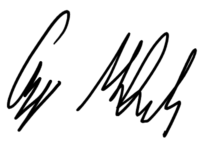
- The pressure regulation issue in the ethanol tank is suspected to have been caused by an inadequate power supply to the solenoid valve during hotfire. This was not an issue in previous cold flows.
- Manual pre-pressurization affected test accuracy but provided useful insights into the system's behavior under non-ideal conditions.
- The load cell data from the ethanol tank was highly reliable, allowing for confident mass flow estimates.

Attachments:





Signatures:


Static Fire

Date / Time	2025-08-04
Participants	• Lutfi Celik (lead) • Diego Grünberger (support) • Johannes Eschner (Mission Control) • Matthias Rier (propulsion support & fire safety) • Fabio Winkler (documentation & analysis)
Testing purpose	• First vertical static fire with flight hardware • Evaluate feed system performance under staticfire conditions • Validate chamber pressure performance and propellant mass flow consistency
Module	Propulsion/GSE/Avionics
Component	Full propulsion system and avionics except batteries

Preparations:

• Venturi diameter adjusted (Fuel: 3.1 mm vs. earlier 3.2 mm)
• System tuning from WDR (Ox Vent voltage increased, PI controller parameters updated)
• Warm leak check: Ox and fuel systems nominal
• Fuel Vent Valve became leaky shortly before test → fuel tank re-pressurized
• Pressurant bottles filled, target Ox tank target pressure set to 30 bar
• Static fire sequence flashed to onboard avionics with ignition timings

---

Test execution:

• sensor sampling rate dropped from ~100 Hz to ~10 Hz when switching to Internal Control
• Supply voltage of ECUs dipped briefly (current limit at ~5.1 A), visible in data

Oxidizer Feed System:

• Performed very well → Ox tank stayed within ±1 bar of 30 bar setpoint for

full burn
 • Best ox system performance observed to date

Fuel Feed System:
 • Fuel Vent leak caused pressure loss → re-press before ignition
 • Regulator overshot at ignition, tank peaked at ~40 bar
 • Despite higher-than-nominal pressure, fuel delivery lasted ~9.5 s
 • Fuel mass flow higher than planned, but propellant quantity matched LOX duration (Ethanol ran out ~0.5 s before LOX)

Engine:
 • Chamber pressure peaked at 15.4 bar, Target: 15 bar
 • No thrust load cell active → thrust estimated from chamber pressure + geometry
 • Burn duration: ~9.5 s (first firing test, in which the full burn duration was tested)

Results:

• Stable Oxidizer feed
• Fuel overshoot caused by leaky vent + servo behavior → ~40 bar peak tank pressure
• Chamber pressure nominal, >15 bar
• Estimated peak thrust: ~2000–2100 N depending on efficiency assumption
• O/F ratio 1.27 → 1.44 over burn
• Max fuel mass flow: ~428 g/s
• Max oxidizer mass flow: ~554 g/s
• Max specific impulse: ~228 s

Learnings:

• Ox feed system stable — confidence in Ninja V3 regulator & new venturi setup
• Fuel press servo needs recalibration
• Venturi efficiency mismatch between fuel and ox must be rechecked (possible partial blockage)

• Coldflow tests with Ethanol recommended to validate fuel venturi behavior
• ECU current draw exceeded PSU limits → new PSU required for future static fires without final avionics. Will be no problem, once flight battery pack is manufactured and integrated

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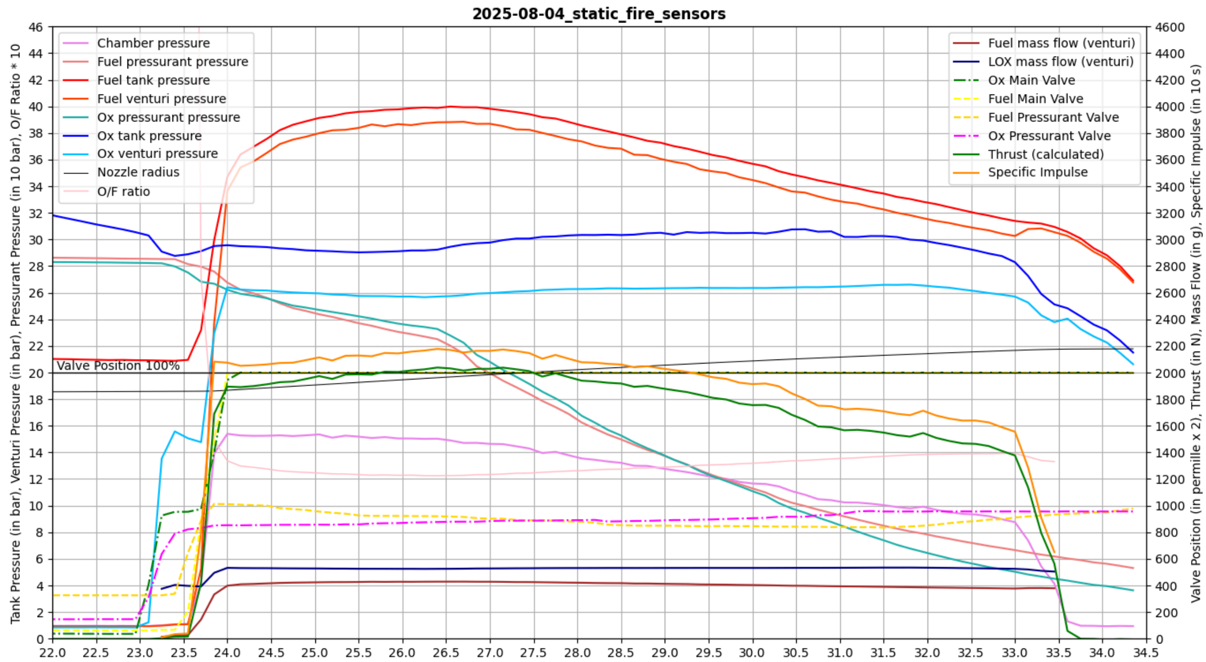
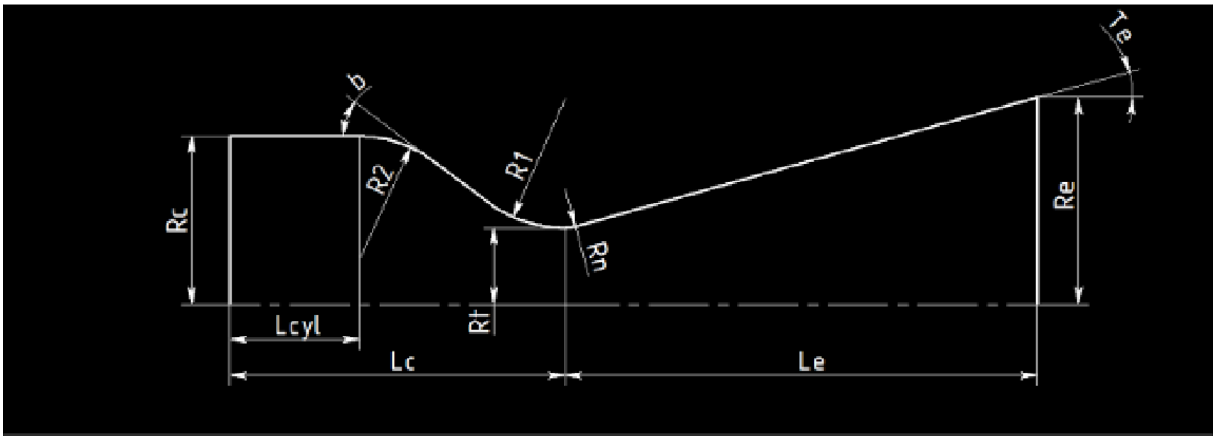
Attachments:

• Attachment 1: Static Fire pressure plot



• Attachment 2: Thrust derivation using RPA



Combustion chamber size		
Dc	73.52	mm
Dt	37.81	mm
Lcyl	122.57	mm
Lc	150.00	mm
L*	517.51	mm
R1	18.91	mm
R2	4.20	mm
b	45.00	deg
Ac/At	3.78	

Nozzle size		
Type	Conical nozzle	
Rn	18.91	mm
Tn	15.00	deg
Te	15.00	deg
De	73.52	mm
Le	69.11	mm
Le/Dt	1.83	
Le/Lc15		%
Ae/At	3.78	

Parameter		**Engine**	**Chamber**	
Thrust	sea level	2.2135	2.2135	kN
	opt exp	2.3647	2.3647	kN
	vacuum	2.6582	2.6582	kN
Specific Impulse	sea level	1985.2330	1985.2330	N·s/kg
	opt exp	2120.8262	2120.8262	N·s/kg
	vacuun	2384.0583	2384.0583	N·s/kg
Mass flow rate	total	1.1150	1.1150	kg/s
	oxidizer	0.5575	0.5575	kg/s
	fuel	0.5575	0.5575	kg/s
Number of chambers		1		

```
Thrust and mass flow rates
------------------------------------------
   Chamber thrust (vac):    2.16440      kN
 Specific impulse (vac):  197.94377       s
   Chamber thrust (opt):    1.87709      kN
 Specific impulse (opt):  171.66768       s
   Total mass flow rate:    1.11500    kg/s
Oxidizer mass flow rate:    0.55470    kg/s
    Fuel mass flow rate:    0.56030    kg/s

Geometry of thrust chamber with conical nozzle
------------------------------------------
    Dc =   67.52  mm       b =   45.00 deg
    R2 =   27.47  mm      R1 =    1.04  mm
    L* =  593.82  mm
    Lc =  165.00  mm    Lcyl =  136.79  mm
    Dt =   34.73  mm
    Rn =    1.04  mm      Te =   15.00 deg
    Le =   61.33  mm
    De =   67.52  mm

  Mass =   -7.07  kg

  Divergence efficiency:    0.98296
```

Signatures:

Static Fire

Date / Time	2025-08-25
Participants	• Lutfi Celik (lead) • Diego Grünberger (support) • Johannes Eschner (Mission Control) • Matthias Rier (propulsion support) • Fabio Winkler (documentation & analysis)
Testing purpose	• Repeat of 04.08.2025 Static Fire test • Goal: capture thrust measurement via Hold-Down load cell in addition to chamber and feed system data
Module	Propulsion/GSE/Avionics
Component	Full propulsion system and avionics except batteries

Preparations:

• Nozzle geometry unchanged from 04.08, casing re-used

• Several fuel coldflows were executed with varying target pressures to ensure nominal operation

• Hold-down load cell calibrated and connected

• Rocket prepared in same configuration as previous static fire

---

Test execution:

• Static Fire initiated with data logging of pressures, valve feedback, temperatures, and thrust via load cell

• Chamber suffered **burn-through** at the location where the pintle jet impinges on the liner wall

• Burn-through caused **drop in chamber pressure**, which led to **lower thrust** than targeted

---

Results:

• Chamber burn-through limited achievable pressure and thrust
• Corrected thrust data from load cell aligns well with chamber pressure–derived estimates
• Thrust: ~1700N

Learnings:

• Measured thrust matches well with thrust calculated for previous static fire, validating the results of the previous calculations

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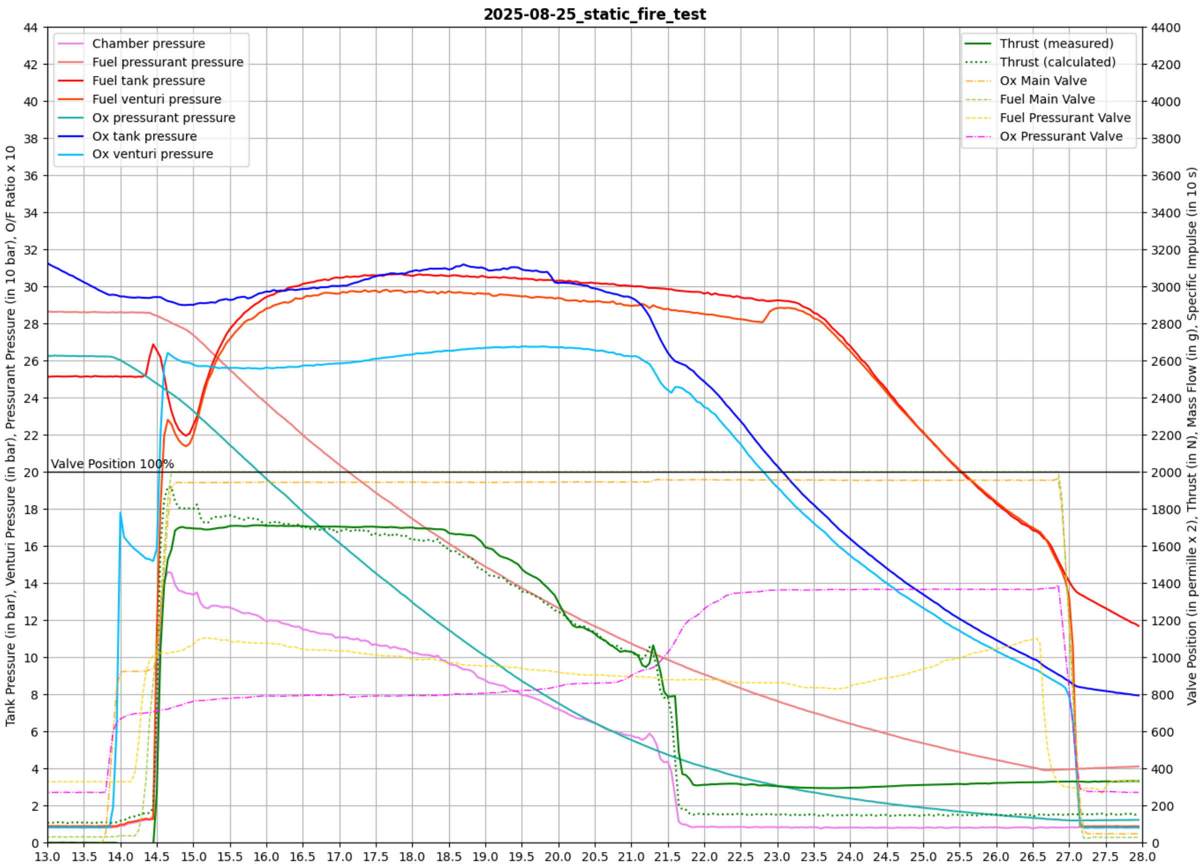
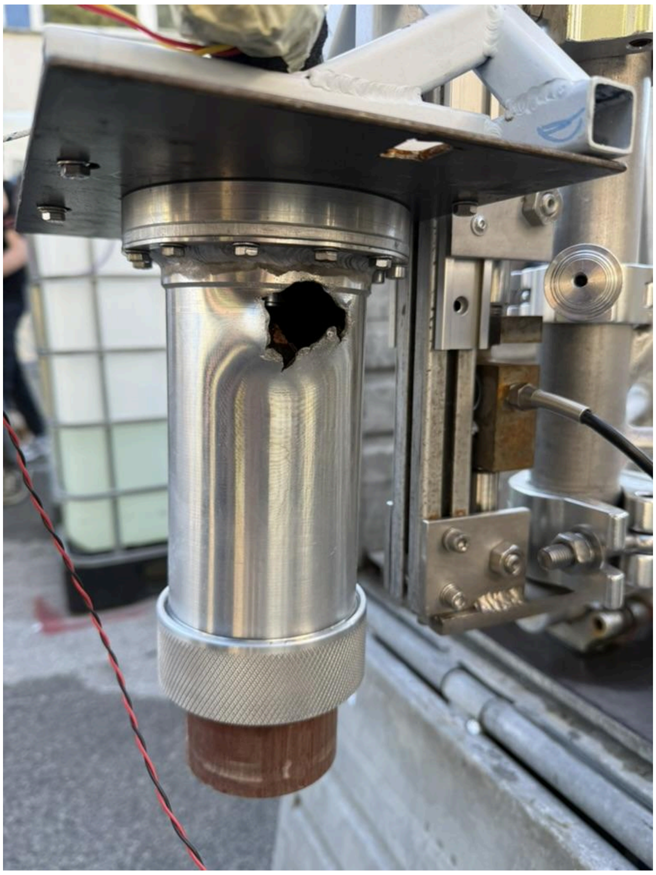
Attachments:

• Attachment 1: Static Fire pressure plot



• Attachment 2: Damaged combustion chamber casing



Signatures:

A.2.6 Proof pressure testing pressure vessels:

Test Report

Date / Time	2024-09-24
Participants	Matthias Rier
Testing purpose	Pressure testing propellant tanks for the operating pressure
Changes	Version 1
Doc. Ref.	

Preparations:

The propellant tanks are plugged downstream with a filler plug and filled with water. The hydrostatic pressure testing machine is connected upstream with fittings. In case of a leak or rupture of the tanks, a heavy protective suite was put on top to contain the water or the potential energy of a compressed air bubble.

Test execution:

First propellant tank:

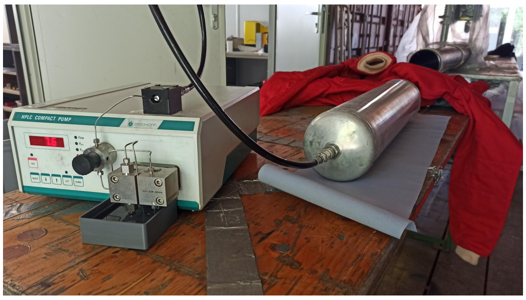
The first tank is connected to the testing machine. The first target pressure is chosen to be 5 bar which is held for 5 minutes to see if the tank has holes or the fittings are leaky.

The second target pressure is the operating pressure of 50 bar, which is held for 30 minutes. If the tank would be bulging under pressure, we should be able to see it now. No bulging was observed

The third target pressure is 75 bar, which is 1.5 times the operating pressure. It is held for an hour to ensure safety in case of extended hold shortly before lift off. Also no bulging was observed

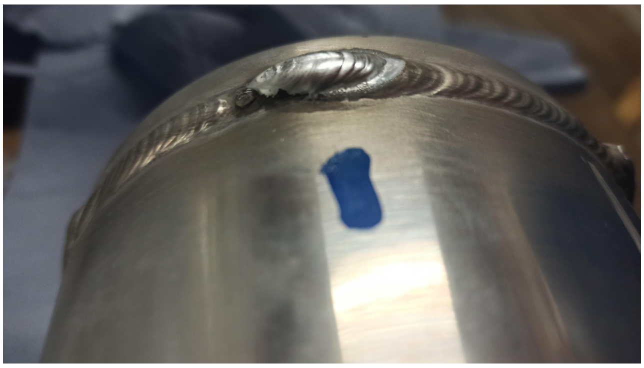
Second propellant tank:

The second tank testing procedure is identical to the first test



Third propellant tank:

The third propellant tank has minor defects in the weld which was seen in an X-ray. To verify the reliability of the tank, the test procedure is the same as for the first and the second tank, but the last target pressure is 85 bar. The pressure is held for 2 hours. No pressure loss or bulging was observed. Also no leaks were found at the welding seam.



Results:

All three tanks held the pressure of at least 75 bar for more than one hour without bulging or leaking. Tank number three is chosen to be a reserve tank due to its minor defects and to minimize the chance of a failure , but is still eligible as a flight tank.

Learnings:

The design of the tank endcaps is suboptimal because not all air is able to escape while filling and not all of the fluid is going to be flushed out. Therefore it is harder to clean and will have a small amount of dead weight in the form of propellant at the time of the ascent.

Attachments:

Signatures:

Diego Grünberger

Test Report

Date / Time	14.08.2024 / 12:00
Participants	Simon Waldl
Module	Propulsion
Component	Adapter Pressuranttank
Version	1
Test No.	2
Test Type	Hydrostatic
Doc. Ref.	Propulsion-Adapter Pressuranttank-T2

Testing purpose:

Evaluating the structural strength up to a pressure of 45 MPa for 30 minutes, to see if the designed geometry is safe and functional.

Preparations:

The whole assembly was cleaned with distilled water and Isopropanol-Alcohol to get rid of remnants from manufacturing and oils. To ensure proper disassembly all threads have been lubricated with a drop of oil. The pressureregulator's side was closed off with a plug, which has the same UNF-5/8-18 thread and O-Ring geometry as the regulator. This side (5/8-18-side) was tightend until the O-Ring (NBR90, 14.5x2mm) was fully compressed and the mating surfaces touched and was then tightened to ensure enough contact force for the triangle groove. The tank side is exchanged with a massively oversized dummy tank with the exact geometry of the later used flight-tanks. The adapter was connected to the dummy tank until the mating surfaces touched and was then only slightly tightened, as this is a radial o-ring seal (NBR90, 17.5x2mm) and no extra preload is mandatory. The dummy-tank is connected to a ¼" -fitting for connecting to the test pump hose, and was sealed with a USIT-Ring (NBR80, BS821 for 1/4").

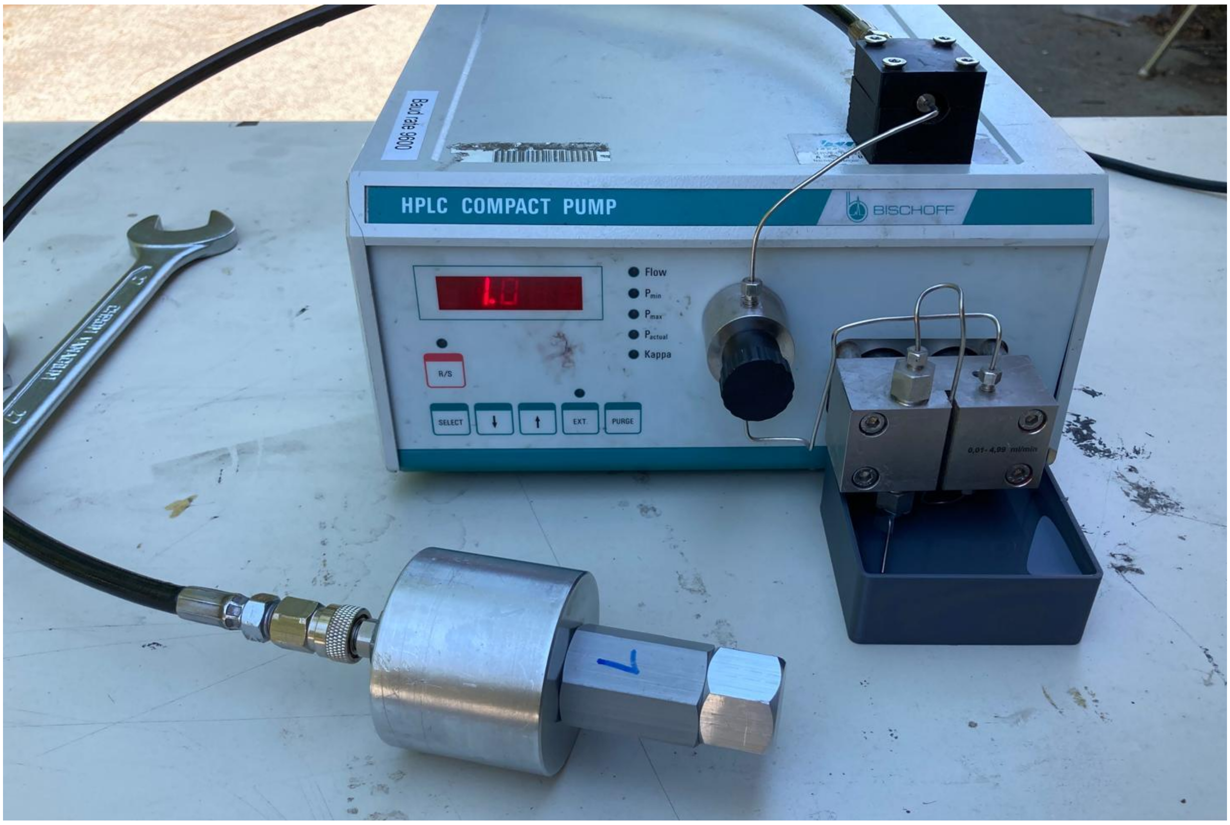


figure 1 - overview testsetup

figure 2 - overview testparts with O-rings

Test execution:

<u>Adapter 1:</u>

The Testassembly and the pump hose have been filled with distilled water until full and then connected.

The Pump settings where set to:
Flow=2 ml/min
Pmax=50 MPa
Kappa = 5

Pump was activated.
At a pressure of 25MPa(250bar) the USIT ring between hose-fitting and dummy tank started dripping.

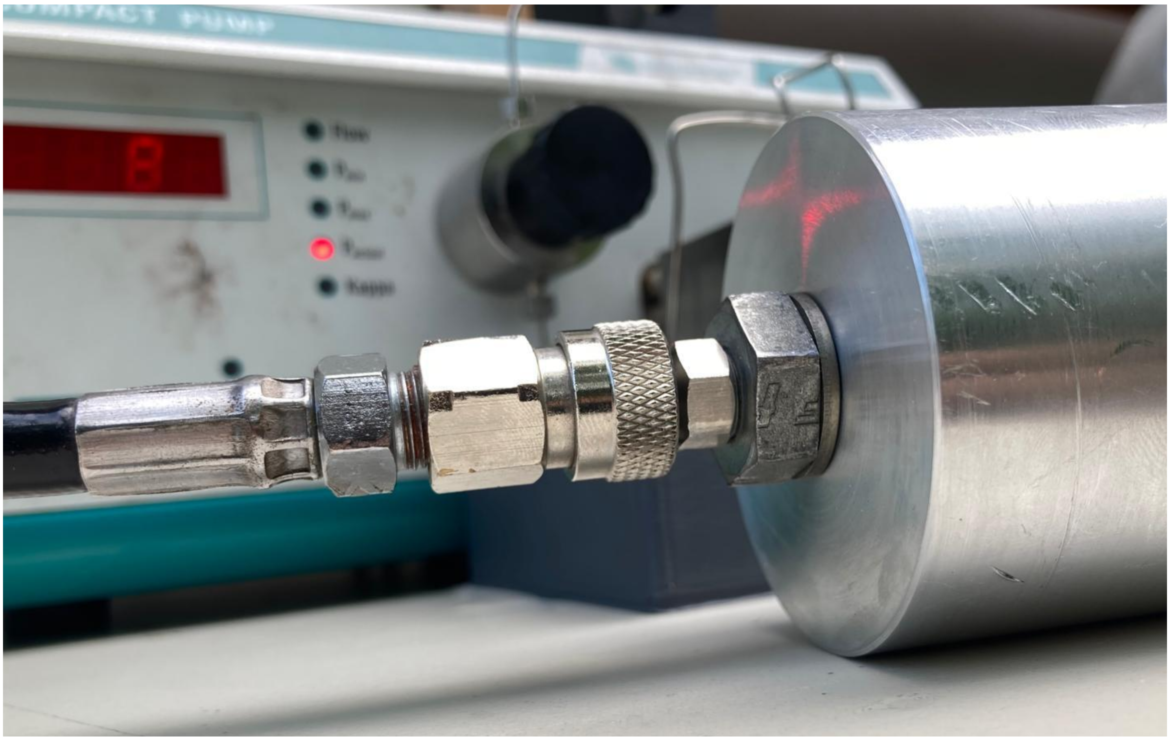


figure 3 - connection between dummy tank and hose fitting with USIT ring

The pressure was vented and fitting disconnected. The fitting was cleaned, the sealing surface has been recut and polished and again assembled and connected as described in the preparation section.

Pump was activated again.
After 5 min a pressure of 45MPa (450bar) was reached and the pump deactivated.
No deformation of any kind was detectable, also no water droplets have formed on all 3 sealing points.
After over 30 min wait time the pressure fell to about 44.2 MPa (442 bar), still no leaking was noticeable.

figure 4 - adapter 1: no leakage after 30+ min wait time

Test setup was vented and adapter 1 was removed for the test of adapter 2
No deformation was visible after a detailed search of the critical locations by eye.

Adapter 2:

The second adapter was filled with water and installed with new o-rings the same way as mentioned above.

Pump settings are(same as test for adapter 1):
Flow=2 ml/min
Pmax=50 MPa
Kappa = 5

Pump was started and kept running until a pressure of 45.3MPa (453bar) was reached.
No leakage or droplets evolved at any sealing point.<

After turning off the pump pressure started to drop at a rate of about 1MPa/min but still no water drops could be found.

The purge vent of the pump was tightened and the test table was moved so the (black) pump hose was in the shade as in the test for adapter 1. Temperatures have been around (30°C to 35 °C) ove the test period.

The pressure was again pumped up to 45.1MPa (451bar).
After a waiting period of 30 min, pressure dropped to 43.8MPa (438bar).
Still no visible leakage or water drops at any of the sealing points.

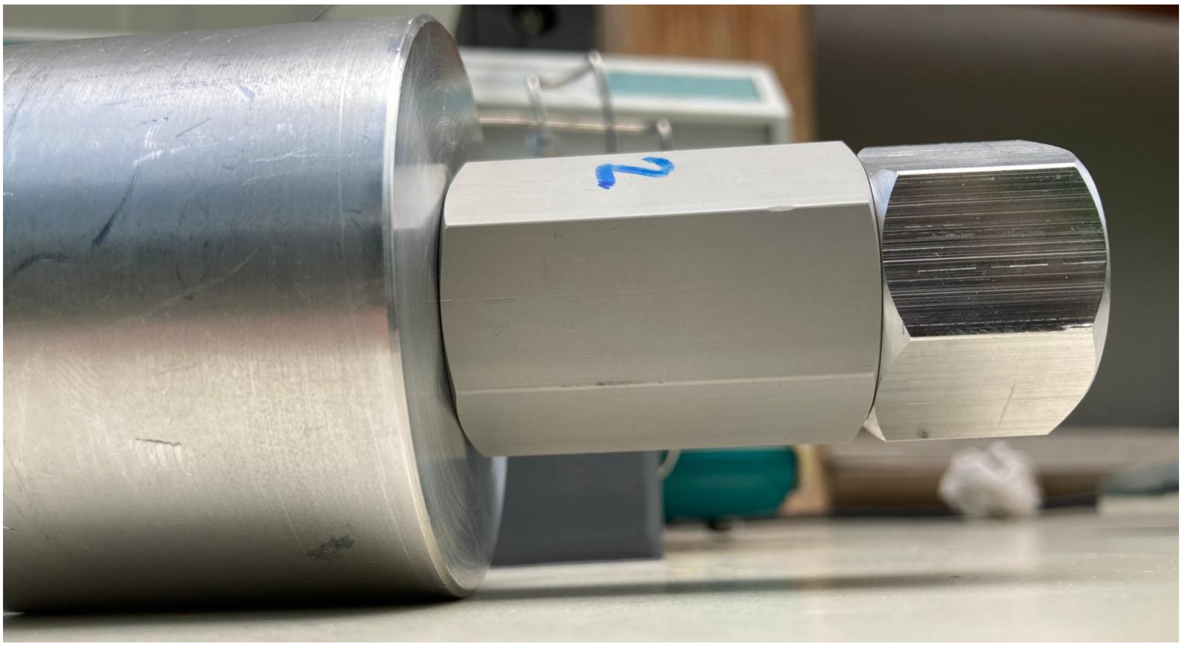


figure 5 - adapter 2: no leakage after 30+ min wait time

Preassure was purged and Testsetup disassembled. No visible Deformation on Adapter 2 after a detailed search on expected failure locations.

Results:

Both adapters show no signs of failure up to a pressure of over 45MPa (450bar) and 30 min wait time.
None of both adapter's sealing points showed any leakage at any time of the test.

There have been slow pressure drops over the extended wait time of 30 min (<0.05 MPa/min) . These can be connected to Temperature changes and the black elastic hose for connecting the test pump and high surrounding ambient Temperature of over 30°C .

Attachments:

Test video adapter 1:
hydrostatic preassure test adapter 1 up to 450 bar.mp4

Signatures:

Simon Wondel

Test Report

Date / Time	2.7.2024 / 11:00
Participants	Simon Waldl
Module	Propulsion
Component	Decoupler
Version	1
Test No.	3
Test Type	Hydrostatic
Doc. Ref.	Propulsion-Decoupler hydrostatic 3

Testing purpose:
Evaluating the prototype’s seal tightness to a pressure of 4.5 MPa (nominal 3MPa) for 10 minutes, to see if the designed geometry is functional. WhichFor the final parts a pressure of 1.5 times the design pressure and 2 times the actual expected duration is mandatory.

<u>first step:</u>
At what pressure is the magnetic holddown-force overpowered and the Decoupler openes?

<u>second step:</u>
Is the checkvalve closed? Is the pressure dropping?

<u>third step:</u>
Is the checkvalve free of leaks up to a Preassure of 4.5 MPa and a duration of 10 min?

Preparations:

The whole assembly was cleaned with distilled water and Isopropanol-Alcohol to get rid of remnants from manufacturing and oils. All Parts have been Installed according to the CAD assembly:

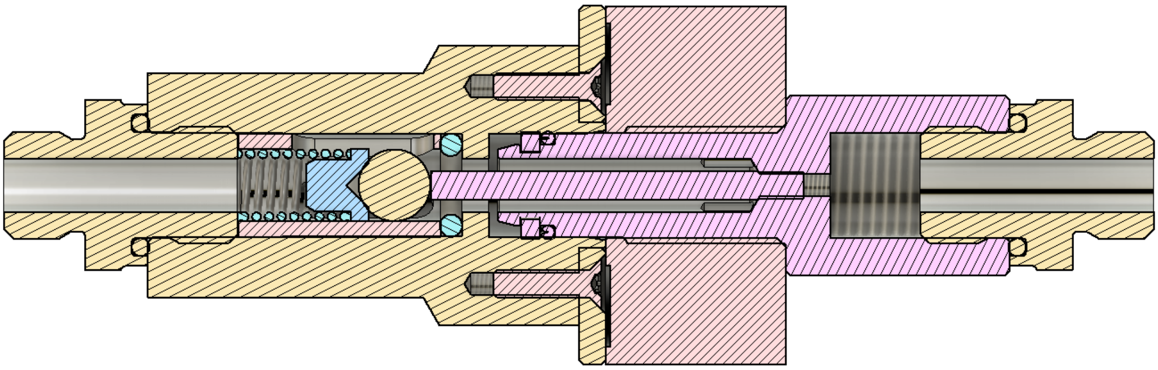


Figure 1-Decoupler Assembly section-view in CAD

The constructional changes since last test (Propulsion_Testreport-Decoupler_20240702_hydrostatic 2) are only on the checkvalve side. The valve-ball was changed to 304 stainless steel because the original balls startet rusting after last tests:

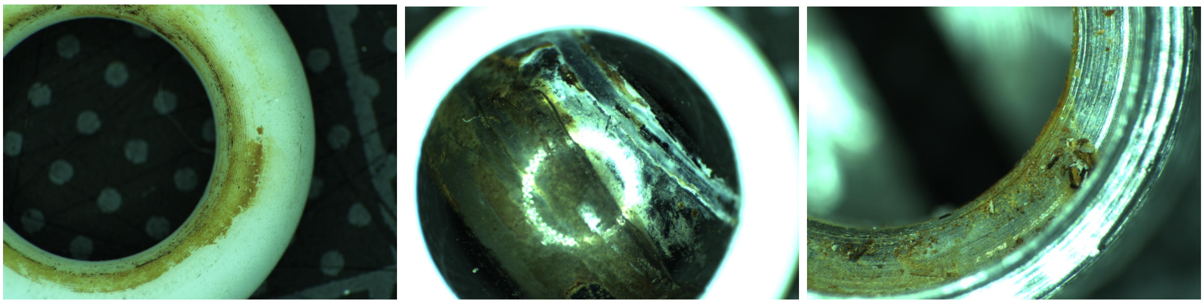


Figure 2-rust on checkvalve parts (O-ring, valvebody, sleeve)

For preventing any damage to the valve-body, a protective PTFE plunger was added. Also the sleeve geometry was simplified and is no longer a screw-in part. Finally the new stainless steel spring (D8,d1,n9) was installed.
This new Decoupler-assembly was connected to a ¼" fitting sealed by a Usit ring on the checkvalve's side and closed off with a NBR-Ring sealed endcap on the fillnipple's side.

Figure 3-Checkvalve parts

With the Decoupler assembled and the Magnet hooked up to a 12v powersupply, the pressure testing pump was filled with distilled water, hose and Decoupler-body.

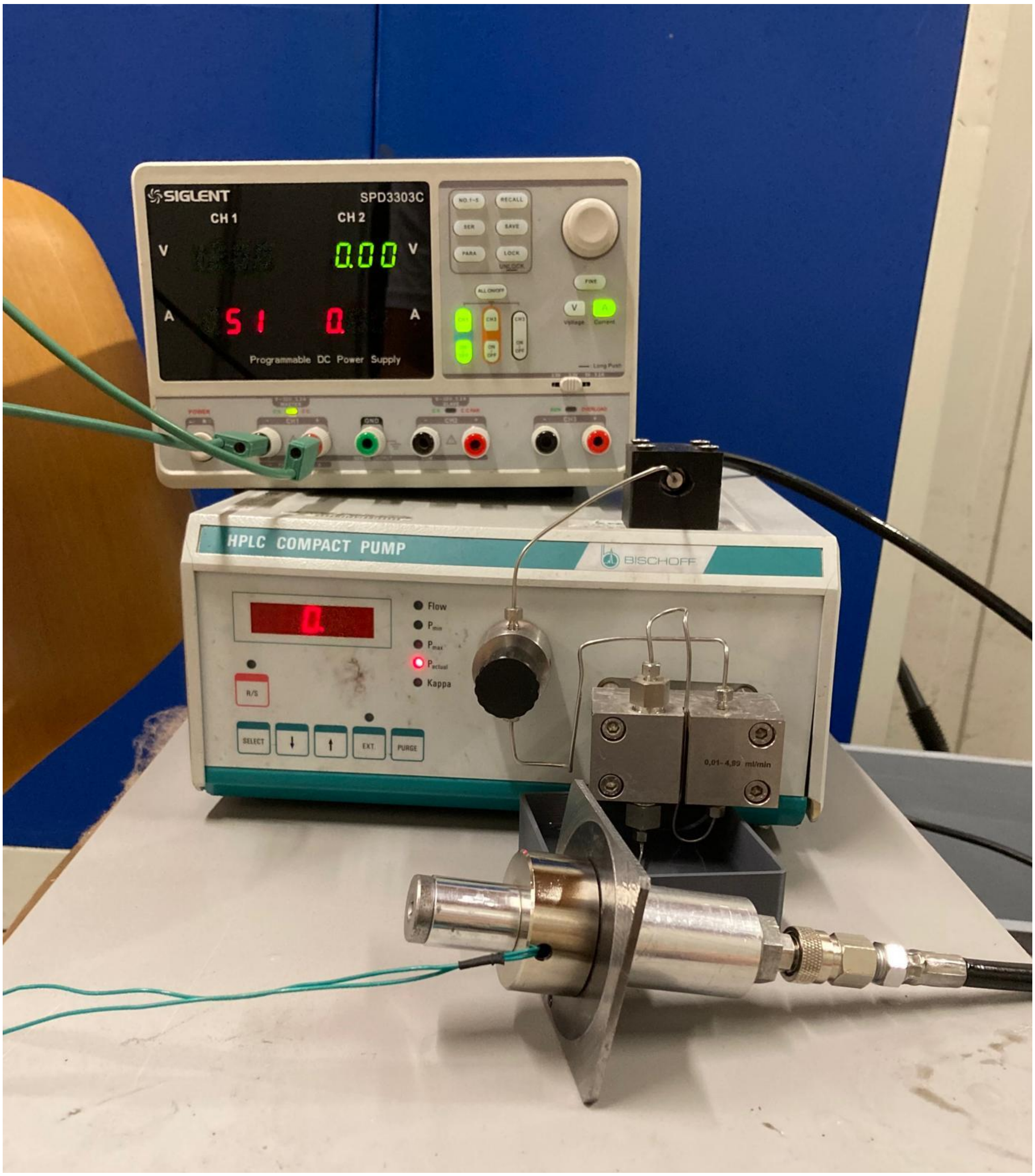


Figure 4-Testsetup

Test execution:

<u>Setup check:</u>

The setup was fully dried and slowly pressurized to about 0.5 MPa and the two sealing points (endcap and hose-connector) have been checked for leakage. No leakage was observed.

<u>pump-settings for all tests:</u>

Flow 0.1 ml/min

Pmin	0 MPa
Pmax	50 MPa
Kappa	50

1.Holdownforce:
Measured pressure shows signs of fluctuation, probably because it is a piston pump and cannot create a continuous flow. This problem was migrated by lowering the flow to 0.10 ml/min. The measured pressure slowly climbed up to 1.8 MPa (=18bar) without the Decoupler decoupling. Only in the exact second a pressure of **1.9 MPa** (19bar) was measured by the pump. The holddown-force was overpowered and the **Decoupler opened up** and the Decoupler-Nipple **fully ejected**.

2.Correct closing of checkvalve:
After ejecting the Decoupler-Nipple the pressure dropped to about 1 MPa and the pump was stopped. After a waiting time of at least 1 min still no further decrease of pressure was measured. Only a small droplet of water dripped out, This can be matched to the small amount of water captured between Decoupler Nipple and the actual sealing surfaces. This decoupling process was tested 3 times at pressures between 1 and 1.5 MPa and showed the exact same outcome.

3.45bar and 10 min:
For the final teststep the pressure was increased up to 6.5MPa and no leakage was noticeable even after a wait time of at least 15 min.

Results:

Decoupling under pressure works very well. Maybe even better at higher pressures (10+ bar) than lower ones (around 3 bar), which was not tested.

The checkvalve reliably closes after decoupling. After an initial pressure drop due to the decoupling process the pressure is held and shows no further decrease.

The checkvalve withstands a pressure to at least 65 bar and is able to hold the pressure and therefore shows minimal to no leakage over a periode of 15 min.

Learnings:

The checkvalve geometry is working as intended and the force generated by the spring is high enough to ensure proper decoupling and sealing, but not overpower the electromagnet. The Piston for protecting the valve-body fro the spring is also doing it’s job and not jamming the system.

As mentioned in the report of the second hydrostatic test, the seal between Nippel and Muffe ist still holding up perfectly without special treatment except keeping it clean.

Attachments:

-

Signatures:

Test Report

Date / Time	2025-08-31
Participants	Matthias Rier, Oliver Balint, Stefan Galavics
Testing purpose	Pressure testing propellant tanks for the operating pressure
Changes	Version 1
Doc. Ref.	

Preparations:

The propellant tanks are plugged downstream with a filler plug and filled with water. The hydrostatic pressure testing machine is connected upstream with fittings.

Test execution:

First propellant tank:

The first tank is connected to the testing machine. The first target pressure is chosen to be 5 bar which is held for 5 minutes to see if the tank has holes or the fittings are leaky.

The second target pressure is the operating pressure of 50 bar, which is held for 30 minutes. If the tank would be bulging under pressure, we should be able to see it now. No bulging was observed

The third target pressure is 75 bar, which is 1.5 times the operating pressure. It is held for an hour to ensure safety in case of extended hold shortly before lift off. Also no bulging was observed

Second propellant tank:

The second tank testing procedure is identical to the first test

Third propellant tank:

The third tank testing procedure is identical to the first test

---

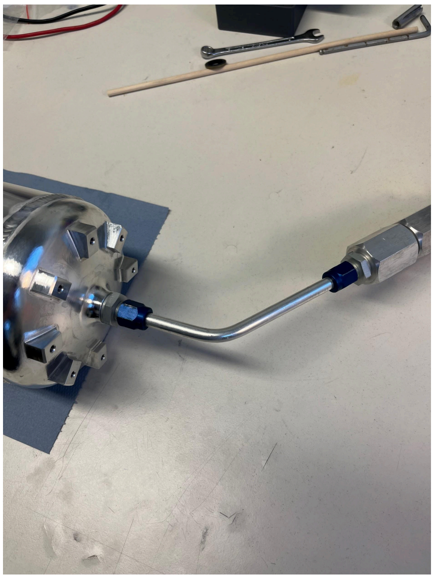
Results:

All three tanks held the pressure of at least 75 bar for more than one hour without bulging or leaking.

Learnings:

The new Tank solved the problem of dead volume in the tank which the V1 had. Therefore it is a major improvement over the first one. This one also includes integrated mounting hardware, which the previous one didn't have.

Attachments:



Signatures:

A.2.7 Additional Test Reports:

Fuel Coldflow

Date / Time	2025-01-24 / 18:00
Participants	Martin Schmer, Oliver Balint, Lutfi Celik, Johannes Eschner
Testing purpose	Train new test personnel on testing procedures. Measure mass flow of the fuel system.
Module	Propulsion
Component	Fuel System

Preparations:

Test setup assembled, rocket mounted on rocket crane.

Results:

• Initial issue: low-level server did not recognize fuel ECU during checklist step 2.3

◦ Troubleshooting included power cycling rocket and GSE, reconnecting CAN cable, restarting low-level server, and replacing long CAN cable with two shorter ones

◦ Problem solved at step 5; all ECUs recognized and functional

• During tanking, load cell failed to provide feedback (constant 600 g rocket weight). Tank was fully filled until overflow via vent valve; 500 g of fuel subsequently dumped

• Fuel pre-press sequence initially unsuccessful due to leaky fuel vent valve → corrected by tightening

• Second attempt successful:

◦ Fuel tank reached 31 bar

◦ Pressure tank reached 194 bar

◦ Ethanol coldflow sequence executed nominally

◦ Observed issues: drain tube too long, missing scale reading of dumped fuel

• Final state: fuel system functional; vent valve tight; main valve showed minor leak

---

Learnings:

Safety:

◦ Add eyewash station to safety gear

◦ When opening pressure bottles fully, turn back half a turn

• Checklist improvements:

◦ 1.1 Verify hook and pulley rope alignment

◦ 1.2 Ensure suspension arm retainer is in place

◦ 1.6 Lift rocket only to safe point for plugging CAN/power connectors

◦ 2.2.6 Verify pressure regulator is at minimum

◦ 3.1.10–3.1.11 Write voltages more clearly

◦ 3.4.5 Verify contents/level of tanking canister; always use safety glasses near tank

◦ After 8.7 add “link” for retanking if needed

◦ 9.6 should be 8.8 → note down weight of collected fuel immediately after sequence

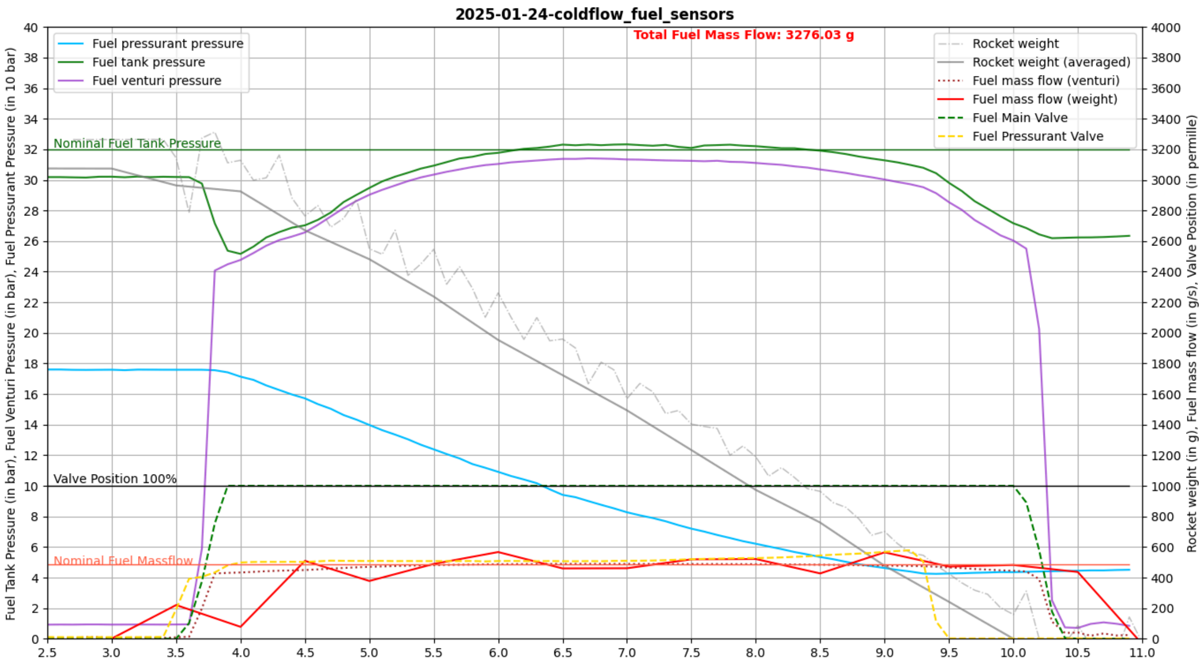
• Hardware/process improvements:

◦ Better catch can for coldflows (20 L capacity)

◦ Improved tanking system with rope lift for canister

◦ Better countermeasures against swinging (rails are unsafe/impractical)

Attachments:


2025-01-24-coldflow_fuel_sensors
Total Fuel Mass Flow: 3276.03 g
Fuel pressurant pressure
Fuel tank pressure
Fuel venturi pressure
Rocket weight
Rocket weight (averaged)
Fuel mass flow (venturi)
Fuel mass flow (weight)
Fuel Main Valve
Fuel Pressurant Valve
Nominal Fuel Tank Pressure
Valve Position 100%
Nominal Fuel Massflow
Fuel Tank Pressure (in bar), Fuel Venturi Pressure (in bar), Fuel Pressurant Pressure (in 10 bar)
Rocket weight (in g), Fuel mass flow (in g/s), Valve Position (in permille)

Fuel Coldflow

Date / Time	2025-01-30
Participants	Lutfi Celik, Eric Drößiger, Martin Schmer, Matthias Ogris, Johannes Eschner
Testing purpose	Train new test personnel on testing procedures. Measure mass flow of the fuel system.
Module	Propulsion
Component	Fuel System

Test 1 (18:00)

Preparations:

- Ox tank and ox line insulated with ArmaFlex
- Rocket lifted on crane

Results:

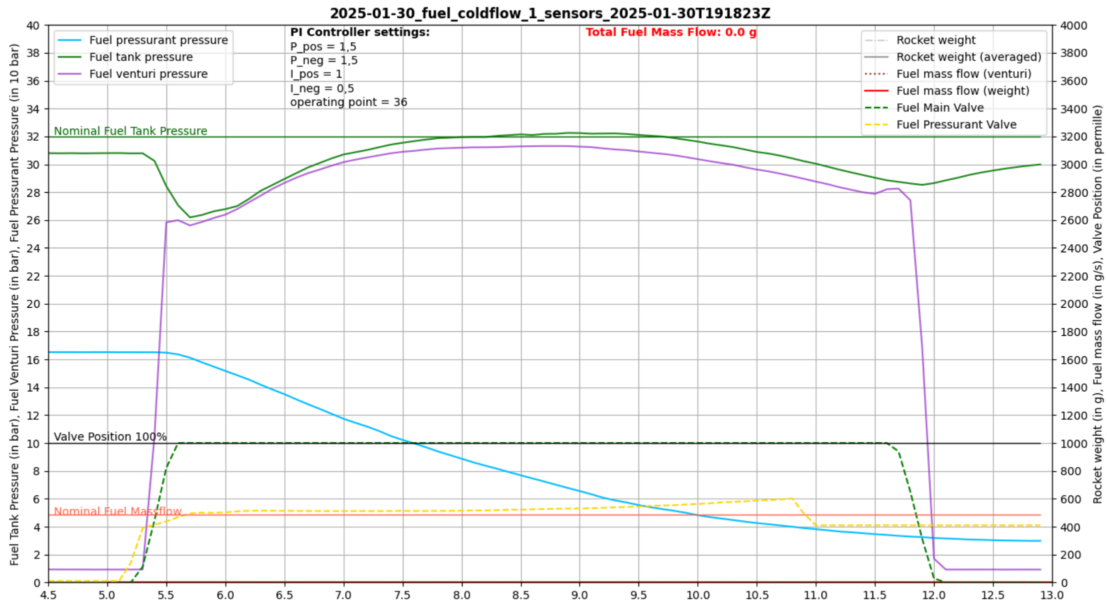
- P&ID did not work at step 3.1, restored to an older version
- At 3.1.5 fuel vent was already open → closed, reopened, and continued nominally
- OX temperature sensor displayed 700 °C (not plugged in)
- Checklist missing instruction: fuel canister venting tube needs to be tied upwards
- Mixed up steps 5.7 and 5.8
- Repeated 5.1.11, stopped at 80 bar
- ECUI did not indicate load cell was disconnected → no data for last 10 minutes of test; after GSE power cycle, weight reappeared, but root issue unresolved
- Fuel pressurant valve only opened to 50% after the sequence, no further

---

Learnings:

- Safety:
  - Add eyewash station to safety gear
  - Add warning sign for test area
- Checklist improvements:
  - Add instruction to verify that fuel canister is leakproof
  - Add comment to 4.1.9 (“connect to fuel tanking” → hold hand underneath)
  - Add filter for fuel tanking line
  - Give more regular fuel tanking callouts (every 20 seconds)
  - Add instruction to move fuel tanking arm aside
  - 4.1.11 “close valve” should be added to 4.1.10 for clarity
  - Add “lower fuel tanking pole” to previous instruction
  - 4.3.2 & 7.2 unclear — specify who is responsible for opening/closing
  - At 7.7 verify that pressurant tanking line is unpressurized
  - Add a callout after sequence goes beyond T-0
- Hardware/process improvements:
  - Replace warning sign for test area

Attachments:



Test 2 (20:00)

Preparations:

• Ox tank and ox line insulated with ArmaFlex
• Rocket lifted on crane

Results:

• Test started with step 3. Check Systems (system already set up from previous test)

• Load cell operational during 3. Check Systems

• 3. Check Systems completed without incidents

• Engine ECU came into contact with ethanol during tanking → rebooted, but remained operational

• 4. Final Test Preparations: adapted order of execution while tanking ethanol was used (starting with 4.1.7)

• 4. Final Test Preparations completed with minor incident

• Pressurant pre-filling sequence terminated at 65 bar after first run (aim: 75 bar); no impact on further procedure

• Prepress finished without incidents

• Pressurant filling finished without incidents

• Ethanol cold flow sequence started at 21:18 → finished without incidents

  ◦ Fuel pressurant valve fully closed after sequence terminated (PI controller operating point set to 38; 36 during previous test)

• Rocket saving finished without incidents

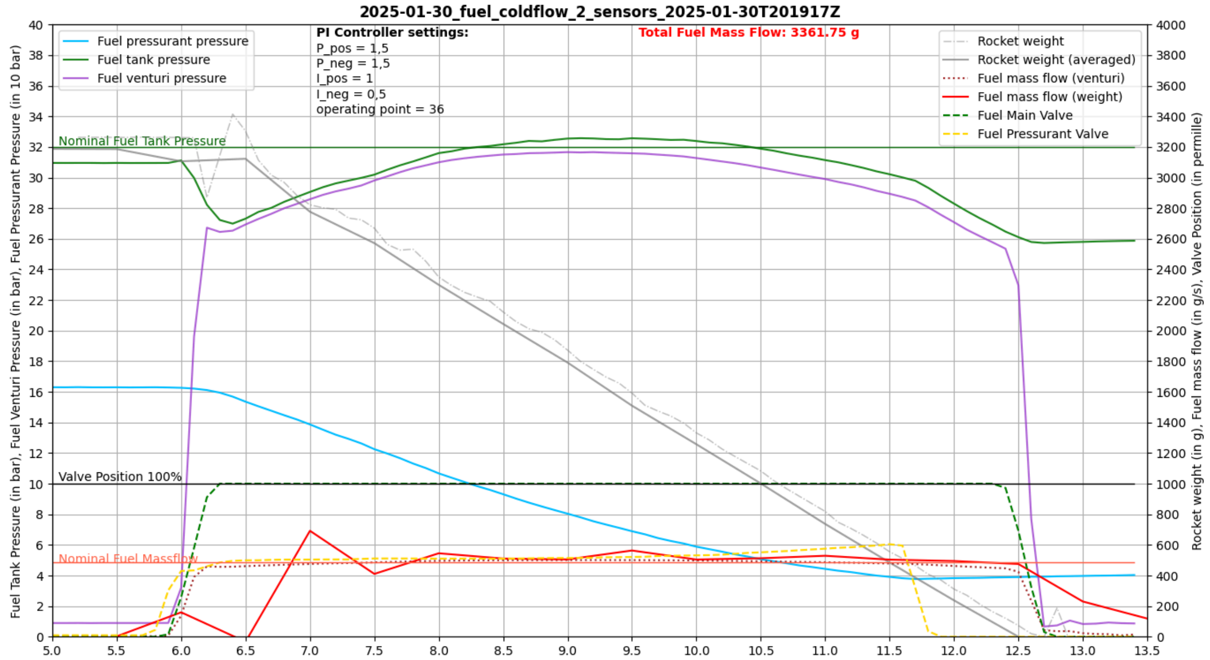
• Safety line remained tied after test completion

Learnings:

• Ethanol cold flow test can be conducted nominally
• Sources of previous errors (load cell disconnect, fuel pressurant valve not fully closing) remain unknown

- Engine ECU should be protected from ethanol during tanking
- Add checklist item: “Disconnect safety line from rocket” (section 11)

Attachments:



LN2 Endurance Test (Dry Run)

Date / Time	2025-02-01 / 16:40
Participants	Lutfi Celik, Eric Drößiger, Johannes Eschner, Diego Grünberger
Testing purpose	Dry run to learn procedures for LN2 Endurance test
Module	Propulsion/Avionics
Component	Ox System and electronics

Preparations:

- Heat decoupler mounted
- Rocket lifted on crane
- Network camera connected

Results:

- Preparations nominal
- At 3.2.3 dewar pressurize solenoid had problems closing properly and actuating
- 3.2.7 was skipped
- 3.2.11 unclear — needs clarification/notes
- 3.2.18 was skipped
- Pre-press OX sequence used and abort tested
  - Solenoid reacted late on first attempt, faster on second
- Continued with dry run
- 7.1 actuated during sequence
- At 9.1.2 LCB died after 58 minutes → GSE and rocket power cycled

---

Learnings:

• Dewar pressurize solenoid in GSE needs to be connected properly

• OX decoupler was not decoupled

• 4.1.5 requires more detail (add tanking line, pressurize, and overpressure steps)

• Power cycling GSE preserved the tared rocket weight

• 13.4 redundant, already covered in 11.8

• Time-critical section took longer than 1 minute → procedure needed to clear pad and vent

• Add a 30-minute timer after 4.0 is complete → checklist should include repeated section every 30 minutes with additional checkboxes/instructions

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Attachments:

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Diego Grunberger

LN2 Endurance Test

Date / Time	2025-02-02 / 18:30
Participants	Lutfi Celik, Eric Drößiger, Johannes Eschner, Diego Grünberger
Testing purpose	Evaluate performance of oxidizer system and electronics under cryogenic endurance conditions (simulating idle scenario with fully fueled rocket on pad)
Module	Propulsion/Avionics
Component	Ox System and electronics

Preparations:

- Heat decoupler mounted
- Rocket lifted on crane
- Network camera connected
- Dewar weight: 38.86 kg

Results:

- (7.2) Ox main valve leaky
- (8.2) ECUI visual bug/state out of sync → required double click
- (9.3.12) Ox vent valve opened further than usual due to insufficient mass flow
- (9.3.12) Ox tanking line leaky → planned swap with braided line
- (10.2.8ff) Pressure fluctuations: –5, –5, +3
- (10.3.2) Ox vent stuck
- (11.4) Pressurant tank at 160 bar
- (13.3.1) Solenoid leaky
- (14.2) Same ECUI visual bug reappeared
- (15.2) N2 line pressure oscillating
- 19:32 restart at 11.0.1 → loss of pressure at 13.3.2; N2 line oscillations continued
- 19:45 restart at 11.0.1 → variance: pressurant bottle stayed open during

pressurization; loss of pressure repeated
- 20:02 body tube mockup placed over engine bay
- 20:39 system check → (10.2.8ff) –0.5, –19.4, –2.6; current draw 460 mA; strange sounds from ox main valve
- 20:37 load cell: 0.33 kg
- 20:49 dewar weight: 26.2 kg
- Warm pressure test: potential leak, ~1 bar/min loss (possibly from ox main valve)
- Cold pressure tests: ox tanking connector possibly leaky, ox vent leaky

Discussion insights (post-test analysis):
- Cooling phase: ~15 minutes required to bring down line and tank temperatures (see Attachment 1)
- Tanking: ~3.5 L LN2 transferred in 10 minutes at 1.5 bar Dewar pressure (see Attachment 2)
- Boiloff: 3.5 L LN2 evaporated over ~1.5 hours (see Attachment 3)
- Pressure decay: tank pressure dropped quickly after prepressurization, while ox tank wall temperature increased; once temperature stabilized, pressure decay slowed (see Attachment 4)
- Total tanking: 3.7 kg LN2 over ~25 minutes (15 min cooldown + 10 min fill)
- Endurance: 3.7 kg LN2 fully boiled off after ~90 minutes
- Pressure stability limited during cryogenic idle:
    - Test 1 (3.15 kg LN2, no topoff): 27 bar → 8.5 bar in 55 sec (+30 °C rise)
    - Test 2 (2.6 kg LN2, no topoff): 30 bar → 20 bar in 40 sec (+30 °C rise)
    - Test 3 (1.9 kg LN2, with topoff): 37 bar → 26 bar in 60 sec (+40 °C rise)
- Chamber pressure sensor began registering only after 2nd pressurization; increased from 0.9 bar to 1.4 bar
- Electronics thermal data (with body tube cover):
    - Ox servo: 3 °C
    - Fuel manifold: –5 °C
    - Engine ECU: 0 °C
    - Ox venturi: –1 °C
    - Fuel venturi: –20 °C
    - Chamber pressure sensor: –3 °C

Learnings:

• Multiple oxidizer system leaks (main valve, vent, tanking connector) must be addressed

• ECUI synchronization bug persists ⟶ requires fix to avoid double commands

• N2 pressurant line oscillations observed consistently ⟶ damping/regulator tuning needed

• Cryogenic endurance limited by rapid pressure decay after prepressurization

• Chamber pressure sensor delayed activation ⟶ further cryo validation required

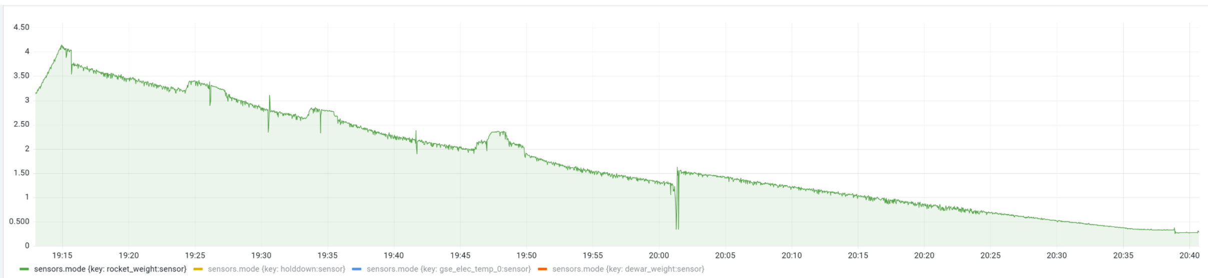
• LN2 endurance: ~90 minutes until full boiloff under test setup

• Electronics remained within operational thermal limits with body tube cover (minimum –20 °C at fuel venturi)

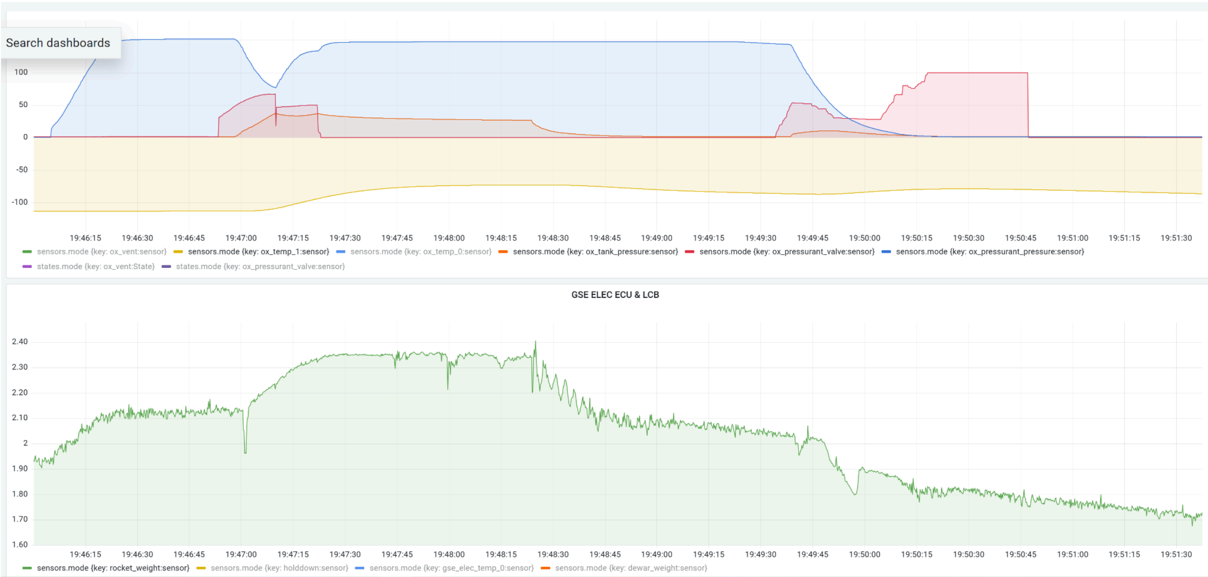
Attachments:

• Attachment 1: Line and tank cooldown time (~15 min)

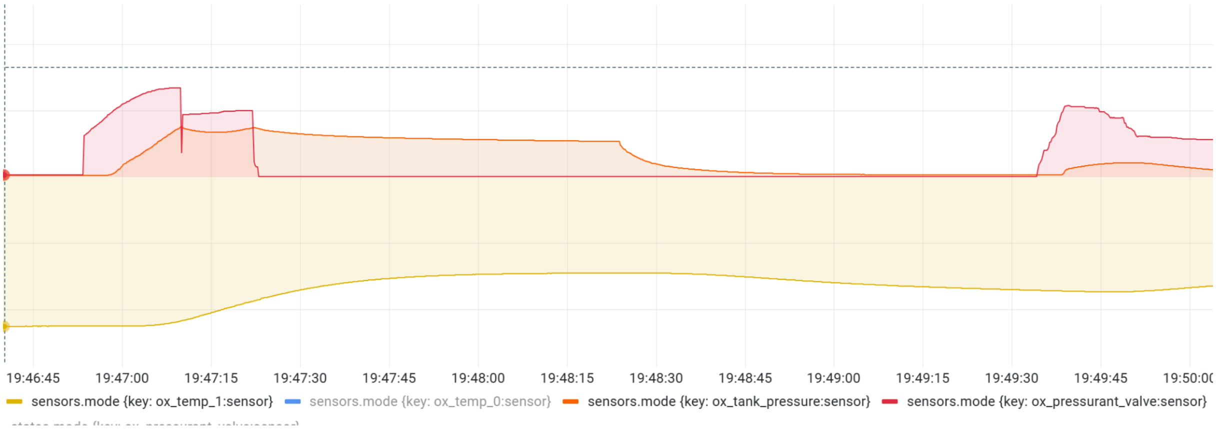
• Attachment 2: Tanking rate (3.5 L in 10 min at 1.5 bar Dewar pressure)



- Attachment 3: LN2 boiloff curve (3.5 L over 1.5 h)



- Attachment 4: Pressure decay vs. tank temperature rise after pressurization



Signatures:

Diego Grunberger

LN2 Cold Flow

Date / Time	2025-02-14
Participants	• Lutfi Celik • Oliver Balint • Matthias Rier • Bernhard Hansemann • Fabio Winkler
Testing purpose	• Check oxidizer system pressurization • Evaluate performance of new dewar press valve • Test ox vent solenoid under cryogenic conditions • Perform cold flow to characterize engine performance
Module	Propulsion/Avionics/Software/GSE
Component	Ox System and electronics

Preparations:

- Chamber removed

Results:

- 3.1: Vent valves gave bad feedback in ECUI until cycled closed and open
- 3.3.1.4: Ox decoupler disengaged but continued hanging on after being unpowered
- Ox pre-press target: 30 bar ⟶ tested, nominal
- Coldflow LOX target: 30 bar, endpoint 4 s ⟶ tested, nominal
- 3.4.1: No chamber pressure thermocouple installed
- 3.4.3: Fuel venturi press sensor: 18.5 °C; Ox venturi press sensor: 16.6 °C
- 3.4.4: Current draw 0.4 A
- 3.4.5: 24%, 15.1 °C
- 4.1.1: Dewar weight: 14.7 kg
- 6.5: Pressurant tank at 220 bar
- 7.1: Solenoid opened at 28.6 bar ⟶ abort
- Skipped to 7.4
    - Ox vent solenoid leaky at 16 bar

    ◦ Ox tanking line possibly leaky
    ◦ Ox tanking line check valve leaky
- 9.1 (21:54):
    ◦ Pressurized dewar → pressurization slow → depressurized via riser cap
    ◦ New attempt: after 5 min still slight gas flow; after 6 min dewar still pressurized → depressurized via riser cap
- 9.2.4: Dewar mass: 15.6 kg
- 9.2.16: 0.45 kg
- 9.2.17: skipped
- 10.1 (22:38):
    ◦ Fuel venturi press sensor: 8.6 °C
    ◦ Ox venturi press sensor: 3.9 °C
    ◦ Current draw 0.39 A
- 11.4: Pressurant tank at 210 bar
- 13.3.2: Slight pressure drop observed
    ◦ Pressurant bottle closed, pressurant line depressurized
    ◦ Ox pressure stable for ~4 minutes, then vented via ox tank
    ◦ Continued at 15.1, then at 18
- 18.8: Dewar mass: 13.340 kg

Discussion insights (post-test analysis):
- Solenoid valve opened at ~28 bar in warm state and leaked slightly at 16 bar → recurring issue
- New dewar pressurization valve had very limited mass flow for both pressurization and depressurization → 5 minutes insufficient to reach 1.5 bar; 6 minutes still venting gas
- Lower equilibrium tank pressure (~1.1 bar during fill) reduced LN2 flow compared to previous tests, but sufficient for tanking
- LOX decoupler or LOX tanking line was very leaky during fill → LN2 visibly escaping
- LN2 amount insufficient for coldflow → rocket only pressurized and vented
- Servos operated without issues
- OBS video recording worked well → file size acceptable
- Protocol and videos uploaded to Drive; checklists online

Summary of observations:
- New dewar press valve unsuitable for endurance pressurization (mass flow insufficient)
- Multiple leak points identified: vent solenoid, tanking line check valve,

decoupler

- Solenoid (tollenoid) failure critical → opens at ~28 bar, leaks at 16 bar warm
- Coldflow not possible due to insufficient LN2 volume
- Recording setup improved → video logging successful without oversized files

---

Learnings:

• Manual actuation of LOX pressure solenoid overrides all electrical actuation

• Old dewar press valve may need to be reused with ≥1.5 bar, or a replacement with higher mass flow sourced

• Solenoid must be hot-fixed or redesigned before proceeding to LOX tests

• Potential improvements discussed:

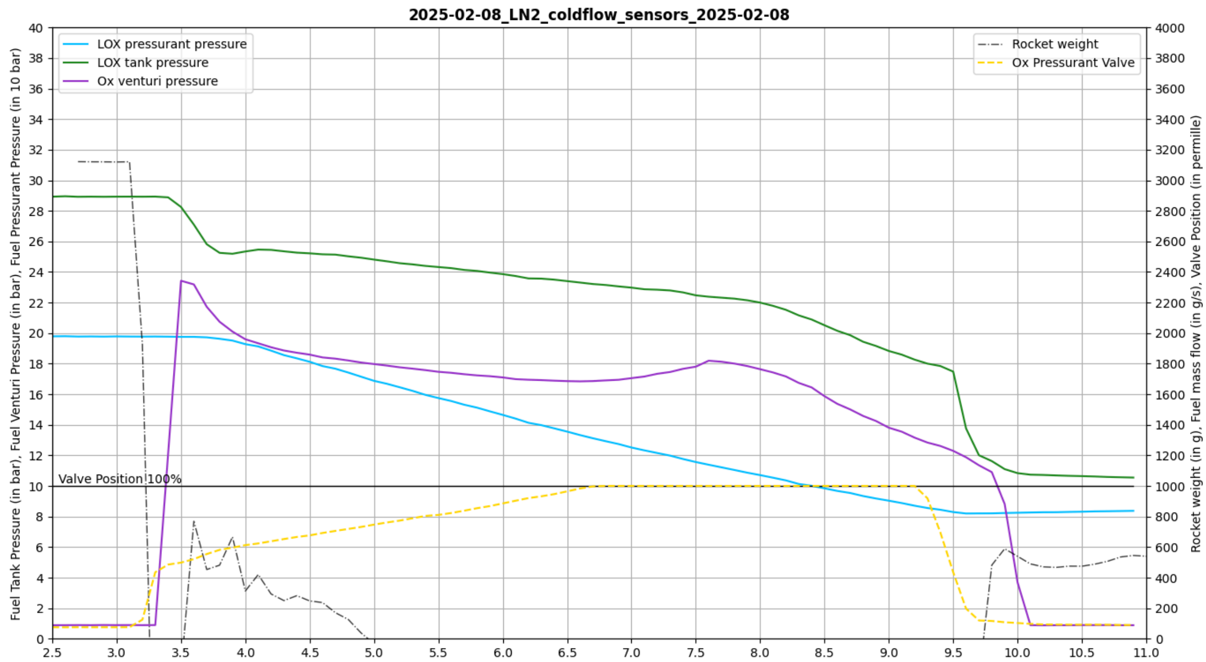
◦ Hydrostatic test of solenoid before reinstallation

◦ Rebuild ox diffuser with smaller bore (3 mm) and PTFE-tipped stem seals (axial and radial)

Attachments:

—

• Attachment 4: Coldflow data



Signatures:

LOX Coldflow Attempt

Date / Time	2025-02-22 / 23:03
Participants	• Lutfi Celik • Oliver Balint • Matthias Rier • Johannes Eschner • Fabio Winkler
Testing purpose	First test of new tank pressures and sequences with LOX
Module	Propulsion
Component	Ox System / Ox Vent

Preparations:

- Removed fine mesh in diffuser to reduce pressurant pressure loss

---

Results:

- 3.5.3: Ox venturi pressure sensor: 17.8 °C
- 3.5.3: Fuel venturi pressure sensor: 16.3 °C
- 6.5: Pressurant bottle pressure: 200 bar
- 7.2: Ox main valve leaky; max oxidizer pressure 32 bar ⟶ valve not tightened properly
- Ox pressurant fill check valve not working
- 8.12.4: LOX dewar extremely unstable on weight scale (wobbly, risk of tipping)
- 8.12.4: LOX dewar weight: 70.5 kg
- 9.4: Door not opened (oxygen redirected outside by pipe)
- 9.11: Ox decoupler added 850 g to rocket weight
- 9.12: Ox main valve servo position not visible
- 9.17: Engine ECU dripped with LOX during tanking
- 9.17: Ox decoupler could not be fully inserted due to ice buildup

- 9.17: Ox tanking leak fixed after defrosting ice in decoupler
- 9.17: Long ox tanking line leaky at middle connector
- 9.17: Rocket weight 6 kg after tanking
- 9.20: LOX decoupler did not disengage automatically; remained very leaky
- 9.21: Rocket weight 5.150 kg
- 10.5: Ox venturi pressure sensor: 2.8 °C
- 10.5: Fuel venturi pressure sensor: 3.5 °C
- 10.6: Power supply: 370 mA
- 10.7.2: Ox vent valve not closing reliably
    - Did not close after actuation or repeated attempts
    - Closed temporarily after manual intervention ("organic bonking stick")
    - Reopened under low pressure (~1.05 bar)
- 11.1: Ox target pressure changed from 30 bar → 35 bar
- 11.8: Pressurant bottle pressure: 180 bar
- 12.2: Ox vent valve opened at 38.6 bar → remained leaky even when closed
- 12.2: Ox vent valve leaky from ~10 bar; tank only pressurized to 34 bar
- Test aborted due to vent valve underperformance

Discussion insights (post-test analysis):

- First LOX test since EuRoC24; previous known issues (internal tanking line leaks, solenoid hot-fix) had been resolved beforehand, but hot-fix was not installed in time for this test
- Key observations:
    - LOX dewar scale unstable; must be secured to avoid tipping
    - Ox main valve leak caused by loose connection, not a hardware fault
    - Gas bottles poorly positioned; pressure gauge facing wall, hoses too short
    - Dewar placement suboptimal → rocket must be rotated to allow autonomous decoupling
    - Ox decoupler leaked heavily during tanking; LOX spilled over Engine ECU → mockup tube, button, and ArmaFlex removed to mitigate
    - Line between dewar and tanking valve very leaky, but tanking completed quickly regardless
    - Ox decoupler back-check valve strongly leaking; resolved after repeated actuations
    - Cryogenic pressurization tests failed due to unmodified solenoid valve → did not remain closed, leaked at low pressure, sometimes failed to actuate
    - Abort sequences caused unintended dumping of pressurant gas through tanking line → likely due to faulty check valve in regulator
- Test terminated by returning LOX to dewar; no useful data obtained on

pressurization behavior or thermal response of components
 • All identified problems have clear fixes and can be resolved before next LOX test

Summary of observations:
 • Test aborted early due to repeated ox vent valve failures
 • Multiple leak sources identified (decoupler, tanking line, main valve connection)
 • ECU exposed to LOX during tanking → requires additional protection
 • LOX handling issues caused by poor dewar stability and suboptimal test stand layout
 • Solenoid hot-fix validated at room temperature but not yet integrated; would likely have prevented main failure mode
 • Pressurant regulator check valve anomaly caused unintended gas dumping

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Learnings:

• LOX vent valve and solenoid reliability remain critical bottlenecks; hot-fix must be installed before further testing

• LOX dewar handling must be stabilized (secure scale, improve positioning)

• Gas bottle placement and rocket orientation must be revised for accessibility and reliable decoupling

• Tanking system requires reinforcement to prevent leaks and icing at couplings

• ECU must be shielded against LOX exposure during tanking

• Ox decoupler switch (taster) requires more robust mounting without interfering with function

• Mockup bodytube opening for tanking must be enlarged

• Pressurant regulator check valve requires inspection and repair

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Attachments:

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Signatures:

LOX Coldflow Attempt

Date / Time	2025-02-24 / 20:30
Participants	• Matthias Rier • Raffael Rott • Florian Marek • Michael Debertol • Bernhard Hanseman
Testing purpose	• Verify ox system pressurization under cryogenic conditions • Evaluate LOX tanking and pressurization sequence reliability • Test functionality of recalibrated ox vent valve and tollenoid
Module	Propulsion
Component	Ox System / Ox Vent

Preparations:

- Ox temp 1 cable broken → sensor inoperable
- Checklist updates required:
  - Connect ox decoupler feedback
  - Connect hose to pressurant tanking valve
- Power supply draw: 0.3 A
- Ambient humidity: 32%
- Ambient temperature: 15.3 °C
- Pressurant bottle pressure: 155 bar

Results:

- Abort during ox pre-press → ox vent leaking; manually recalibrated, reran sequence
- Tollenoid remained leaky after multiple manual adjustments:
  - Attempt 3: opened at 20 bar → adjusted

    - Attempt 5: opened at 25 bar → abort
    - Attempt 6: still leaky → test scrubbed
- Ox pressurant valve leaky at lower pressures; slight leak at 30 bar; no leak observed at 133 bar
- Checklist improvement: “Disconnect the LOX dewar riser from the right of the LOX tanking valve” → should be performed at second connection, not at the valve
- Execution of checklist provided partial training opportunity for new personnel

Discussion insights (post-test analysis):
- Primary issue: tollenoid remained leaky despite hot-fix and O-ring replacement; test scrubbed as insufficiently meaningful to justify LOX usage
- GSE relocated to right side of rocket; cables and pneumatics routed via overhead cable tray
- CAN cable now shorter; rocket must hang lower; 3D-printed holder repositioned
- Several 3D-printed parts broken: connectors at GSE valves and 12 V power supply holder → require redesign in stronger material than PLA
- Ox top temperature sensor cable broken (likely mechanical stress); to be replaced
- Decided to perform test in assembly hall with other teams (Racers present); briefing and hearing protection provided; worked safely but with high noise levels → recommendation to continue this practice with proper safety protocols and dedicated earmuffs
- Waage (scale) stability improved (loose bolts tightened), still slightly wobbly
- Ox tanking line fittings tightened; expected to be leak-tight now
- Ox pressurant fill nipple replaced with fuel press manifold nipple (previous valve stuck and O-ring damaged); requires spares for future replacements
- Ox decoupler fittings: left side left unconnected; right side piece left in place to reduce wear
- Faulty pressurant regulator check valve suspected for anomalies during abort sequences → further inspection required

Summary of observations:
- LOX coldflow attempt aborted due to persistent tollenoid leakage
- Pressurant system anomalies tied to regulator check valve → further troubleshooting required
- Test stand reconfiguration improved cable and pneumatic routing, but

revealed weaknesses in 3D-printed hardware
- Improved Waage stability and better tightening of fittings addressed prior issues
- Safety and coordination in assembly hall testing proved workable with briefings and PPE

Learnings:

• Tollenoid requires redesign or further hot-fix validation before meaningful cryogenic testing

• Pressurant regulator check valve must be inspected and repaired to prevent unintended gas dumps

• 3D-printed parts (valve holders, cable mounts) must be redesigned with stronger material and improved layout

• Rocket cabling needs to be secured to prevent recurring sensor cable damage

• ECU and tanking components must be further protected against LOX exposure and icing

• Continue testing in shared assembly hall with strict safety protocols (briefings, dedicated earmuffs)

Attachments:

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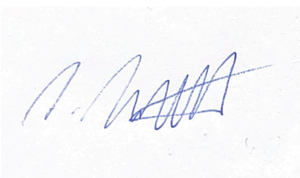
Signatures:


Ox Vent Tests

Date / Time	2025-02-27 / 21:00
Participants	• Lutfi Celic • Diego Grünberger • Oliver Balint • Fabio Winkler
Testing purpose	• Test vent valve for leaks and performance issues • Characterize ox pressurant valve closing behavior under pressure
Module	Propulsion
Component	Oxidizer Vent & Pressurant System

Preparations:

- Vent valve tested and adjusted after previous failed tests
- Anti-rotation 3D-printed part installed on vent valve

Results:

- 22:00 Test 1: Tollenoid opened at 32 bar → power supply failure suspected
- 22:10 Test 2: Pressurized to 35 bar → pressure dropped to 30 bar, then stable for 3+ minutes
- 22:20 Test 3: Pressurized slowly to 45 bar → tollenoid remained seal-tight; manually opened at 45 bar
    - Ox pressurant valve leaky after sequence, servo stuck at 5% position
- 22:25 Test 4: Tollenoid opened at 40 bar
- 23:00 Test 5: Pressurized to 32.5 bar → pressure dropped to 30 bar, then 29.5 bar in 2 minutes (likely thermal effect)
    - Ox vent seal-tight throughout
    - Ox pressurant valve did not close completely; leaked when closed quickly, seal-tight only when closed slowly
- 23:25 Test 6: Target 35 bar, sequence ended at 38 bar; ox pressurant valve leak continued pressurizing system to 48 bar → manually vented via tollenoid
- 23:33 Test 7: Target 35 bar, end at 38 bar; continued leaking pressurization up

to 55 bar → manually vented
• 23:45 Test 8: Target 30 bar; ox pressurant valve still leaky after quick close; tollenoid vented at 43 bar
• 00:00 Test 9: Ox press valve seal-tight only until 55% open; after closing at 10 bar ended in 5% position and leaky; “wiggling” valve restored tightness
• 00:10 Test 10: Same as Test 9 → jiggle to 0% required for seal-tight behavior

Discussion insights (post-test analysis):
• Tollenoid performed reliably, seal-tight up to 55 bar in most runs; opened at 40 bar once, likely operator abort
• Inconsistent results may stem from mechanical tolerances (stem play, plate alignment); next step proposed: refabricate stem and magnet plate
• Orientation may affect behavior → tests were horizontal; must repeat with rocket suspended
• Ox pressurant valve consistently leaky when closed after gas flow began → closes only to 5% position; seal-tightness restored only via manual adjustment (“wiggling”)
• Higher pressure differences worsened pressurant valve closing position (1% at Δp=20 bar vs 5% at Δp=100 bar)
• PI controller operating point may need adjustment to account for valve opening characteristics (~54% threshold)
• First test anomaly (tollenoid opening at 32 bar coinciding with power supply failure) likely caused by PSU, not valve

Summary of observations:
• Tollenoid validated to >50 bar, seal-tight in most tests; occasional early opening requires mechanical refinements
• Ox pressurant valve unreliable: fails to close seal-tight after flow; leaks worsen under higher pressure differences
• System pressure behavior consistent with thermal contraction effects after pressurization
• Test confirmed that vent valve opening pressure too high to function as pressure relief without risking burst disc activation

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Learnings:

• Tollenoid valve requires mechanical refinements (new stem, plate, improved alignment) and repeat testing in vertical rocket configuration

• Ox pressurant valve closing issue persists → redesign or refurbishment needed before reliable cryogenic operation

• PI controller tuning could reduce initial pressure dip by shifting operating point higher

• Test stand hardware (power supply, orientation setup) influenced results → requires further stabilization

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Attachments:

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Signatures:

Ox Coldflow Attempt

Date / Time	2025-03-01 / 21:00
Participants	• Lutfi Celic • Diego Grünberger • Oliver Balint • Matthias Rier • Raffael Rott
Testing purpose	• Verify tollenoid performance under LOX conditions • Check system pressurization and detanking sequence
Module	Propulsion
Component	Oxidizer System

Preparations:

- GSE positioned on right side of rocket
- Ambient humidity: 40%
- Room temperature: 16.8 °C
- To-do: add ECUI recording to OB

Results:

- 7.1: 1.5 bar below target pressure after 4 minutes
- 7.5: Lost 80 bar in pressurant system via bleed valve in 5 minutes
- 8.2: ECUI bug → ox vent button required double input for feedback
- 8.2: Re-ran ox pre-press sequence → tollenoid seal-tight after opening under pressure, no leaks
- Warm pressurization test: tollenoid closed and tight at 38 bar
- LOX tanking nominal
- With LOX in system: tollenoid repeatedly leaky, sometimes opening prematurely at 30 bar and later at 23 bar
- Multiple manual adjustments attempted → valve remained unreliable
- Test scrubbed due to persistent tollenoid malfunction
- Detanking completed nominally

Summary of observations:

- Pressurant bleed valve caused significant gas losses (80 bar / 5 min)
- ECUI bug continues to complicate ox vent control
- Tollenoid reliable under warm conditions but failed under LOX: premature opening and leaks could not be resolved in situ
- LOX tanking and detanking sequences functioned nominally despite valve issues

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Learnings:

- Tollenoid must be redesigned or replaced to ensure reliable cryogenic sealing and actuation
- Pressurant bleed valve issue requires immediate investigation
- ECUI bug (vent double-input) should be fixed to prevent operator error
- Test setup with GSE on right side worked nominally and should be kept

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Attachments:

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Signatures:

Ox Coldflow Attempt

Date / Time	2025-03-03 / 19:30
Participants	• Lutfi Celik • Oliver Balint • Diego Grünberger • Raffael Rott • Johannes Eschner
Testing purpose	• Verify whether ox vent remains closed with new current limiter settings • Attempt coldflow test under cryogenic conditions
Module	Propulsion
Component	Oxidizer System

Preparations:

- Increased current limit of ox vent to maximum supported by power supply
- Ox and fuel vent current draw: 600 mA engaged, 400 mA idle
- Prep completed after mission briefing at ~20:00

Results:

- Warm pre-press test: ox vent leaky at ~25 bar
- Decision: continue to cryo test, expecting improved sealing at lower temps
- LOX tanking started 20:37
  - Ox decoupler leaky on first attempt due to tension on tanking line → fixed by repositioning rocket
  - Still leaky after repositioning → second attempt also unsuccessful
  - Tanked 2.7 kg LOX; tanking completed at 21:00
- Ox vent current draw: ~900 mA in cold state
- Test series:
  1. Pressurized to ~40 bar → vent leaky from 38 bar upward
  2. Pressurized again → vent leaky
  3. Adjusted vent → opened at ~28 bar → aborted
  4. Increased rocket supply voltage to 15 V; total draw ~2 A with vent closed

→ vent opened at ~35 bar → aborted

5. Vent leaky but did not open
6. Vent rotated → leaky at 25 bar
7. Vent rotated again → opened at 27 bar → aborted

- Detanking: ox pressurant valve unexpectedly opened fully → ox tank pressure spiked; suspected overvoltage from 15 V PSU setting

Summary of observations:

- Ox vent unable to hold pressure despite increased current limit and adjustments
- Coldflow attempt scrubbed due to repeated vent leakage and premature openings
- Ox decoupler remained leaky during tanking, complicating setup
- Unexpected spontaneous opening of ox pressurant valve (with ~30 bar remaining in tank) captured on video

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Learnings:

- Increasing current limit to 15 V / ~1 A did not resolve ox vent leakage issue
- Ox vent requires fundamental redesign or replacement to ensure cryogenic reliability
- Ox pressurant valve malfunction indicates possible electrical or overvoltage sensitivity → must be investigated before further cryo operations
- Decoupler line tension and sealing must be improved to avoid recurrent leaks during LOX handling
- OBS video logging successfully captured pressurant valve anomaly and should be standard for future troubleshooting

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Attachments:

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Signatures:

Pressure Regulator Tests

Date / Time	2025-03-03 / 19:30
Participants	• Lutfi Celik • Oliver Balint • Raffael Rott
Testing purpose	• Compare mass flow performance between Ninja V2 (bored out) and Ninja V3 pressure regulators
Module	Propulsion
Component	Ox Pressurant System

Preparations:

• Regulators connected to ox system and tested by running short (~10 s) sequences
• Sequences: ox main valve and ox pressurant valve fully opened to measure flow behavior
• Starting pressure: ~170 bar, decreasing across runs
• Data recorded via Grafana timestamps and exported to spreadsheet

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Results:

Main comparison (170 ⟶ 120 ⟶ 70 bar range):
• **Ninja V2:** mean Δt ≈ 2.84 s (std dev: 0.08)
• **Ninja V3:** mean Δt ≈ 2.48 s (std dev: 0.05)
• **Difference:** Ninja V3 ~0.36 s faster in pressure drop range tested
• **Mass flow ratio V3/V2:** ~1.14 (≈14% higher flow capacity)

Secondary observations:
• At lower ranges (80 ⟶ 70 bar), Ninja V2 mean Δt ≈ 0.41 s vs Ninja V3 ≈ 0.00 s ⟶ V3 outperforms significantly in this regime
• Fuel-side tests show similar trend: Ninja V3 provides higher flow with mean Δt ≈ 0.56 s vs V2 at ≈0.28–0.32 s

• Temperature data consistent: regulator performance not limited by thermal effects in tested range

Summary of observations:

• Ninja V3 regulator consistently demonstrated higher mass flow than Ninja V2, including the bored-out version
• Improvement estimated at ~14% over V2 based on averaged Δt values
• Testing method: pressurant system filled, then released via ox and pressurant valves; flow measured until tank pressure fell to target
• Results reproducible across multiple runs with low standard deviation

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Learnings:

• Ninja V3 regulator provides higher flow capacity and is therefore preferable for high-demand cryogenic pressurization. Ninja V3 outperforms V2 by ~14% mass flow

• Current analysis based on Δt timing between pressure ranges → further detailed mass flow calculation (using real gas correction factors) would refine results

• V3 performance margin indicates potential for more stable pressurant supply during coldflows

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Attachments:

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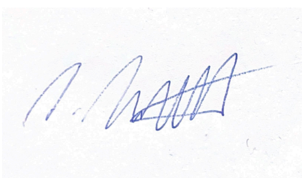  

Pressure Regulator Tests

Date / Time	2025-03-15 / 16:30
Participants	• Lutfi Celik • Oliver Balint • Florian Marek • Michael Debertol
Testing purpose	• Compare performance of new pressure regulator with old one • Verify stability of fuel pressurant valve during automated sequences
Module	Propulsion
Component	Pressurant System (Fuel & Ox)

Preparations:

• Swapped between old and new pressure regulators
• Pressure regulator and pressure sensor of ox system temporarily mounted on fuel system
• Power supply failed during setup → replaced with spare (no further issues observed)
• Thermocouple of ox main valve servo relocated to fuel pressurant tank

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Results:

- Test 1–2: 3.21 kg fuel flowed
- Regulator and sensor swapped into fuel system
- Test 3: Fuel press opened fully at end of sequence → overpressurized; fuel vent opened at 46 bar
  ◦ Subsequent runs showed intermittent malfunctions: valve not closing, over-closing (>100%), or partially closing (e.g. stopping at 30%)

    ◦ Power cycling restored nominal behavior temporarily
    ◦ After tightening grub screws and reassembling, valve ran nominally in multiple sequences but inconsistently repeated earlier issues

- Test 4: Nominal sequence, 3.04 kg

- Test 5: Nominal, 3.135 kg

- Test 6: With pressurant bottle connected → better pressure stability, 3.26 kg

- Test 7: Reverted to old regulator with pressurant bottle connected → 3.36 kg

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Discussion insights:
• New ethanol pressure-fed system worked well, easier to handle and faster tanking than old gravity-fed system
• Fuel flows: ~3.0 kg with new regulator vs ~3.2–3.3 kg with old → old regulator provides higher mass flow
• Pressure trends confirm: Ninja V2 (old, bored) regulator maintains higher tank pressures than Ninja V3
• Power supply anomaly (self-resetting) identified as faulty lab PSU → replaced, issue resolved
• Fuel pressurant valve servo showed multiple failures:
  ◦ Opened fully at sequence end and stayed open
  ◦ Did not close after timeout
  ◦ Closed prematurely to nonzero setpoints (e.g. 30% or –45%)
  ◦ Behavior inconsistent; sometimes nominal, sometimes erratic
• Debugging showed PI controller output unaffected → issue traced to servo feedback channel giving inconsistent data/offsets
• Valve behavior not tied to controller logic but to servo feedback or mechanical issues

Summary of observations:
• Old (modified Ninja V2) regulator provided higher mass flow than new Ninja V3 in ethanol cold flow testing
• Fuel pressurant valve reliability is a major concern due to inconsistent servo

behavior
- Power supply failure traced to PSU, not rocket or GSE

Learnings:

- Adopt Ninja V2 regulator for higher flow until V3 can be modified/improved
- Servo feedback interpretation must be debugged further; offset and missing datapoints cause unpredictable valve control
- PI controller debugging clarified: current “sensor” channel represents servo feedback, not controller output
- Checklists should note PSU reliability → use new tested supply for all future runs

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Attachments:

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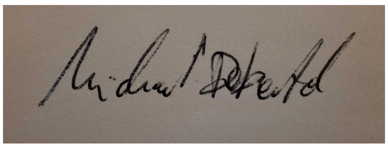
Signatures:



Ox Coldflow Attempt

Date / Time	2025-04-06 / 17:00
Participants	• Lutfi Celik • Oliver Balint • Diego Grünberger • Michael Debertol
Testing purpose	• Verify if ox vent remains leak-tight under cryogenic conditions
Module	Propulsion
Component	Oxidizer System

Preparations:

• Only ~2 kg LOX available in dewar ⟶ no full coldflow possible
• Power supply current limit interfered with ox press valve response ⟶ fixed by raising limit
• Baseline current draw: 0.39 A

Results:

Warm leak checks before cryo test:
• *Old ox vent tested warm; multiple orientations trialed ⟶ started leaking heavily*
• *Inspection showed vent stem fractured between plate and nut (old flat-cone design)*
• *Mesh wire from diffuser found lying on vent O-ring ⟶ likely contributed to leak issues*
• *Old vent removed; Fabio's latest ox vent installed*
• *Initially leaky at hex/diffuser connection ⟶ cleaned threads, removed burrs ⟶ retested and found tight*
• *Repeated cycles showed it remained sealed, except for slight leakage in final run*

Cooled LOX test:
- *During tanking, LCB repeatedly disconnected → GSE repowered*
- *Ox decoupler unpowered mid-process → aborted; after re-power it remained leaky*
- *Multiple disconnect/recouple attempts failed; LOX depleted before stable tanking achieved*
- *Tank cooled to –30 °C at top end*
- *During pre-press: ox vent stuck, would not close*
- *Manual force required to partially close; later failed to open on command*
- *At –18 °C: vent inoperable (neither open nor close possible)*
- *Test scrubbed*

Summary of observations:
- *Old ox vent failed due to stem breakage; design flaw in flat-cone stem tip*
- *Diffuser mesh may have interfered with sealing → should be inspected and cleaned regularly*
- *New Fabio vent initially promising, but cryogenic performance still unsatisfactory → stuck and immovable under load*
- *Ox decoupler again proved unreliable under cryogenic conditions*
- *LCB unstable → disconnected three times during test*
- *LOX supply insufficient for full coldflow, limiting data*

Learnings:

- Fabio's new vent design remains too stiff; requires redesign (stem/feder geometry, sealing concept)
- Stronger return spring and hydrostatic testing of radial seal suggested
- Old stem design confirmed structurally weak → should be retired
- LOX availability limited test scope; must ensure sufficient reserves before future cryo runs
- LCB disconnection issues continue to affect operations and need root cause analysis

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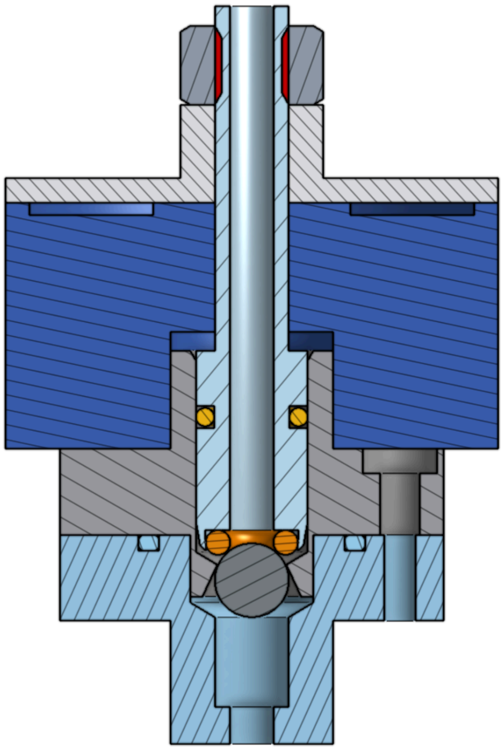
Attachments:

- Attachment 1: New ox vent design



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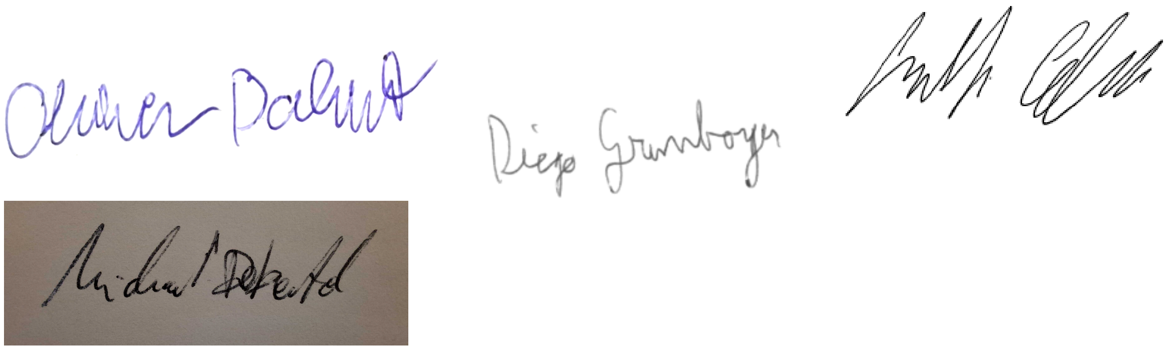


Vent Valve Prototype Tests (VVF1.1 vs VVM5)

Date / Time	2025-04-17 / 14:00–18:00
Participants	• Lutfi Celik • Raffael Rott • Fabio Winkler
Testing purpose	• Verify seal-tightness and functionality of new vent valve prototypes (Fabio's F1.1 and Matthias' M5) under ambient and cryogenic conditions
Module	Propulsion
Component	Oxidizer Vent Valve

Preparations:

• Installed two different vent valve designs sequentially (VVF1.1 and VVM5) for evaluation

---

Vent Valve F1.1 Test (Fabio design)

Execution:

- *Ambient:*
    - Pre-press sequence run with GN2 to 38–40 bar
    - Vent valve opened at ambient tank pressure; closed again around 3 bar
    - System lost <1 bar in >1 min at 40 bar

- *Cryogenic (~–97 °C):*
    - In one plate orientation, valve required ~3 bar to open; other orientations worked nominally
    - During pre-press, valve leaked between two hexagonal casing parts → prevented further testing

• After dumping LN2, vent no longer opened automatically in any orientation

Results:

- Valve held pressure to 40 bar at ambient
- Operated as intended under some cryo orientations but developed casing leak
- After test, valve failed to reopen at ambient pressure

Learnings:

Intended functionality confirmed, but several critical issues:

• Leak between casing parts under cryo (high priority)

• Failure to open automatically after cooldown (medium priority)

• Orientation-dependent opening pressure (~3 bar instead of ambient)

• High seal count → reliability risk

Vent Valve M5 Test (Matthias design)

Execution:

- *Ambient:*
  • System pressurized at ambient → vent valve tight
  • Connection between vent and G1/8–G1/4 adapter leaky
  • Repeated cycling showed occasional sticking when closing

- *Cryogenic (~–96 °C):*
  • Pressurized to ~25 bar, then up to 40 bar
  • Valve remained seal-tight
  • Opened and closed multiple times under cryo, fast response
  • Required ~6 bar to open, ~7 bar to close
  • Mass flow restricted → took >1 min to vent tank from 38 bar to <2 bar
  • High back pressure during venting slowed LN2 tanking (~1.5 kg in 1 h)

Results:

- Valve leak-free at both ambient and cryo
- Reliable open/close cycles at cryo temperatures
- Mass flow capacity too limited for operational needs
- Connection adapter leaky, not valve itself

Learnings:

- Concept fundamentally works under cryo, but design needs:
    - Higher mass flow capability (missing vent bore suspected)
    - Improved closing reliability to avoid sticking
    - Better adapter sealing

Shared observations:

- Neither prototype opened below 38 bar, true relief pressure not determined
- Ox decoupler remained completely tight during tanking
- LCB froze twice during tests
- Abort sequence revealed ox pressurant valve did not close properly
- Both designs promising but require refinement:

    ◦ VVF1.1 → casing sealing and reliability issues

    ◦ VVM5 → insufficient venting speed, potential design oversight (missing bore holes)

Signatures:

Vent Valve F1.1 Tests (Two Runs)

Date / Time	2025-04-26 / 12:00 & 17:45
Participants	• Lutfi Celik • Diego Grünberger • Oliver Balint (first run only) • Fabio Winkler
Testing purpose	• Verify seal-tightness of vent valve F1.1 under cryogenic conditions • Reassess flange O-ring leakage observed in previous tests • Evaluate design modifications (flange bolts, dynamic O-ring)
Module	Propulsion
Component	Oxidizer Vent Valve (Prototype F1.1)

Preparations:

Run 1: Cleaned vent valve, cleaned LOX pressurant diffuser female thread, changed vent valve flange O-ring, changed diffuser-to-valve O-ring

Run 2: Increased flange hole count from 3 → 6, replaced dynamic radial O-ring

---

Test Execution

Run 1 (12:00)

- GN2 leak check → no major anomalies
- LN2 tanking to ~4 kg target
- Vent valve behavior: did not open automatically at 5.6 bar; opened with slight external force
- Retanked to ~4 kg and repeated checks

- Ran pre-press sequence
- Decoupler initially leaky → greased O-ring → sealed but failed to decouple reliably

Run 2 (17:45)

- GN2 leak check → tight system
- LN2 tanked to ~3 kg
- Pre-press sequence: ox pressurant valve stuck at ~30% opening despite controller command; multiple re-runs
- Coldflow sequence run with ~0.5 kg LN2 remaining
- Vent valve remained seal-tight to 40 bar under cryo
- LOX decoupler leaky again

Results:

Run 1:

- Ox vent valve seal-tight at ambient
- Worked normally at –140 °C in favorable orientation
- Did not reliably open at low pressure (required >5 bar or manual assist)
- Decoupler sealing improved with grease, but release failed

Run 2:

- Vent valve remained seal-tight up to 40 bar in cryo
- Opening/closing reliability reduced after dynamic O-ring replacement
- Coldflow successfully executed (short, limited mass due to ~0.5 kg LN2)
- Ox pressurant valve anomaly: stuck at 30% open under pressure
- Decoupler again leaky

Learnings:

Vent valve F1.1:

- Seal-tight at 40 bar cryo, but O-ring design affects reliability of actuation
- Orientation-sensitive behavior persists
- Higher flange bolt count improved sealing but not consistency of motion
- Dynamic O-ring revision degraded reliability

Coldflow readiness:

- Coldflow possible with vent valve F1.1, but LN2 amount too low for conclusive mass flow data
- Pressure fell rapidly after pre-press (41.3 → 25.3 bar in 24 s during Run 1)
- Heated LN2 in Run 2 reduced density and mass flow

Decoupler:

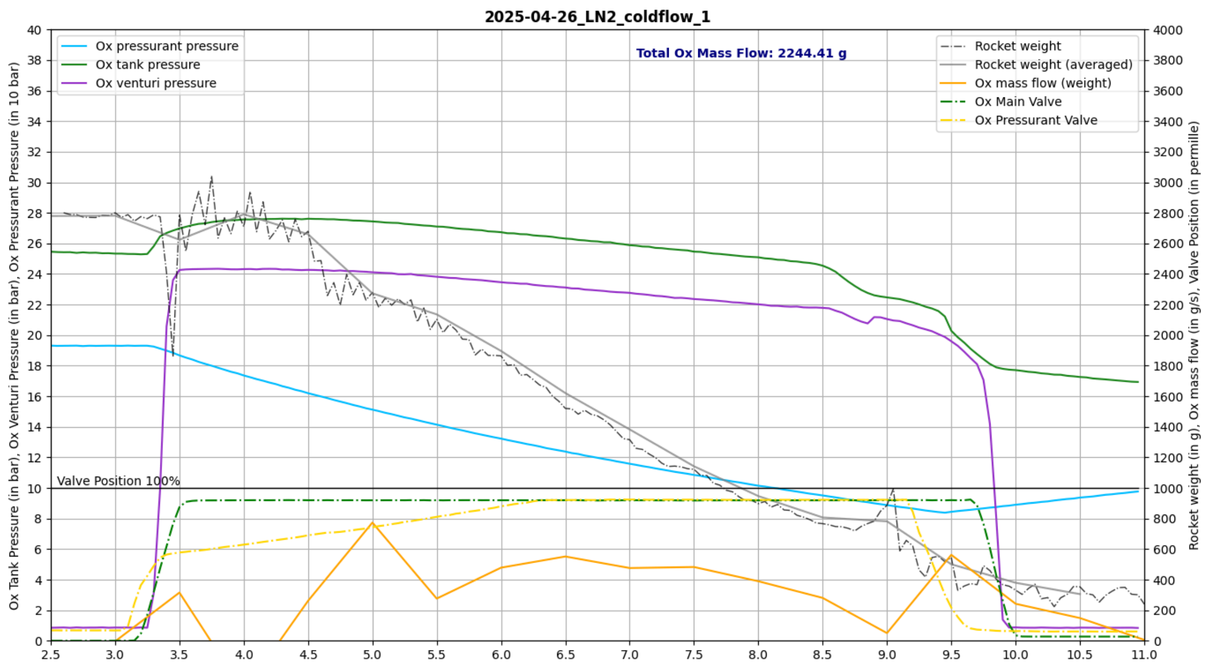
- Greased O-ring seals but fails to release → requires redesign for reliability

GSE / hardware notes:

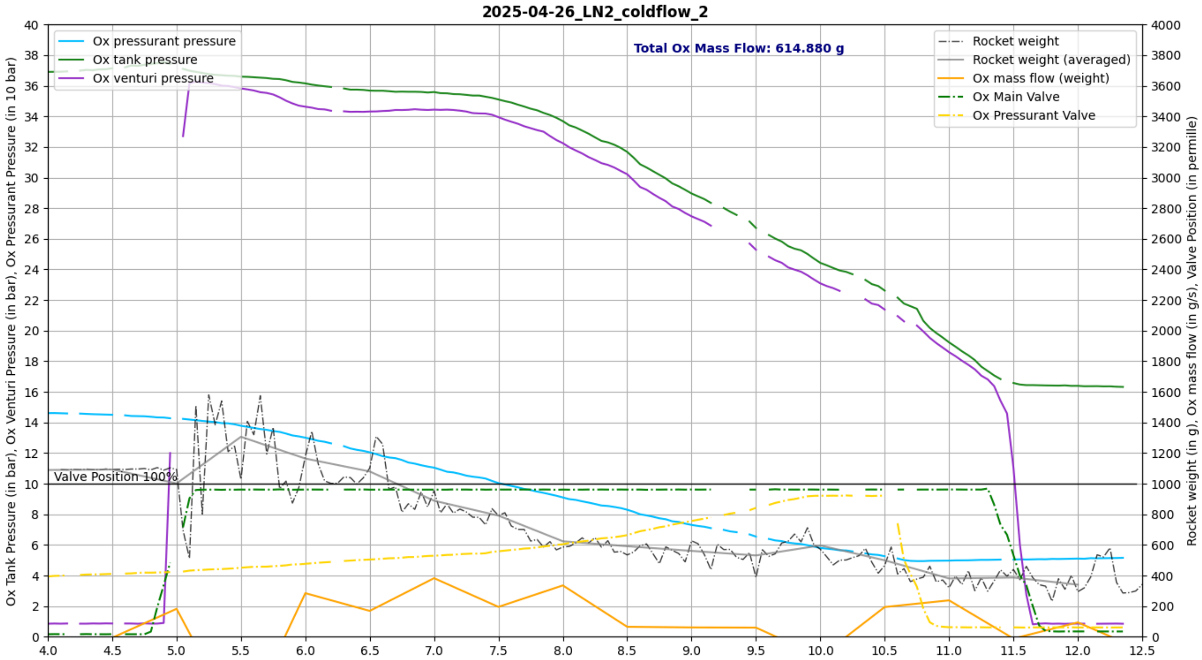
- Ox pressurant valve anomaly (limited to ~30% opening) needs investigation
- PLA actuator holder for press valve broke during handling → replaced with spare

Attachments:

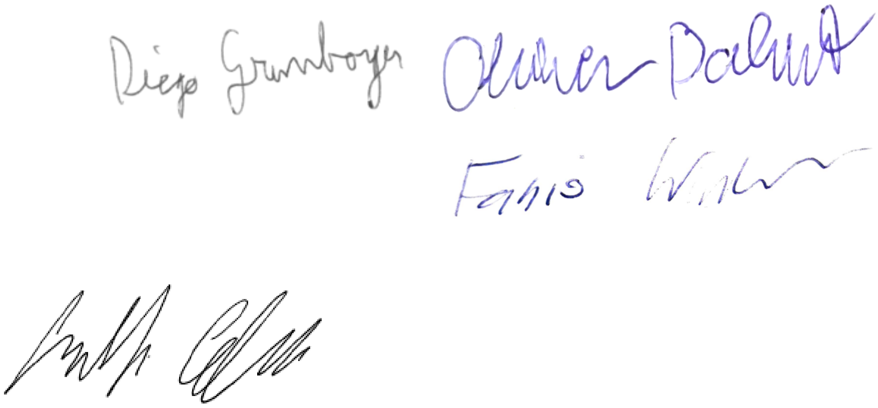
- Attachment 1: First coldflow data plot



- Attachment 2: Second coldflow data plot


2025-04-26_LN2_coldflow_2
Total Ox Mass Flow: 614.880 g
Ox pressurant pressure
Ox tank pressure
Ox venturi pressure
Rocket weight
Rocket weight (averaged)
Ox mass flow (weight)
Ox Main Valve
Ox Pressurant Valve
Valve Position 100%
Ox Tank Pressure (in bar), Ox Venturi Pressure (in bar), Ox Pressurant Pressure (in 10 bar)
Rocket weight (in g), Ox mass flow (in g/s), Valve Position (in permille)

Signatures:



LOX Coldflow

Date / Time	2025-05-03 / 13:47
Participants	• Lutfi Celik (lead) • Raffael Rott (control) • Michael Debertol (control support) • Florian Marek (lead support) • Matthias Ogris (documentation) • Fabio Winkler (appeared mid test)
Testing purpose	• Validate previously cryo-tested ox vent with LOX • Verify ox press valve functionality under LOX conditions
Module	Propulsion
Component	Oxidizer System

GSE Status:

Item	Before Test	After Test
Pressurant bottle	150 bar (low) // 300 bar in full bottle	ca. 60 bar in low bottle, 290 bar in full bottle
Pneumatic bottle	10 bar	
Dewar mass	55,8 kg	40,4 kg
Humidity	32 %	
Temperature	26,1 Celsius	

Preparations:

- Adapted LOX coldflow sequence with initial delay
- Multiple PI controller parameter adjustments tested
- Rocket mounted on pulley, Dewar and bottle setup, camera setup
- GSE repositioned for better tanking access
- All valves, sensors, actuators, voltages nominal
- Combined Prepress + LOX Coldflow sequence implemented and tested

Results:

• Warm prepress tests: ox press valve stuck at various setpoints (14–41%), improved after servo swap

• LOX tanking: 5.3 kg filled, ox vent initially stuck but freed manually; rocket current draw ~1 A

• Cryo prepress sequences: stable at ~40 bar, ox vent intermittently leaky or opened prematurely (~37–38 bar)

• Second LOX tanking: 6.3 kg filled, LOX decoupler leaky without grease; ox vent current 420 mA (open) / 1.2 A (closed)

• Final LOX coldflow: prepress reached 41 bar, peak 46 bar during ejection, rocket emptied

• Ox press valve actuation improved but still inconsistent under pressure

• Ox vent intermittently leaky and prone to premature opening at ~37–38 bar

• LOX decoupler leaky unless greased, but grease prevents reliable release

• Successful LOX coldflow executed at up to 46 bar

• CAN bus overloaded → data logging incomplete

Learnings:

• Ox press valve requires further servo tuning or redesign for reliability

• Ox vent needs mechanical refinement for consistent sealing/actuation

• LOX decoupler must be improved: sealing vs. release tradeoff

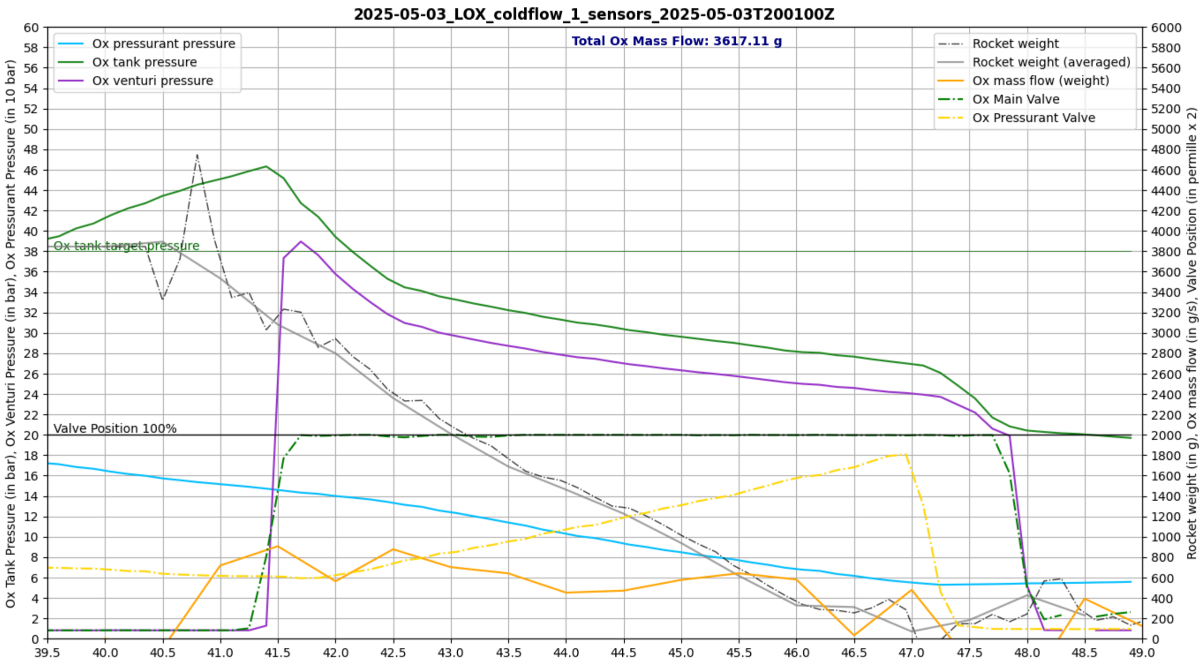
• CAN bus logging must be optimized for high-data-rate tests

• Coldflow sequence structure (prepress → PI off → main valve open) is validated

---

Attachments:

• Attachment 1: Pressure plot


2025-05-03_LOX_coldflow_1_sensors_2025-05-03T200100Z
Total Ox Mass Flow: 3617.11 g
Ox pressurant pressure
Ox tank pressure
Ox venturi pressure
Rocket weight
Rocket weight (averaged)
Ox mass flow (weight)
Ox Main Valve
Ox Pressurant Valve
Ox tank target pressure
Valve Position 100%
Ox Tank Pressure (in bar), Ox Venturi Pressure (in bar), Ox Pressurant Pressure (in 10 bar)
Rocket weight (in g), Ox mass flow (in g/s), Valve Position (in permille x 2)

Signatures:

LOX Coldflow Tests

Date / Time	2025-05-04 / Test 1: 15:58 / Test 2: 17:04
Participants	• Lutfi Celik (lead) • Fabio Winkler (lead support, documentation) • Diego Grünberger (mission control) • Ines Schnabl (mission control support)
Testing purpose	• Verify ox vent valve functionality with LOX • Evaluate ox press valve under cryogenic conditions • Gain insight into fluid system performance
Module	Propulsion
Component	Oxidizer System

GSE Status:

Item	Before Test 1	Before Test 2	After Tests
Pressurant bottle			262 bar
Pneumatic bottle	50 bar	40 bar	32 bar
Dewar mass	39,6 kg	31,2 kg	empty
Humidity	50%	50%	50%
Temperature	20,8°C	19,9°C	19,1°C

Preparations:

- Disassembled ox vent, changed dynamic O-ring, reassembled
- Adapted combined prepress and coldflow sequence
- Tested pre-press sequences and abort functionality
- Tested combined coldflow sequence
- Slightly greased ox-decoupler

Test execution:

Test 1

- Tanked up until LOX exited ox vent at 6.3 kg rocket weight incl. decoupler

- Waited for weight drop, topped off ox tank, decoupled LOX tanking
- Rocket weight before test: 5.5 kg
- Pre-press sequence executed, vent leaks checked
- Combined coldflow sequence run, target pressure 38 bar

Test 2

- Tanked up until LOX exited ox vent at 6.3 kg rocket weight incl. decoupler
- Waited for weight drop, topped off ox tank, decoupled LOX tanking
- Rocket weight before test: 5.5 kg
- Pre-press sequence executed, vent leaks checked
- Combined coldflow sequence run, target pressure 30 bar

Results:

Test 1

- Ox-decoupler perfectly seal-tight, but did not disengage
- ~8 kg LOX consumed for full tanking and top-off
- Ox vent slightly leaky at ball and dynamic seals
- Fuel venturi sensor: 15.3 °C
- Ox venturi sensor: 17.6 °C

Test 2

- Ox-decoupler seal-tight, but did not disengage
- Decoupler check-valve leaky, slightly improved after retanking
- Fuel venturi sensor: 12 °C
- Ox venturi sensor: 16 °C

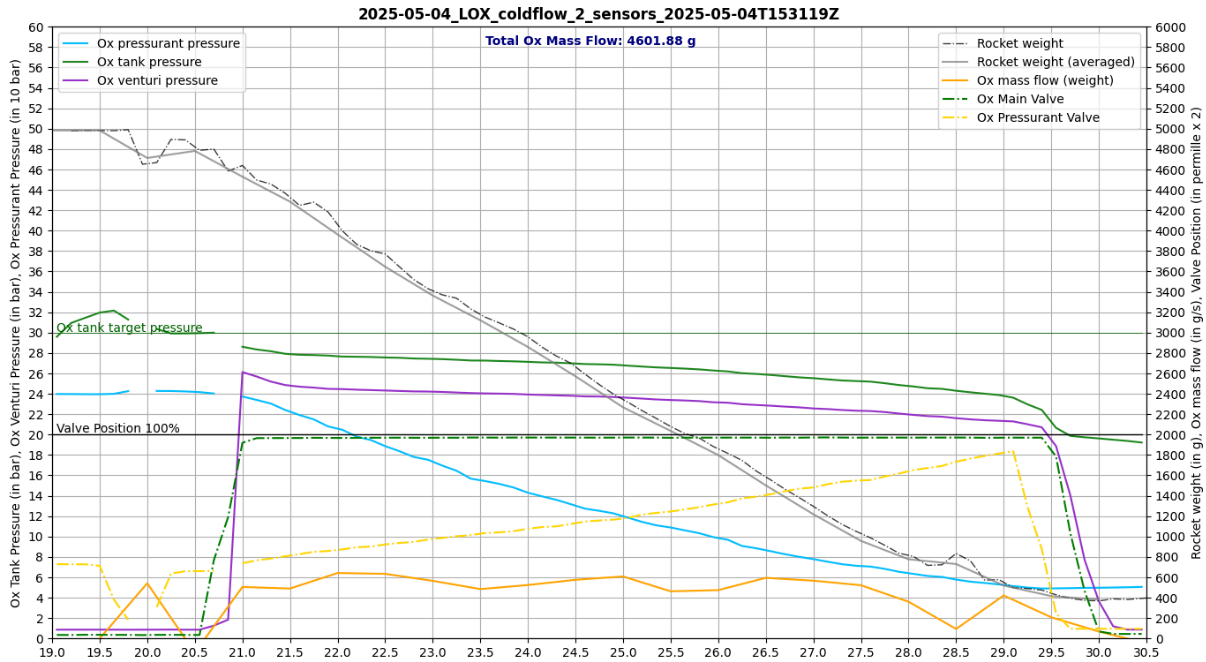
Learnings:

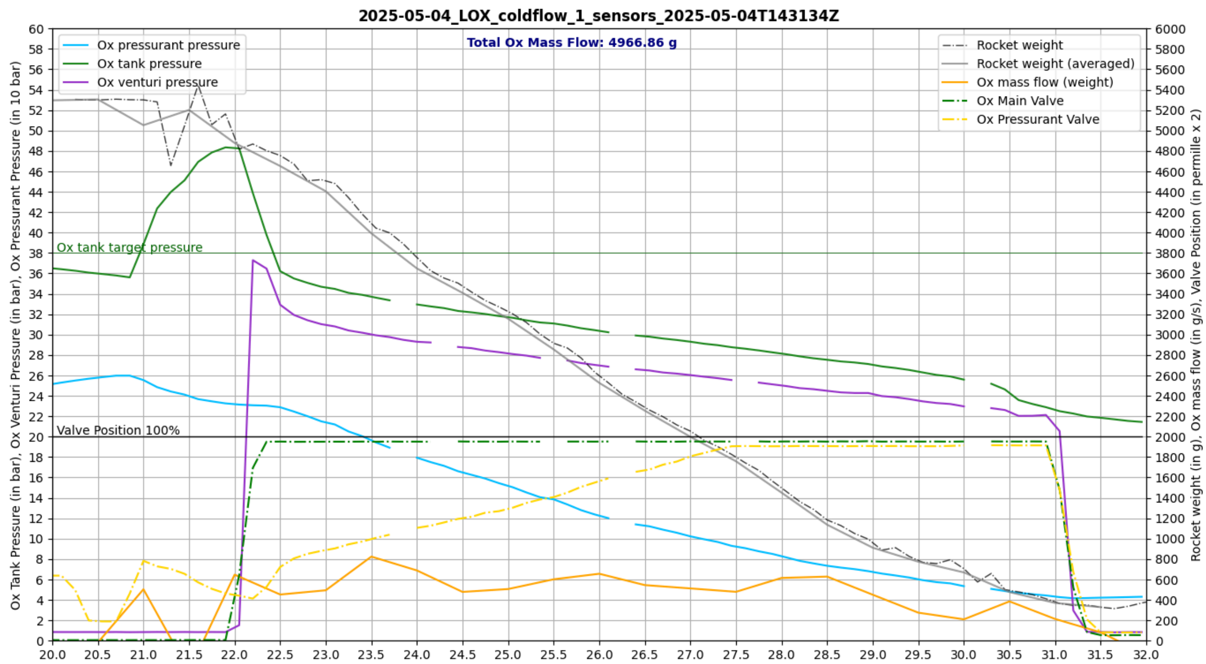
- Greasing of ox-decoupler necessary for seal-tightness before each use
- Greasing prevents reliable decoupler disengagement
- Pressure drop between ox tank and ox venturi ~2.7 bar
- Loosely attaching exhaust diffuser line stabilizes weight curve

---

Attachments:

- Attachment 1: Pressure plot test 1
- Attachment 1: Pressure plot test 2





Signatures:

Ethanol Coldflow

Date / Time	2025-06-19 / 18:15
Participants	• Lutfi Celik (lead) • Michael Debertol (lead support) • Johannes Eschner (mission control) • Luis Büchi (documentation, mission control support)
Testing purpose	• Health check of ethanol feed system (leaks, valve functionality) • Validation of rocket state machine logic and ECU interactions • Pneumatics performance evaluation with new sensors • Ethanol tanking procedure test
Module	Propulsion
Component	Fuel System

Preparations:

• New sensors in pneumatic system
• Firmware flashed on Fuel ECU (local change, Diego)
• Electronics checks completed
• State machine code reviewed
• Pneumatic sensors integrated and calibrated

Test execution:

• Tested rocket state machine sequences — abort behavior problematic (Fuel Press PI controller opens fully on abort). Workaround applied.
• Rocket idle draw: 0.3 A; during sequence: 0.81 A
• Fuel main valve found leaky, rest of system looked nominal but main leak dominated results
• Fuel main servo recalibrated — leak reduced but persisted
• Second leak check: main valve less leaky, still not acceptable
• Fuel tanking attempted despite small leak, tanking worked but system remains partially incontinent

• Pressurized tanking performed, functioned adequately despite leaks
• State machine feedback: ECU responsibilities overlap, CAN IDs unclear, depressurize state actions inconsistent with diagrams
• Pneumatics response tested — mass flow of pressure regulator too low, system pressure drops from 8 bar to <5 bar during fast actuation, takes seconds to recover
• Ethanol tanking tested using pressure-fed setup; tanking worked, small hose leaks observed
• Fuel ECU firmware flashed (unconfirmed local changes by Diego)
• ECUI issues: countdown timer bug (fixed later), reset command not working for holddown timeout, missing state coloring caused operator confusion

---

Results:

• System overall pressurizable, but fuel main valve remains leaky

• State machine behavior inconsistent with diagrams — abort state needs fixing, ECU command structure must be clarified

• Pneumatics regulator bottlenecks mass flow, but actuators remain functional for intended use cases

• Ethanol tanking possible with pressure-fed system; small leaks present

---

Learnings:

• Each ECU should control only directly attached actuators — prevents confusion and CAN traffic

• State machine exit conditions and logging need refinement for traceability

• Pneumatics regulator restricts flow but is acceptable for operations; may need future upgrade

• Ethanol tanking procedure works, weight monitoring via external scale feasible

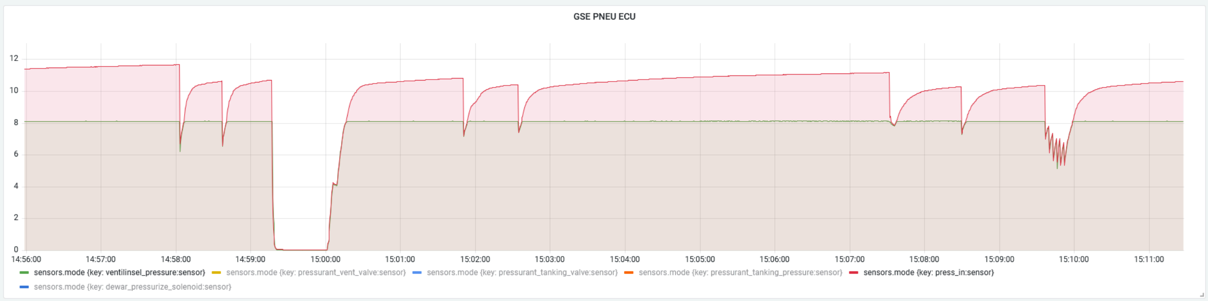
• Greasing/calibration procedures critical to minimize valve leakage

- ECUI requires fixes to reset behavior, state visibility, and countdown accuracy

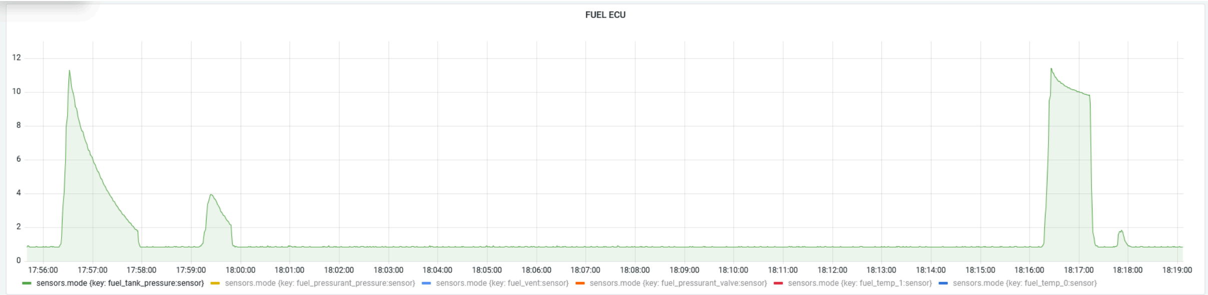
---

Attachments:

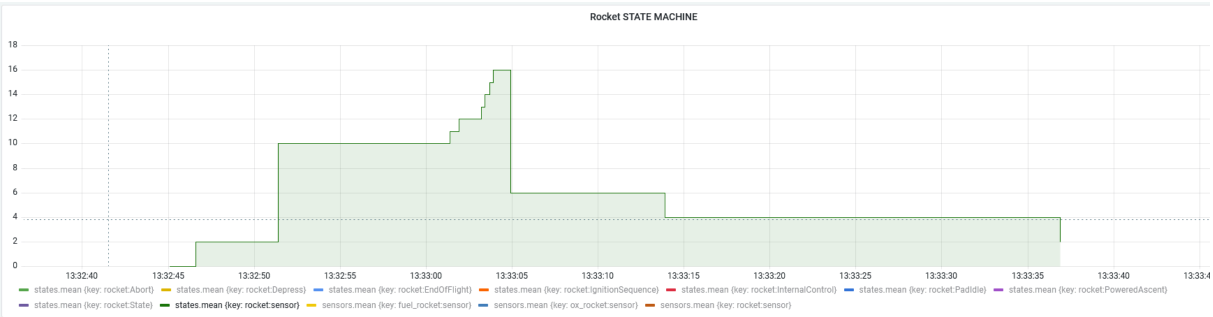
- Attachment 1: Pneumatics pressure graph



- Attachment 2: Fuel tank pressure log



- Attachment 3: State machine log

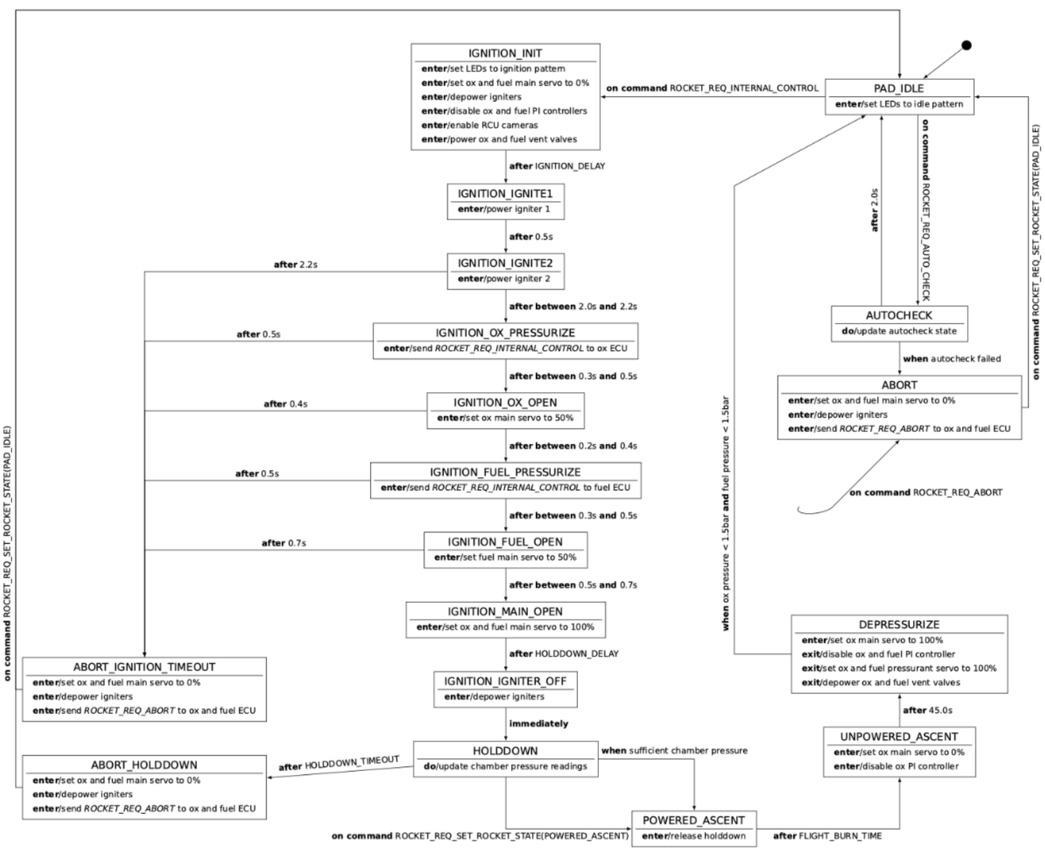


- Attachment 4: State machine diagram

SPACETEAM/LAMARR/SOFTWARE

Rocket Channel: Main State Machine

To be implemented on the *Engine ECU*



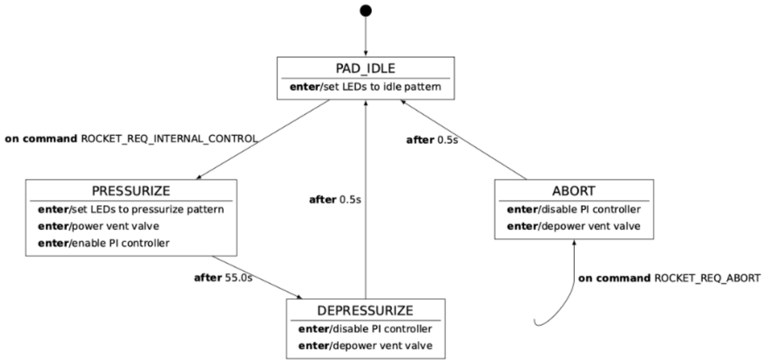
Parameters	
Name	Value
FLIGHT_BURN_TIME	45.0s
HOLDDOWN_DELAY	0.5s
HOLDDOWN_TIMEOUT	3.0s
IGNITION_DELAY	1.7s

LED Patterns		
Name	LED1	LED2
Idle	H	L
Ignition	H	H

SPACETEAM/LAMARR/SOFTWARE

Rocket Channel: Subsidiary State Machine

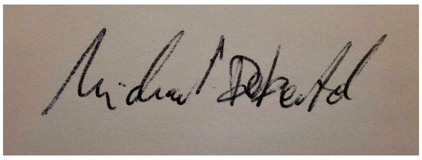
To be implemented on the *Fuel* and *Ox ECU*



LED Patterns

Name	LED1	LED2
Idle	H	L
Pressurize	L	H

Signatures:



Ethanol Coldflows

Date / Time	2025-06-22
Participants	• Lutfi Celik (lead) • Michael Debertol (mission control) • Stefan Galavics (mission control support) • Matthias Ogris (documentation)
Testing purpose	• Verify functionality of new ECUI under internal control • Perform ethanol system leak check • If leak-tight, attempt ethanol cold flow
Module	Propulsion
Component	Fuel System

Preparations:

• Rocket mounted on launch rail with feed system connected
• ECUI update installed — sequence sync feature active initially
• Antenna cable replaced (previous one too short)
• Temperature sensors, LCB, igniter channels tested functional
• PI controller parameters for fuel system manually set in handover sequence (not handled by state machine)

Test execution:

ECUI / state machine tests
• Engine ECU states not displayed correctly at first → fixed quickly
• Major issue: during sequences, sequence timer froze and ECUI aborts were not accepted → traced to new “sequence sync” feature, feature removed to proceed
• Countdown desync observed, abort only worked after fixes and when selecting END OF FLIGHT state
• Abort functionality confirmed after fixes (button, keyboard, browser close)
• State machine handover sequence tested successfully (PI controller switch, igniter sequence, rail erection)

Leak checks

• Fuel main valve inspected after maintenance: very slight leak (<0.5 bar/min), acceptable for testing
• Initial pressurization data collected for new fuel main valve (see attachment 4)

Cold flow tests

Test 1:

• System pre-pressurized and 4 kg ethanol tanked
• Cold flow attempted via internal control
• Test aborted due to major leak downstream of fuel venturi tube
• Post-test inspection revealed low-pressure burst disk of fuel regulator had burst during main valve opening

Test 2:

• Burst disk replaced, pressurant re-tanked
• Cold flow attempted again with lower target pressure
• Ethanol mass flow sustained for ~7.5 s, system stable, main valve leak minor but manageable

Additional observations

• Pneumatic system response sluggish: regulator set to ~10 bar initially, later dropped to ~6 bar after heating in sunlight (see attachment 5)
• Fuel system with 4 kg ethanol showed small residual gas volume in tank, causing high sensitivity to pressure spikes → timing adjustments required before main valve open

---

Results:

• New ECUI functional after removal of sync feature, abort and handover sequences verified
• Slight persistent leak at fuel main valve, but acceptable for cold flow
• First ethanol cold flow aborted due to downstream leak and burst disk failure
• Second ethanol cold flow nominal, ~7.5 s mass flow achieved

---

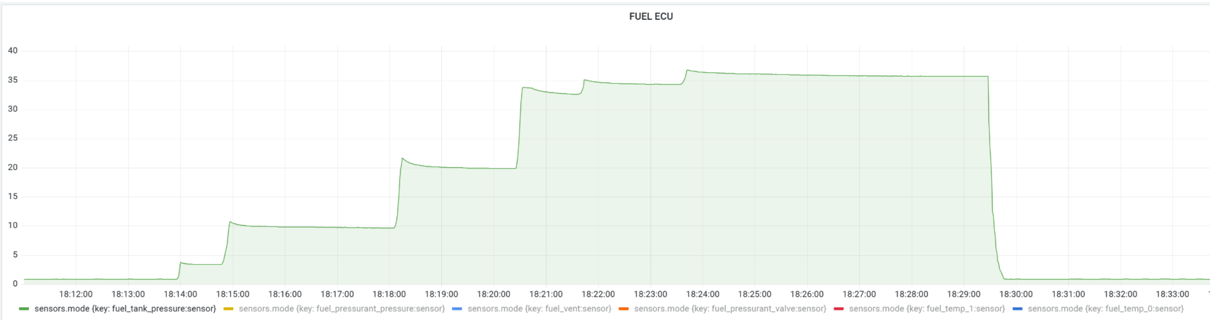
Learnings:

- ECUI state machine requires clearer state ID mapping for Grafana logs
- PI controller parameters must be explicitly set during handover, not assumed
- Fuel main valve maintenance improved leak performance but not eliminated it
- Fuel press system highly sensitive to overpressure with small liquid volumes — timing adjustments (Fuel Pressurize → Fuel Main Open <0.3s) needed
- Pneumatic regulator performance degrades under heat, monitor for EuRoC conditions

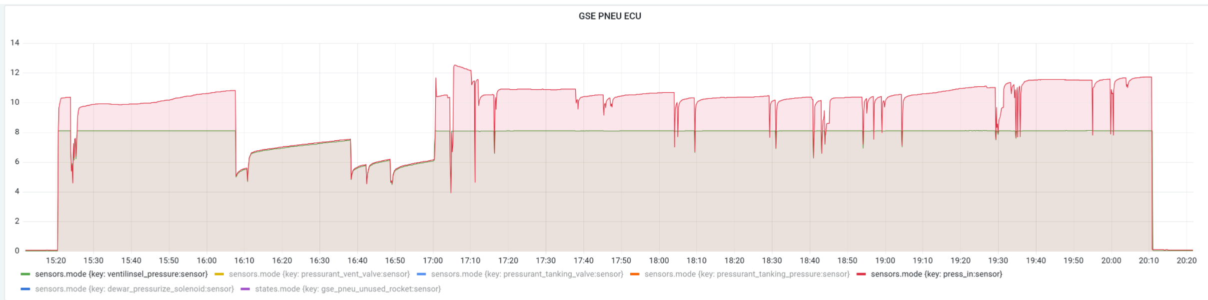
---

Attachments:

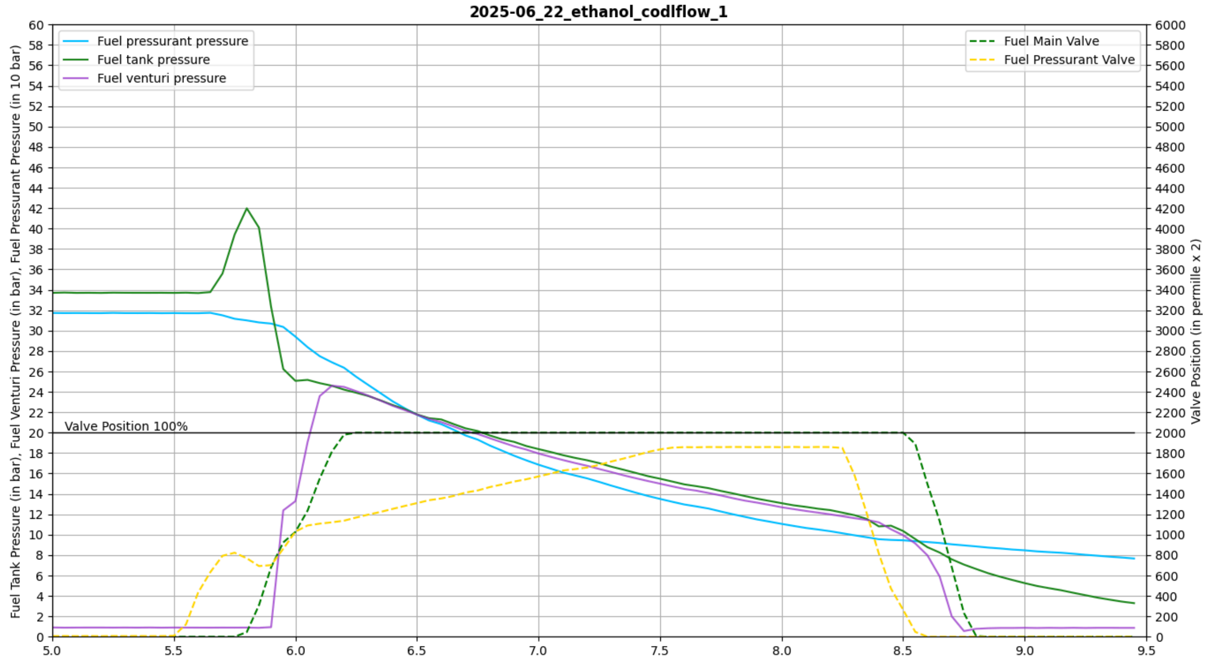
- Attachment 1: Fuel main pressure data



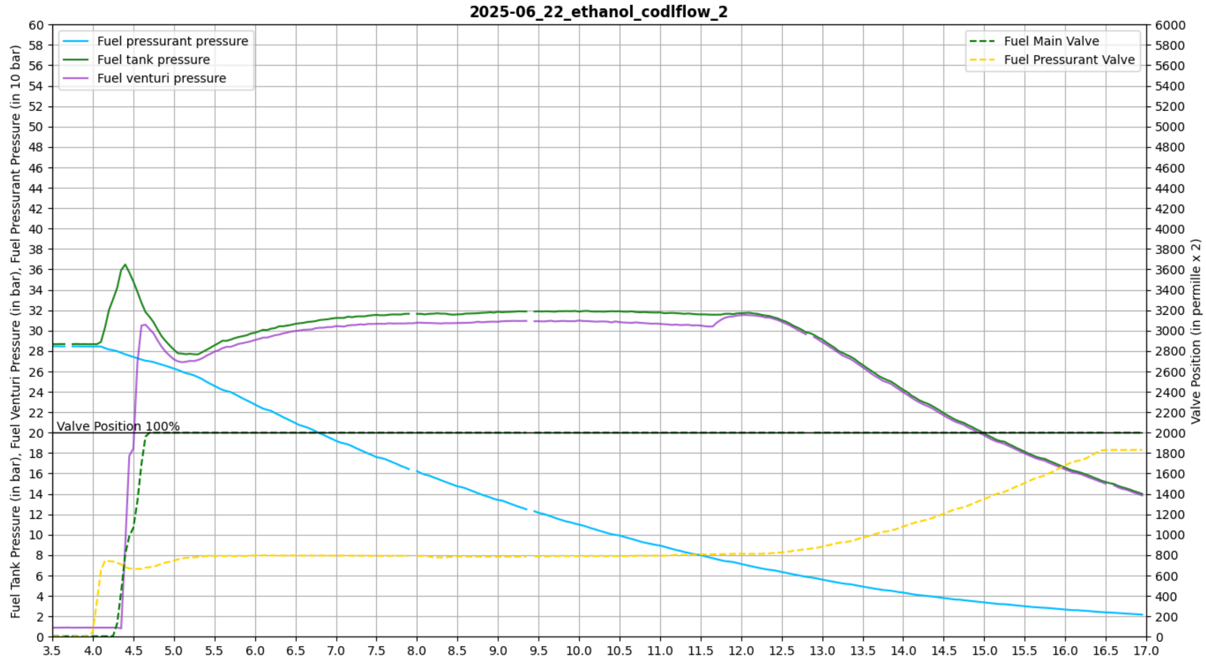
- Attachment 2: Pneumatic system pressure data



- Attachment 6: Ethanol coldflow Test 1 graph



- Attachment 7: Ethanol coldflow Test 2 graph



Signatures:

Ethanol Coldflow, ECUI and Mininoid Test

Date / Time	2025-06-26
Participants	• Lutfi Celik (lead) • Diego Grünberger (mission control) • Matthias Ogris (documentation) • Oliver Balint (support)
Testing purpose	• Verify ECUI functionality under internal control • Leak check Mininoid valve • Attempt nominal ethanol cold flow
Module	Propulsion
Component	Fuel System

Preparations:

• Internal control and prepress sequences adapted
• ECUI restarted after user error
• Fuel line connected, valves set, press system purged
• Safety procedures updated: press bottle alignment, safety light, camera positioning added to checklist

---

Test execution:

ECUI tests

• Initial issue: switching to internal control disabled all inputs (abort, valve commands) → required page refresh to recover
• Same issue observed once during normal sequence abort, not reproducible
• Subsequent sequence executions nominal after fixes
• Abort functionality confirmed (button, keyboard, browser close)

Mininoid leak check

• New Mininoid (0.1 mm orifice) tested at 100 bar pressurant tank pressure
• Not tight above 30 bar, higher mass flow loss than old bleed valve
• Surprisingly seals best when fully open, then leaks less than old bleed valve

Fuel main valve adjustments
- Initially still leaky → seat adjusted by Matthias Rier
- After adjustment: valve completely tight

Coldflow attempts
First attempt:
- Pressurant tank filled to 240 bar, reached 54°C → too hot, cooled with pneumatics to ~38.5°C
- Pressurant throttling improved, prepress attempted with target 36 bar → max 39 bar, vent opened, aborted
- Reduced target pressure to 32 bar → stabilised around 32 bar, vent sealed
- First ethanol coldflow sequence: ethanol line leak at ejection line, valve setpoint ≠ actual position (29 vs. 22), irregular regulation
- Ethanol ejection line seal ring displaced → root cause of leak

Second attempt:
- Ethanol and pressurant re-tanked (4 kg ethanol, 260 bar pressurant)
- Improved PI settings: OP=25, I_POS=0.05, P_POS=0.2
- Coldflow sequence started, peak 38 bar, stable ~34 bar
- Ethanol sprayed from fuel main valve stem → aborted immediately
- Engine bay electronics (Main ECU, Fuel Servo) flooded with ethanol → depowered rocket
- Inspection: fuel main valve stem seal ring displaced, major leak source

---

Results:

- ECUI functional but severe bug when switching to internal control (inputs disabled until refresh)
- Mininoid not leak-tight above 30 bar, unsuitable as bleed valve replacement
- Fuel main valve adjustments improved sealing but ultimately failed during cold flow, causing ethanol spray into engine bay
- One ethanol coldflow executed partially nominal; second coldflow aborted due to catastrophic valve leak

---

Learnings:

• Do not leave ethanol in tank after test

• Internal control breaks ECUI: EOF not registered, NAN in timer, input lockout → critical bug

• Pressurant tank heating critical under high fill rates (>50°C), pressurisation must be slowed; temperature sensor must be placed at top of tank

• Fuel main valve requires redesign or further reinforcement (seal ring failure at stem)

• Checklist updates required:

– Press bottle alignment

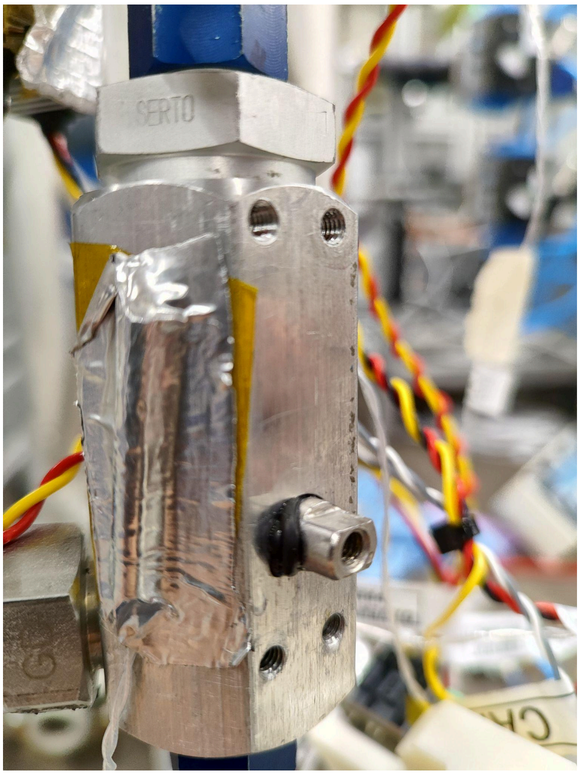
– Camera position check after rocket setup

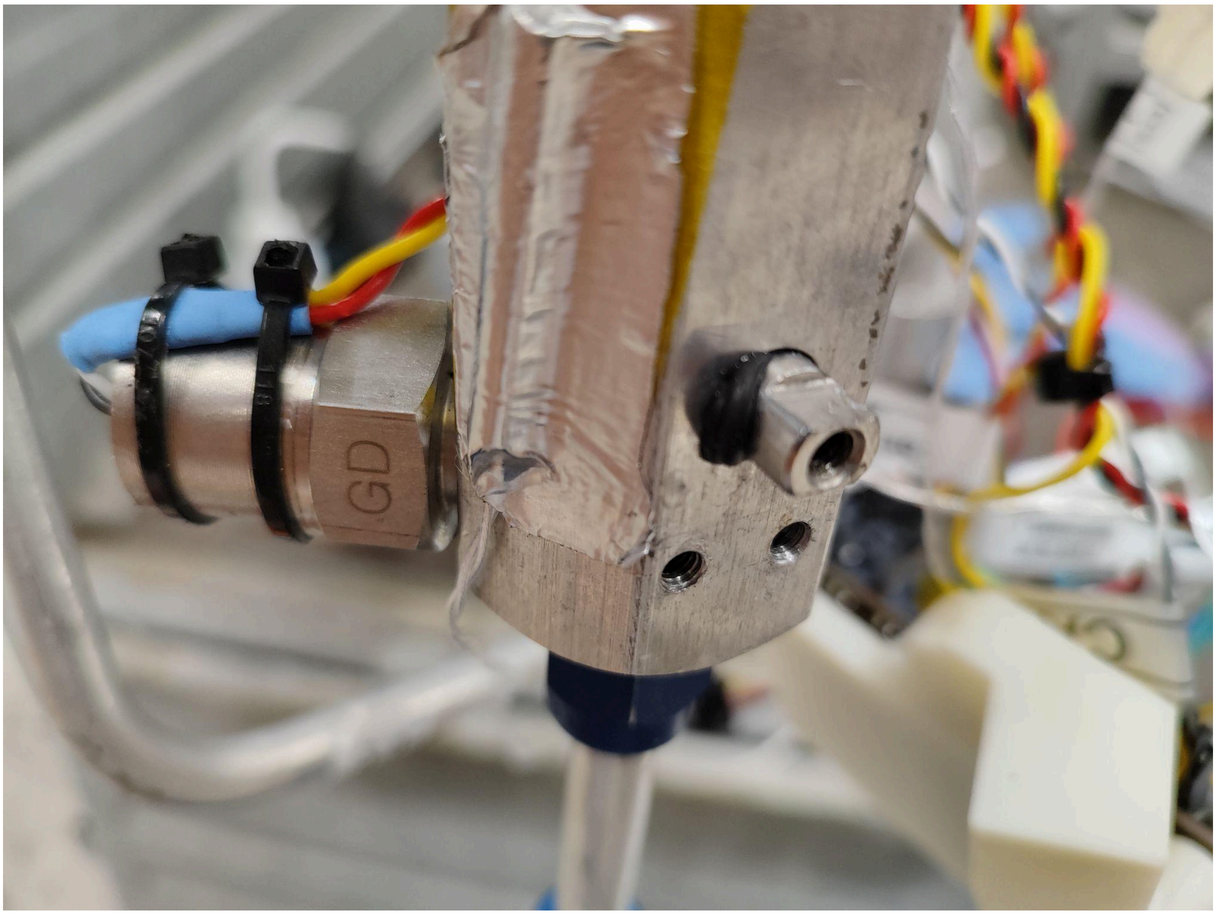
– Safety light placement

Attachments:

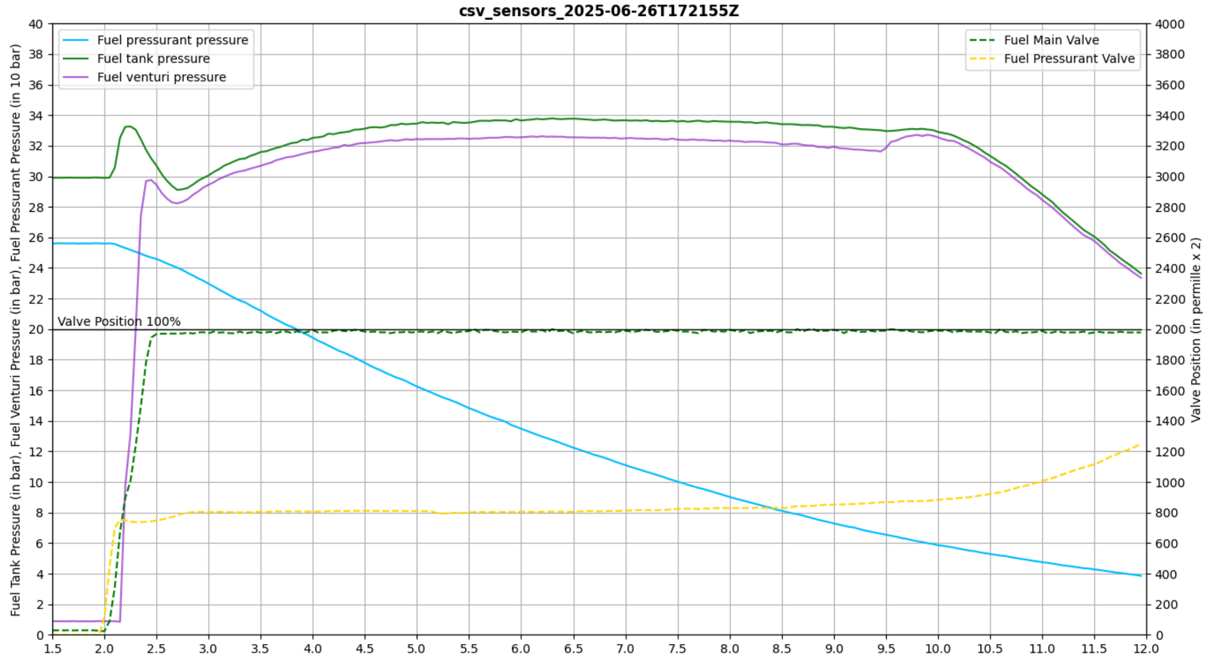
• Attachment 1: Fuel catch system leak images


• Attachment 2: Fuel main valve seal failure images

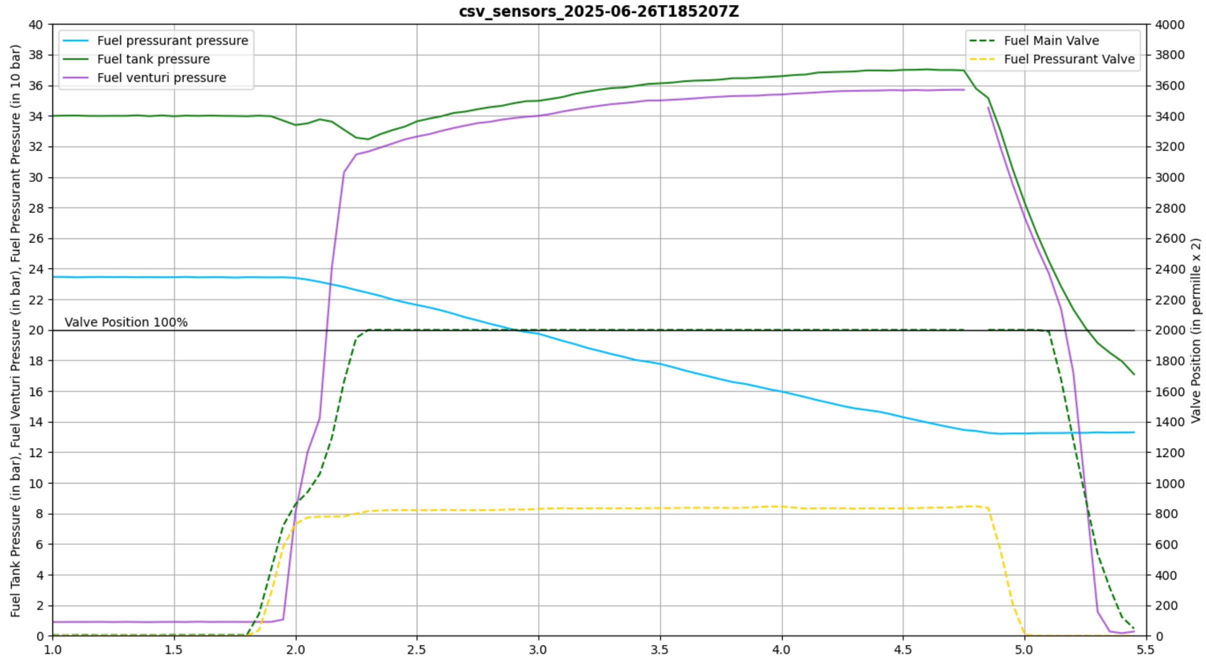




- Attachment 3: Ethanol coldflow Test 1 graph



- Attachment 4: Ethanol coldflow Test 2 graph



Signatures:

Ethanol Coldflow

Date / Time	2025-07-03
Participants	• Oliver Balint (Mission Lead) • Diego Grünberger (Mission Control) • Michael Debertol (Documentation, Range Safety)
Testing purpose	• Execute nominal ethanol cold flow test on static fire setup • Check system leak tightness under pressurised conditions
Module	Propulsion
Component	Fuel System

Preparations:

• Engine ECU reflashed (10 ms → 100 ms delay between fuel press and fuel main open)
• Removed duplicate start from prepress sequence (bug fix)
• Mininoid stem fixed in open position (nut + washer)
• Old fuel vent replaced with ox vent (adapter built to fit)
• LCB provided no data, power cycling unsuccessful
• ECUI bug observed: timer runs ~3–4 s beyond sequence, sometimes negative before stopping
• Internal control and prepress sequences adapted (due to sequence manager bug fix)
• Safety note: green lamp stays on after abort if active during sequence

---

Test execution:

• Pressurant bottle initially opened only ¼ revolution → insufficient flow
• Mininoid (forced open stem) fully tight, pressurant tank slightly leaky
• Tollenoid leaky (0.8 bar/min) → attempted fixes, vent remained leaky, abort triggered
• Depressurised rocket, reflashed ECU to 100 ms, installed ox vent as fuel vent

(via adapter)
• Prepress sequences run: vent slightly leaky (0.4 bar/min loss), adapters/conical joints also slightly leaky
• Tanked 4 kg ethanol
• Prepress run: pressurant tank overheated to 56°C → pressurisation rate too high, cooling considerations required
• Additional prepress runs: cooling caused pressure drop, vent continued to leak slightly
• Coldflow sequence started at 22:41:25 → aborted as ethanol exited container; ~3.8 kg collected, negligible spill on floor

---

Results:

• Ethanol cold flow successful; ethanol ejected into container
• Fuel system leaks persist (fuel vent, adapters, conical fittings)
• Pressurant tank overheated significantly during pressurisation (critical)
• Tollenoid leakage prevented nominal run

Learnings:

• Key required for pneumatics cabinet

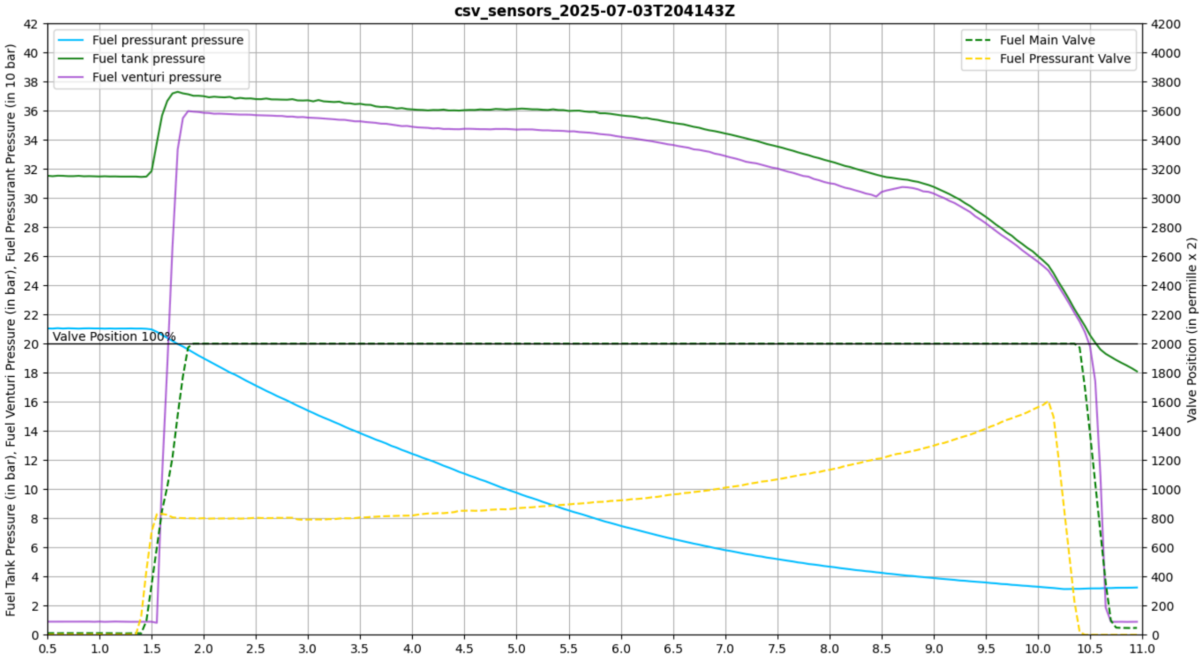
• Pressurant tank heating under sunlight and high flow is severe; must assess pressurisation rate limits and tank temperature rating

• Ox vent functional as temporary fuel vent, though with minor leaks

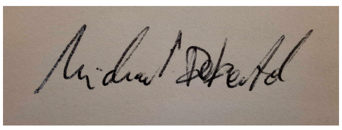
• ECUI sequence timer bug confirmed (continues running ~3–4 s beyond sequence)

Attachments:

• Attachment 1: Fuel coldflow Test 1 graph


csv_sensors_2025-07-03T204143Z
Fuel pressurant pressure
Fuel tank pressure
Fuel venturi pressure
Fuel Main Valve
Fuel Pressurant Valve
Valve Position 100%
Fuel Tank Pressure (in bar), Fuel Venturi Pressure (in bar), Fuel Pressurant Pressure (in 10 bar)
Valve Position (in permille x 2)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0

Signatures:



Ethanol Coldflows

Date / Time	2025-07-04
Participants	• Lutfi Celik (Mission Lead) • Michael Debertol(Mission Control) • Oliver Bailant (Documentation, Range Safety)
Testing purpose	• Execute multiple ethanol cold flows under varying PI controller parameters and target pressures • Evaluate fuel vent opening behavior and overall system stability
Module	Propulsion
Component	Fuel System

Preparations:

• PI controller target pressure adjusted (60 bar instead of 50 bar)
• Sequence updated to correctly close fuel vent
• Adjustments made to sequence naming/description for better clarity
• Leak check performed; adapter (fuel vent = old ox vent) slightly leaky
• Learned that Fuel Press Valve allows gas backflow into press tank under small pressure differential (especially with bleed valve)
• System determined sufficiently leak-tight to proceed with cold flows

---

Test execution:

• Initial attempt: started sequence at 15:40 (ECUI failed) and 15:43
• Tanked ~4 kg ethanol; target pressure 36 bar; 190 bar left in pressurant bottle; peak pressurant tank temperature 52 °C
• 16:25 run aborted due to vent valve open (sequence bug); ~0.5 kg ethanol lost
• 16:32 run: 3.4 kg ethanol ejected, stable at 32 bar target
• Retanked 4 kg; 160 bar left in bottle
• 17:17 run: 3.98 kg ethanol ejected, target pressure 38 bar
• Fuel vent observed to open at 52.6 bar

• Across multiple runs, PI parameters and delays (10–100 ms) were varied to assess mass flow and valve response

---

Results:

• Fuel vent opens at ~52.6 bar
• Prepress sequence nominal; pressure regulation worked consistently after adjustments
• Pressurant tank temperatures acceptable (<55 °C) when throttled to ~5 bar/s fill rate
• Stable cold flows achieved across 7 nominal runs with varying targets and timings
• CAN bus performance degraded with long llserver uptime, reducing sensor sampling rate

---

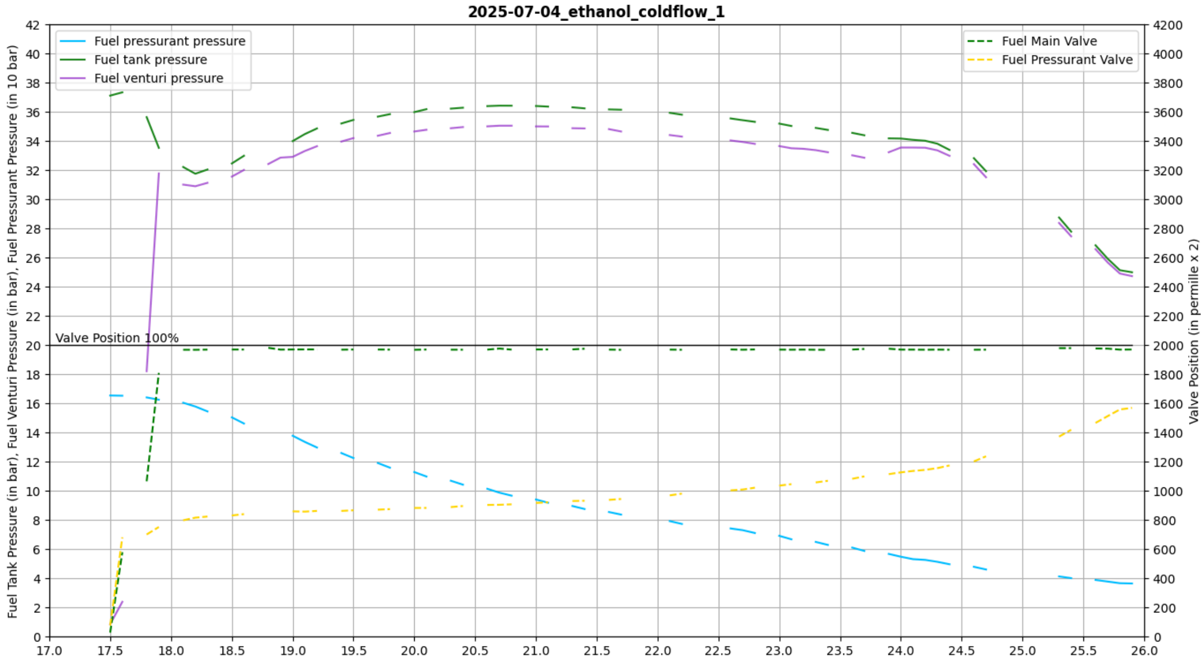
Learnings:

• If loss rate ~1.5 bar/min → backflow through Fuel Press Valve occurs when tank-to-tank Δp small
• Safety lamp must reset to green after abort reset
• PI controller description in sequence must be clearer
• All valve definitions should be explicitly set in sequences (to avoid misbehavior during tests)
• Ethernet cable preferred over wireless to avoid ECUI connection losses
• Attaching short silicone hose stubs to ethanol filter recommended to avoid leaks during coupling
• Need to verify *when* fuel main valve opens relative to gas release → camera + data logging required
• llserver shows signs of memory leak leading to CAN bus overload; restarting temporarily restores performance

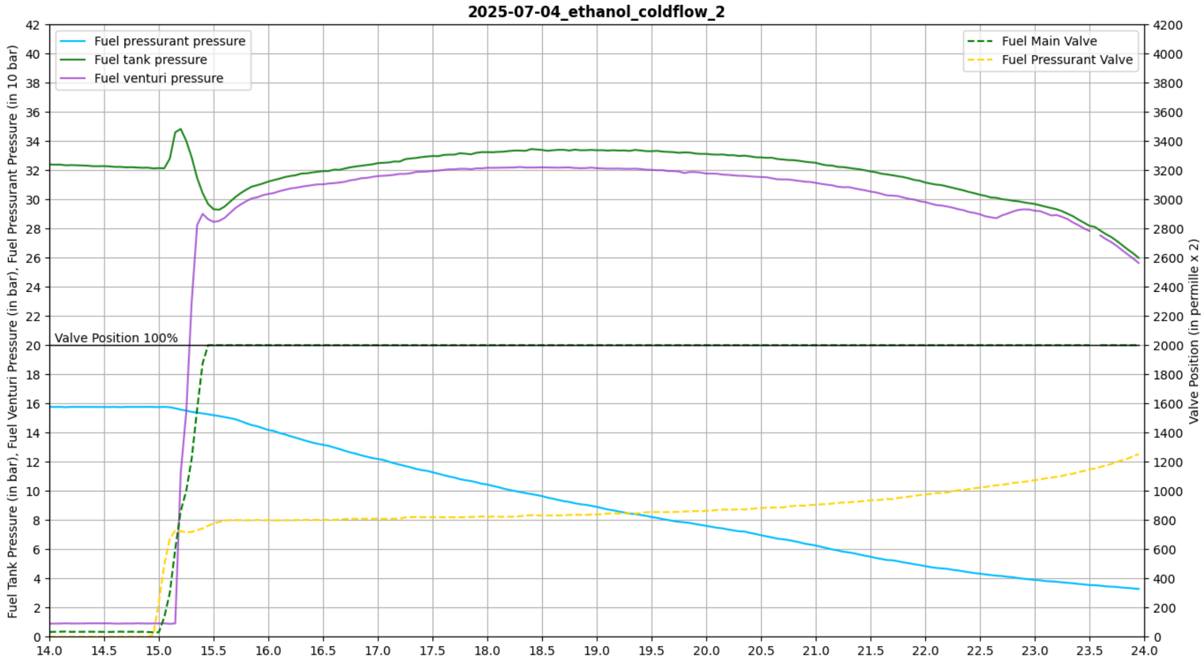
---

Attachments:

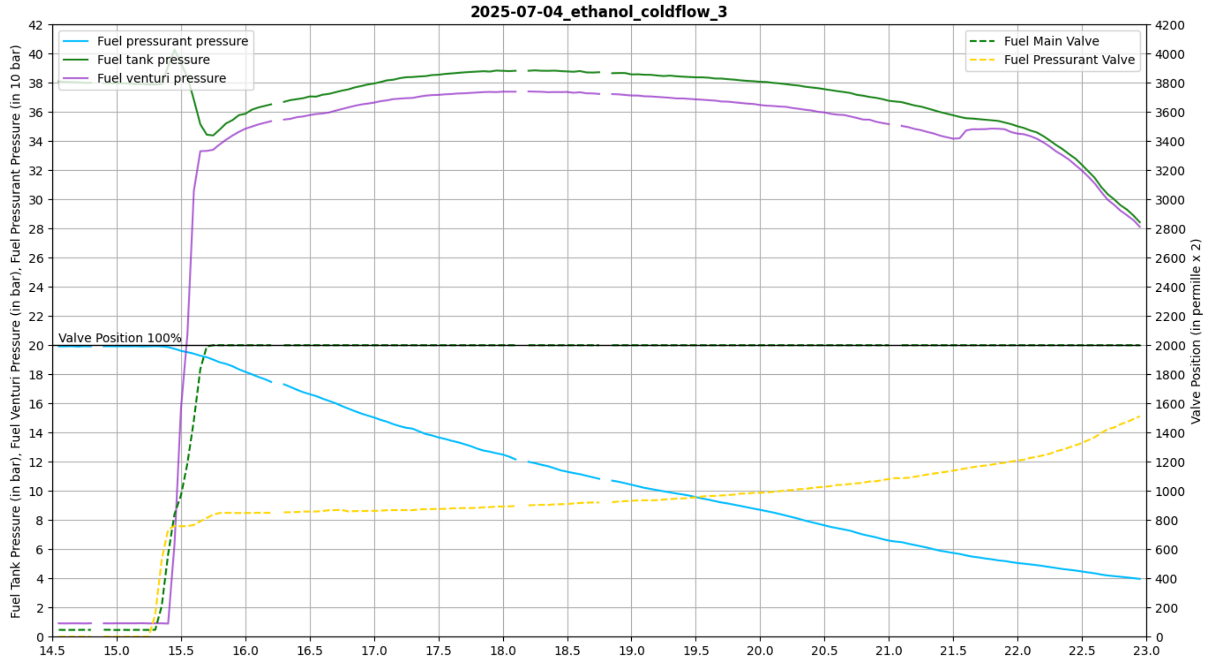
• Attachment 1: Fuel Cold Flow 1 (target 36 bar, 6 s, avg. 0.58 kg/s)



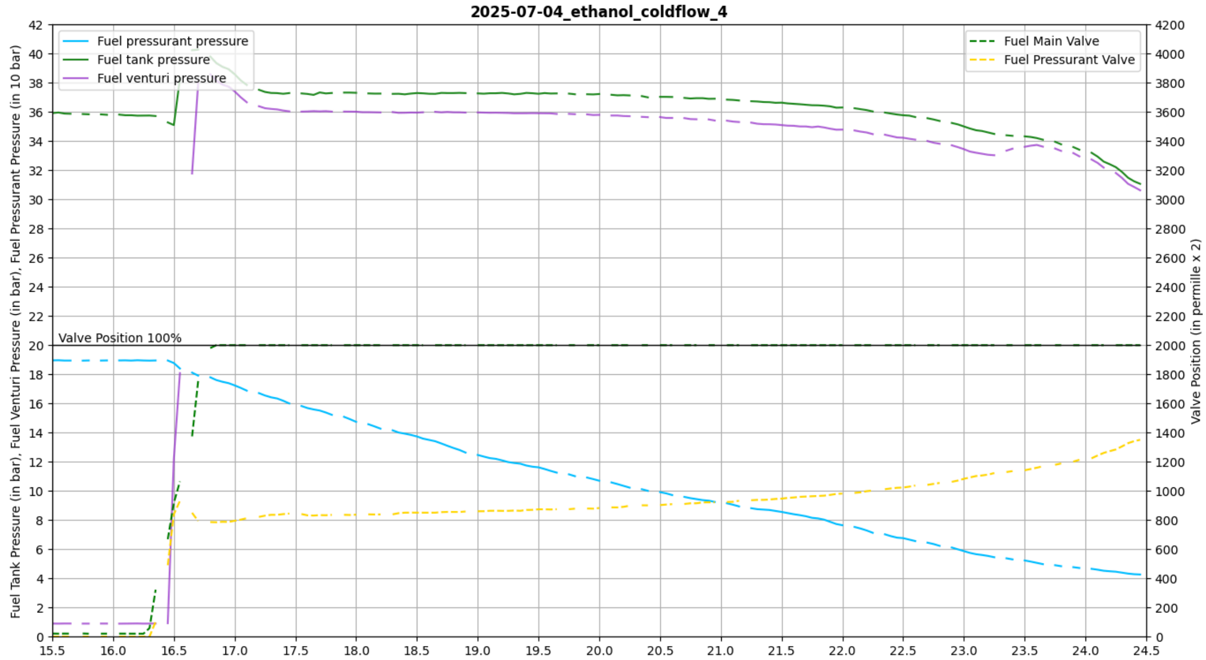
• Attachment 2: Fuel Cold Flow 2 (target 32 bar, 7.5 s, avg. 0.53 kg/s)



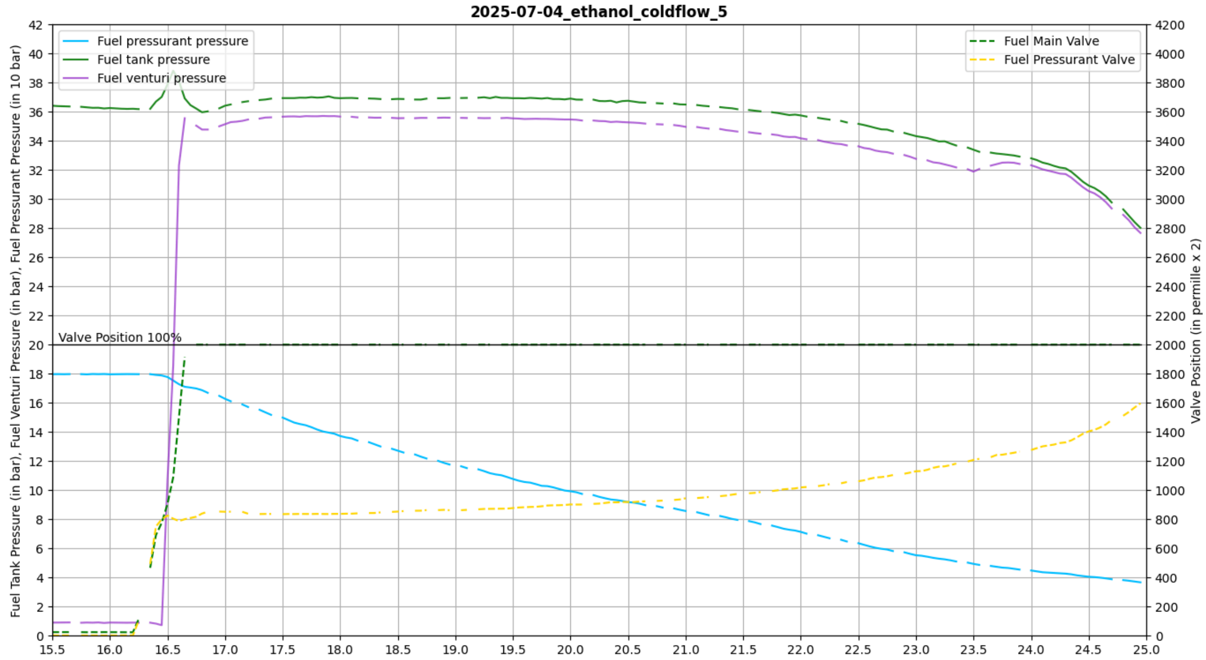
- Attachment 3: Fuel Cold Flow 3 (target 38 bar, 6.1 s, avg. 0.655 kg/s)



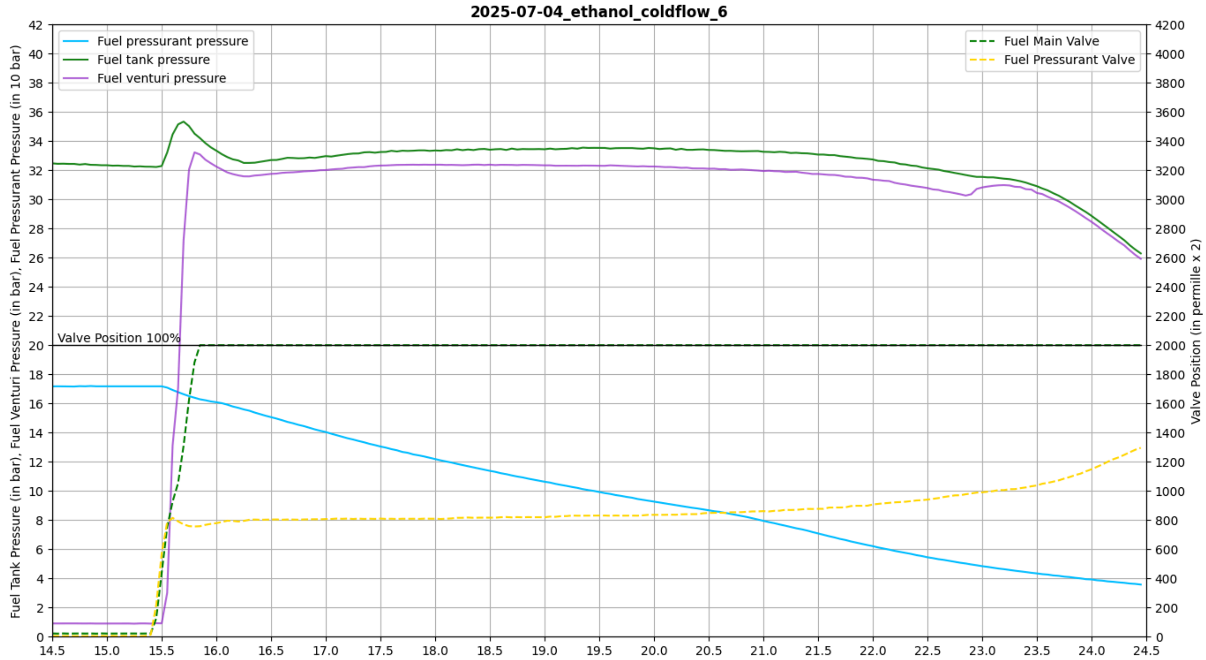
- Attachment 4: Fuel Cold Flow 4 (target 36 bar, 6.9 s, avg. 0.58 kg/s)



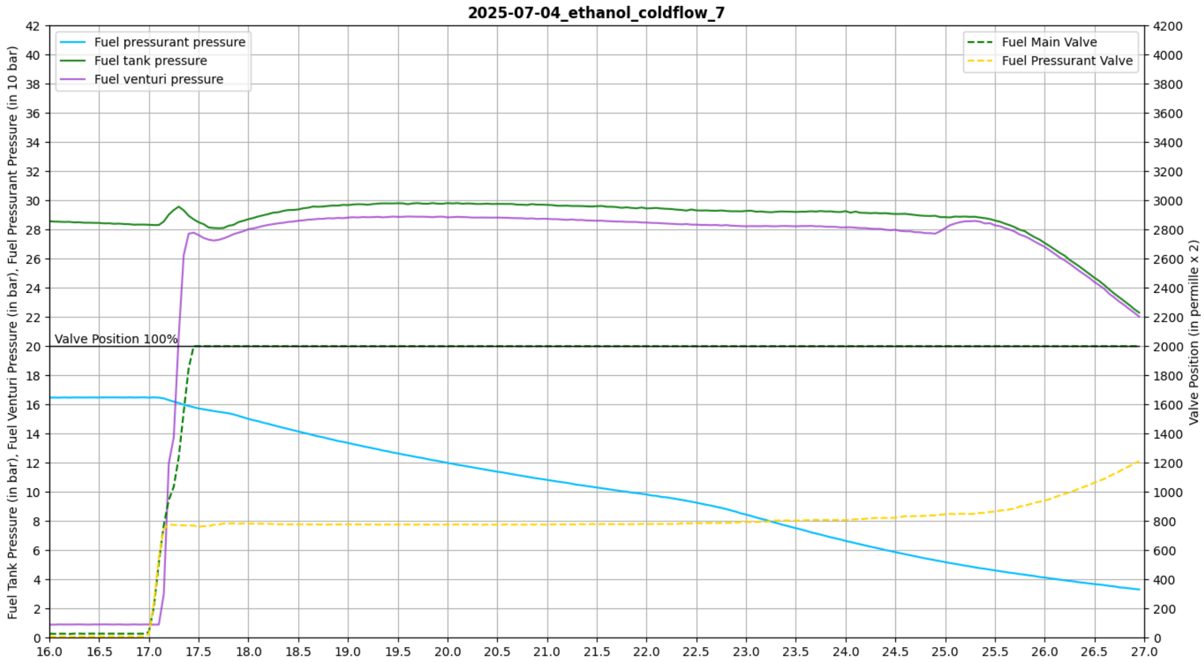
- Attachment 5: Fuel Cold Flow 5 (target 36 bar, 7.1 s, avg. 0.56 kg/s)



- Attachment 6: Fuel Cold Flow 6 (target 32 bar, 7.3 s, avg. 0.545 kg/s)

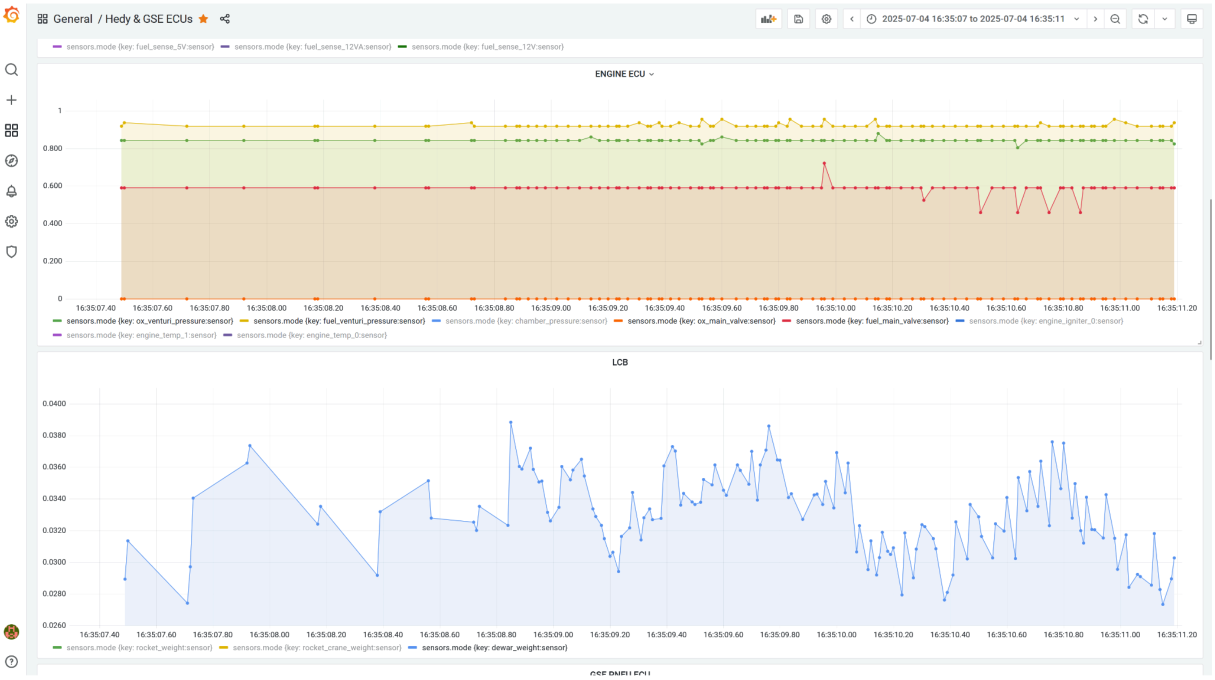


- Attachment 7: Fuel Cold Flow 7 (target 28 bar, 7.8 s, avg. 0.51 kg/s)

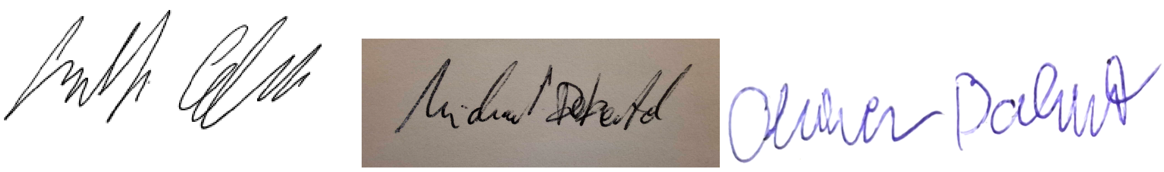


- Attachment 8: Sampling rate improvement after llserver restart

- Attachment 9: CAN bus sampling fluctuation


General / Hedy & GSE ECUs
2025-07-04 16:35:07 to 2025-07-04 16:35:11
ENGINE ECU
sensors.mode (key: ox_venturi_pressure:sensor)
sensors.mode (key: fuel_venturi_pressure:sensor)
sensors.mode (key: chamber_pressure:sensor)
sensors.mode (key: ox_main_valve:sensor)
sensors.mode (key: fuel_main_valve:sensor)
sensors.mode (key: engine_igniter_0:sensor)
sensors.mode (key: engine_temp_1:sensor)
sensors.mode (key: engine_temp_0:sensor)
LCB
sensors.mode (key: rocket_weight:sensor)
sensors.mode (key: rocket_crane_weight:sensor)
sensors.mode (key: dewar_weight:sensor)

Signatures:



LN2 Coldflow

Date / Time	2025-07-05
Participants	• Lutfi Celik • Michael Debertol
Testing purpose	• First LN_2 cold flow test on the launch rail • Verify ox press valve reliability under pressure • Check system tightness and functionality under cryogenic conditions
Module	Propulsion
Component	Ox System

Preparations:

• Vent valve moved from fuel system back into ox system
• Ox lines in engine bay re-insulated
• System check showed ox press valve sticking intermittently → decision to retest under pressure
• Discovered that engine ECU commands were not always executed (CAN TX buffer issue, ox press did not auto-open to depress tank)

Test execution:

• Rocket pressurized → ox tank pressure stable, no immediate leaks
• Ran LOX prepress + internal control sequence with GN_2 only → failed due to chamber pressure spoof resistor connected to wrong channel → rocket entered Hold Down Abort state
• Ox press valve showed no further problems → proceeded with LN_2 tanking
• Ox decoupler connection very leaky during tanking
• Pressurized rocket → found check valve at tanking interface very leaky, plus ox vent dynamic seal heavily leaking
• Depressurized rocket, re-coupled decoupler → check valve slightly improved but still leaky
• Retanked LN_2, pressurant tank filled >300 bar

- Switched rocket to internal control for cold flow
- Test ended with multiple leaks still present, but LN_2 cold flow executed

---

Results:

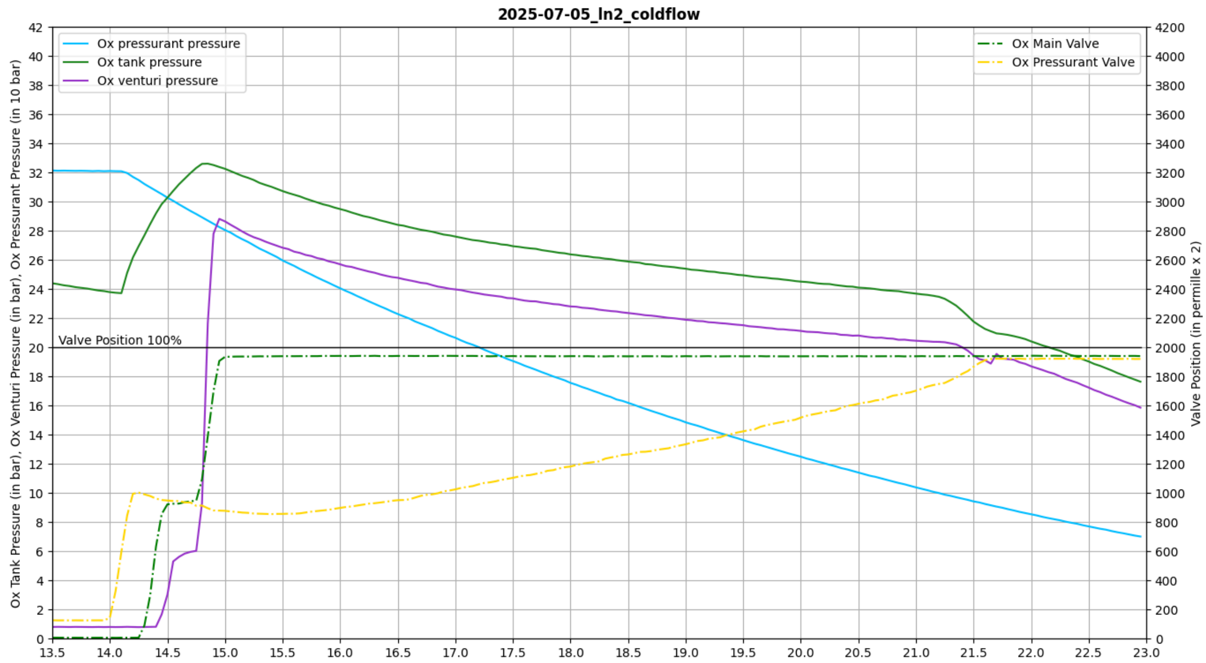
- LN_2 cold flow executed despite issues
- Ox decoupler connection and check valve leaky
- Ox vent dynamic seal strongly leaky
- Engine ECU software bug prevented proper command execution (CAN TX buffer overflow)

Learnings:

- Ox press valve can stick in warm conditions but behaved nominally once pressurized
- Critical leaks found: ox decoupler interface, tanking check valve, ox vent dynamic seal
- Engine ECU limited by small CAN TX buffer → some commands never reach sub-ECUs
- Quick software fix identified, long-term solution required (avoid reliance on `LL_mDelay`)

Attachments:

- Attachment 1: LN2 Cold Flow chart



2025-07-05_ln2_coldflow
Ox pressurant pressure
Ox tank pressure
Ox venturi pressure
Ox Main Valve
Ox Pressurant Valve
Valve Position 100%
Ox Tank Pressure (in bar), Ox Venturi Pressure (in bar), Ox Pressurant Pressure (in 10 bar)
Valve Position (in permille x 2)

Signatures:

LN2 Coldflows

Date / Time	2025-07-07
Participants	• Lutfi Celik (Mission Lead) • Diego Grünberger (Mission Lead Support) • Michael Debertol (Mission Control) • Raffael Rott (Documentation)
Testing purpose	• Execute LN_2 cold flow tests • Verify ox press valve reliability under cryogenic pressure • Leak check ox decoupler check valve and ox vent
Module	Propulsion
Component	Ox System

Preparations:

• Ox fill connection and ox vent disassembled, cleaned, derusted, regreased, and reassembled prior to test
• O-rings in ox fill check valve and ox decoupler replaced
• Warm leak check: ox vent seal-tight, ox fill check valve leaky ⟶ seal replaced ⟶ fully tight
• After reassembly, system leak rate <0.1 bar/min
• LN_2 tanking started slowly due to ox vent spring + O-ring preventing full opening ⟶ required manual intervention to increase tanking speed

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Test execution:

Test 1:
• LN_2 coldflow with 30 bar target pressure
• During prepress, ox press valve servo stuck at ~24% ⟶ no pressurization before coldflow start
• Tank only reached ~22 bar during coldflow
• Ox vent remained tight, ox fill check valve slightly leaky under cryogenic conditions

Test 2:
• Retanked LN_2 (~4 kg, limited supply left)
• Prepress sequence modified: operating point increased to 34, target pressure increased to 36 bar
• Prepress reached ~39 bar, then stabilized
• During coldflow, ox tank pressure dropped significantly → ended at ~24 bar
• Pressurant tank did not fully reach 300 bar despite open throttle and bottle valve

---

Results:

• First LN_2 coldflow failed to reach target pressure due to ox press valve sticking during prepress
• Second LN_2 coldflow executed more nominally, but pressure decay observed in ox tank (39 → 24 bar)
• Ox vent remained tight during cryogenic operation; ox fill check valve still slightly leaky
• Pressurant system performance limited: ox press tank could not reach intended 300 bar

---

Learnings:

• Ox press valve prone to sticking under prepress conditions, requires further refinement (new design under development)
• Ox vent seal improved after maintenance, but fill check valve continues to cause minor leaks
• Manual intervention sometimes necessary to ensure ox vent opens fully during tanking
• PI controller tuning may need non-linear adjustment to allow full valve opening when pressure difference is large
• Pressurant supply chain bottleneck (press tank didn’t reach full pressure) should be investigated

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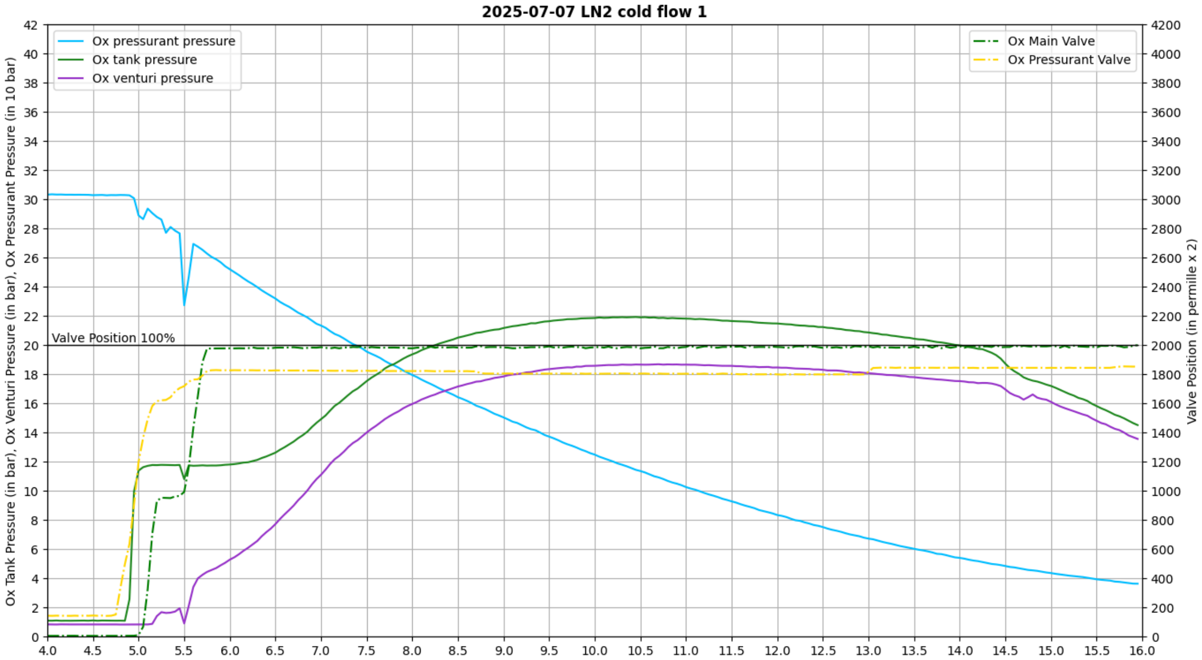
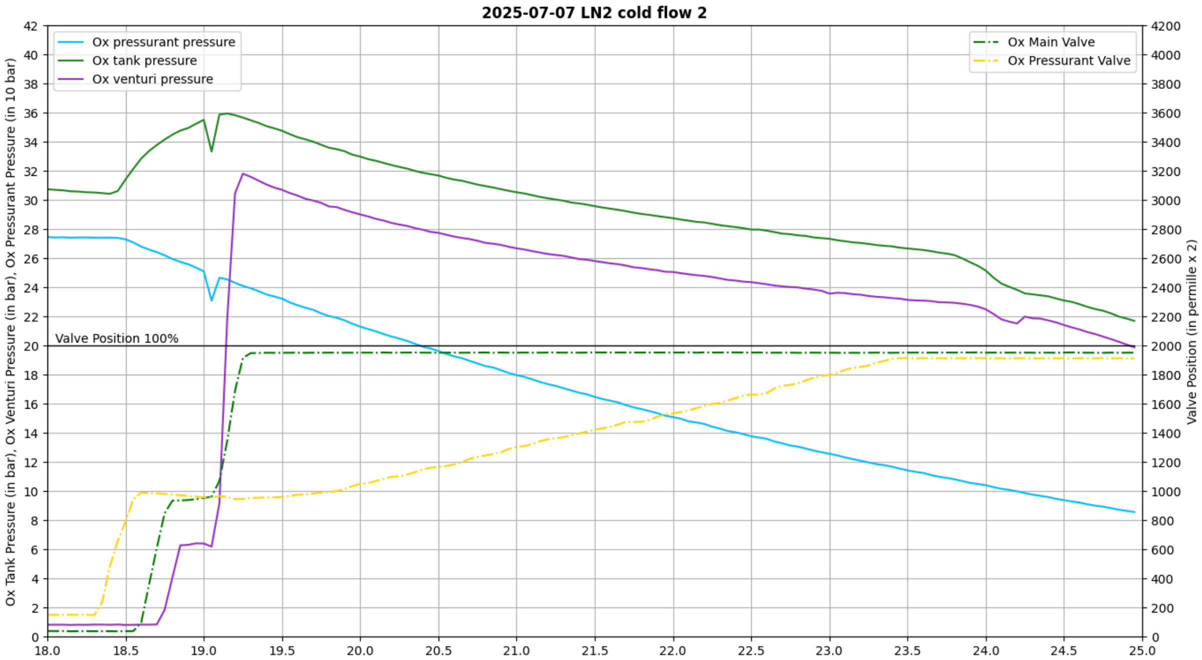
Attachments:

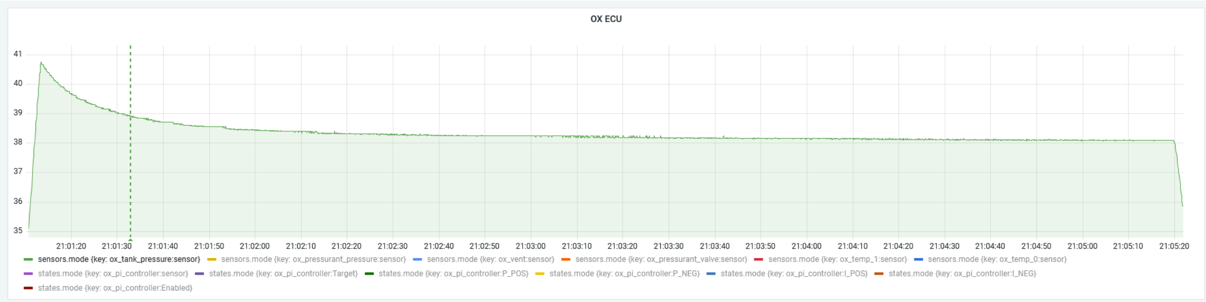
• Attachment 1: LN_2 coldflow test 1 data



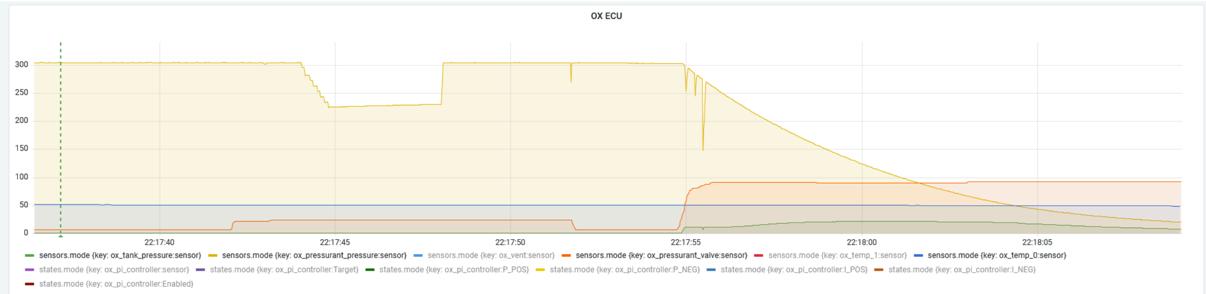
• Attachment 2: LN_2 coldflow test 2 data



• Attachment 3: Ox tank leak check warm



• Attachment 4: Ox press pressure sensor dip during tests



• Attachment 5: LN_2 tanking pressure and temperature profile

Signatures:

LN2 Coldflow

Date / Time	2025-07-11
Participants	• Lutfi Celik (Mission Lead) • Diego Grünberger (Mission Control) • Michael Debertol (Mission Control Support)
Testing purpose	• Execute LN_2 cold flow under cryogenic conditions • Verify ox vent and ox fill sealing performance • Evaluate ox press valve behavior under load • Monitor ECU performance under power draw
Module	Propulsion
Component	Ox System

Preparations:

• Leak in pneumatic box detected (threaded PTFE fitting strongly leaky). Despite this, supply pressure sufficient for GSE valve actuation.
• Fuel press valve found inoperative — servo hardware failure suspected. Last working on 2025-07-05; confirmed with servo tester.
• Rocket warm leak check: all systems tight.

Test execution:

• LN_2 tanking attempted — large losses via ox decoupler despite greasing.
• Under cryogenic pressurization:
  – Ox vent dynamic seal slightly leaky.
  – Ox fill check valve leaky again.
• Prepress + coldflow sequence via internal control:
  – Target pressure: 40 bar.
  – Delay between ox PI controller activation and main valve opening: 10 ms.
  – Ox system never reached target — ox press valve opened fully but pressure did not build as expected.
• Pressure sensor anomalies: ox press pressure sensor (and others) showed

synchronous drops linked to ECU supply voltage dips. Cause: lab power supply hitting 2.5 A current limit when ox vent + multiple servos actuated in cryo state.

Results:

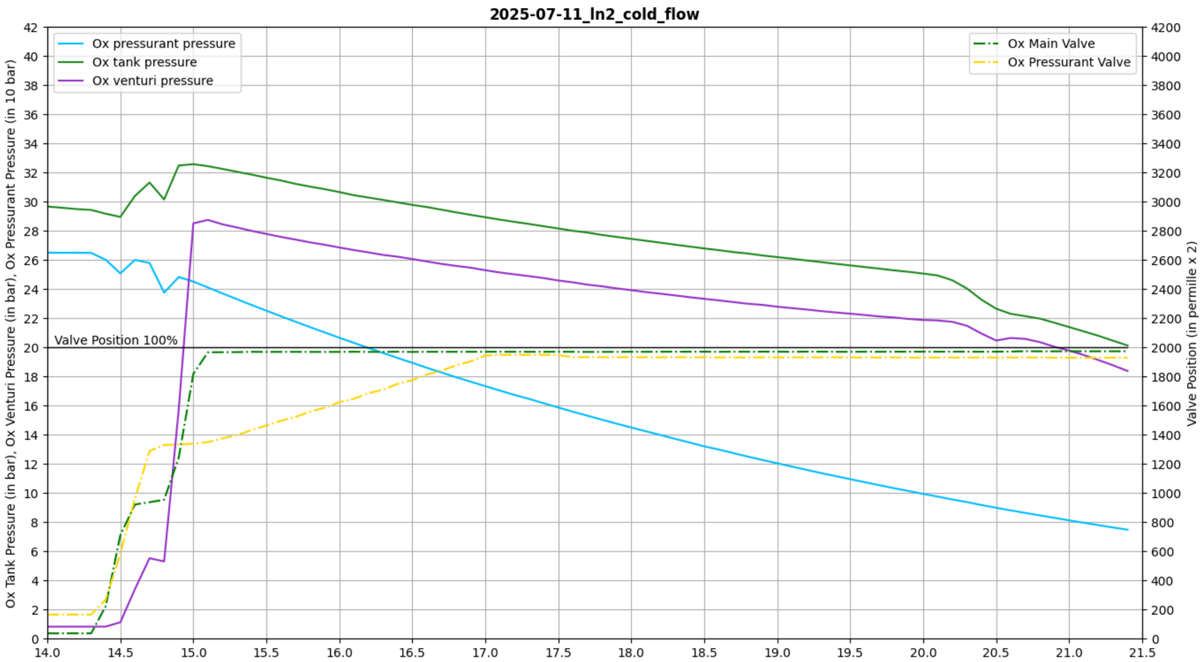
- LN_2 coldflow test incomplete — ox tank pressure failed to reach target.
- Significant cryogenic leaks persisted at ox vent and ox fill check valve.
- Fuel press valve hardware failure confirmed (servo replacement required).
- ECU power dips under cryogenic load compromised sensor reliability.

Learnings:

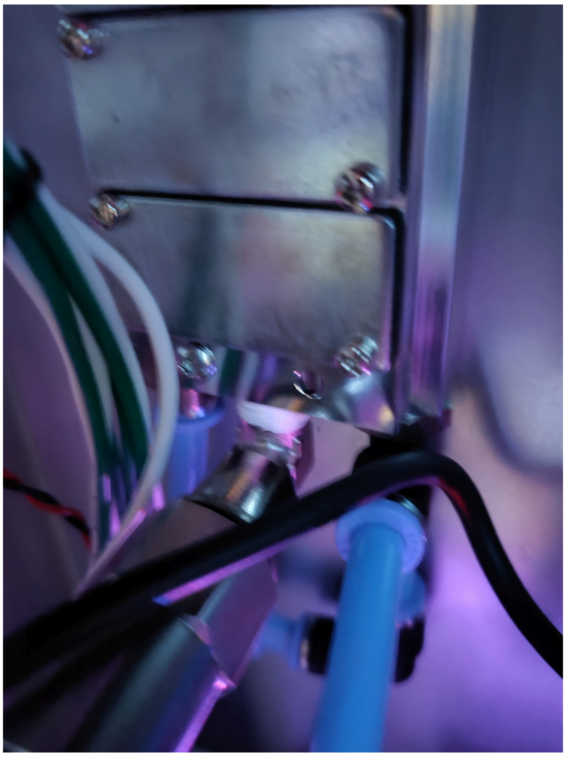
- PTFE-threaded fitting in pneu box is a leak point → replace.
- Ox fill decoupler reliability decreasing (scratched sealing surface suspected); lubrication inconsistent, may worsen leak.
- Ox vent requires further sealing improvements.
- ECU supply requires stronger PSU (>2.5 A current limit insufficient under cryo actuation).
- Use decoupler suspension line (not gloves) for safe remote operation during LOX handling.
- Pressurant and sensor anomalies tightly linked to ECU undervoltage — confirm with new PSU in next test.

Attachments:

- Attachment 1: LN_2 coldflow test data

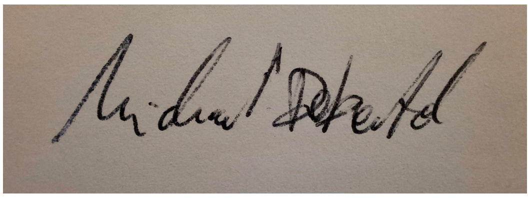


- Attachment 1: Pneu box leak photo



- Attachment 2: ECU supply voltage dip during LN_2 coldflow

Signatures:



LN2 Coldflows

Date / Time	2025-07-12
Participants	• Lutfi Celik (Mission Lead) • Diego Grünberger (Mission Lead Support) • Michael Debertol (Mission Control) • Raffael Rott (Documentation)
Testing purpose	• LN_2 cold flow verification with modified Ninja V3 pressure regulator • Leak checks on ox system (vent, decoupler, fill check valve) • Validation of new fuel press servo and updated PSU under load
Module	Propulsion
Component	Ox System

Preparations:

• Installed Ninja V3 regulator (1.5 mm orifice)
• Replaced ox decoupler check valve seal
• GSE pneu box leaks repaired (valve island)
• New fuel press valve servo installed
• Switched to new power supply for rocket ECUs
• Leak check showed ox decoupler check valve leaky; seal replaced → tight at ambient.
• GSE pneu box leaks at valve island located and sealed.
• All ox lines insulated, vent and fill connections verified.

Test execution:

• Ox vent behavior: did not always open automatically during tanking; manual opening required.
• Cold, under pressure: ox vent static seal slightly leaky, ox decoupler check valve slightly leaky.
• Ox decoupler:

– First LN_2 tanking: ungreased, strongly leaky.

– Second and third LN_2 tankings: tight but froze in place; required heat gun to disconnect.

• First coldflow: ox press servo stuck during prepress; target 30 bar. Tank only pressurized once coldflow started.
• Second coldflow: prepress OP point adjusted to 34; target raised to 36 bar. Performed with partial success.
• Third coldflow: tested PI controller adaptation during sequence; adjusted target from 32 bar → 38 bar. Did not fully reach target due to limited pressurant.
• ECU power system stable with new PSU — no pressure sensor dips observed. Rocket briefly drew ~3 A during coldflow.
• New fuel press servo functional, though noticeable high-frequency coil whine.
• Ninja V3 regulator tight at all fittings (including burst disks, pressure sensor, fill nipple).

Results:

• LN_2 coldflows completed successfully with Ninja V3 regulator.
• Gas mass flow higher and pressure stability improved compared to previous test (July 11).
• Target pressure not maintained continuously, but closer to expected.
• PI controller target adjustment during sequence verified — functional.
• Ox vent remained slightly leaky in cryo, sometimes opening prematurely.
• Ox decoupler remains problematic (leaky when dry, stuck when greased).

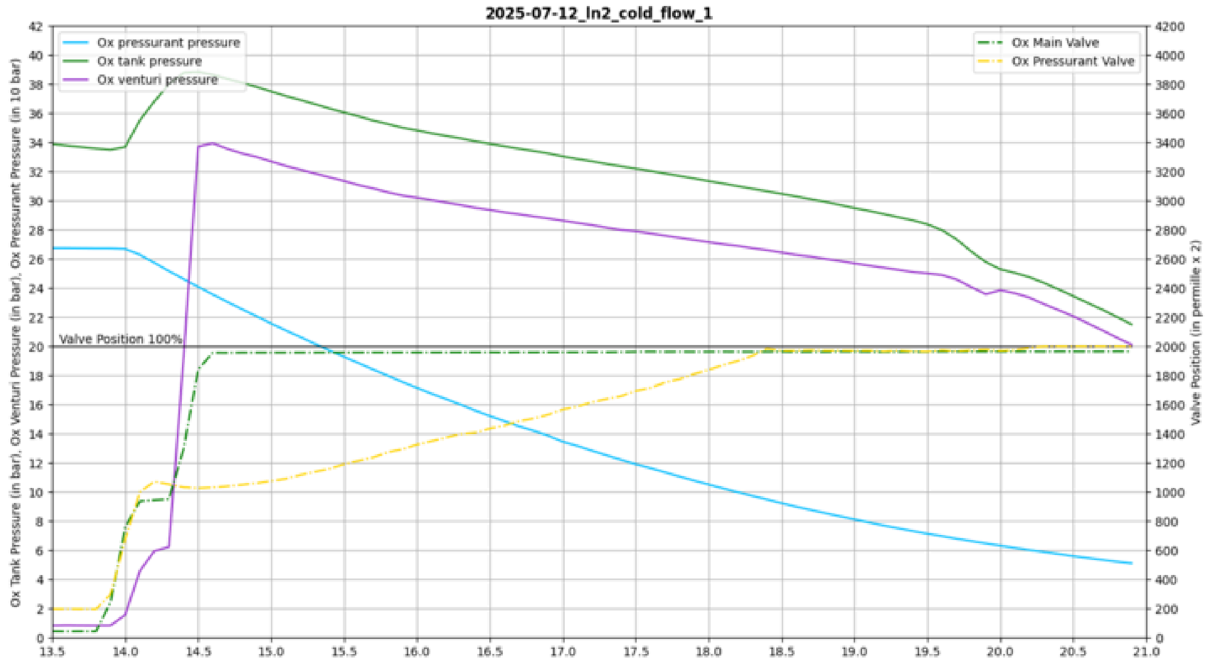
Learnings:

• Ninja V3 regulator provides improved mass flow and stability compared to V2.
• ECU power stability confirmed with new PSU.
• Ox vent and ox decoupler require redesign or improved maintenance for cryogenic reliability.
• PI controller mid-sequence target adjustments are feasible.
• Fuel press servo replacement successful, though acoustic signature noted.

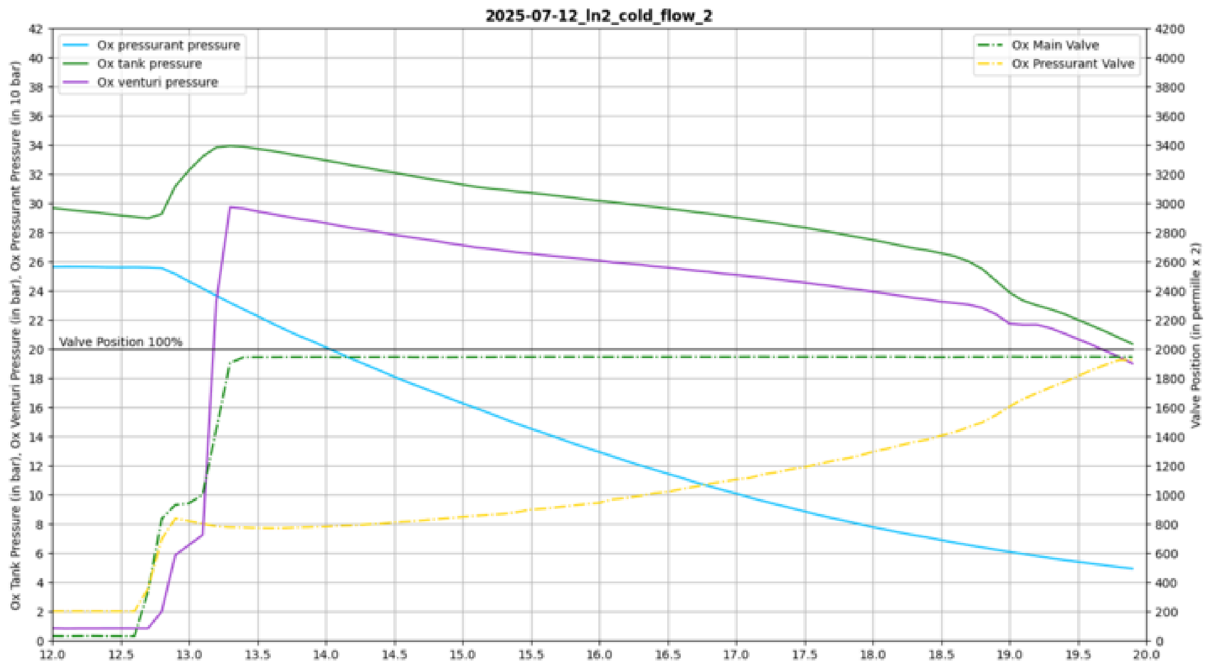
• Temperature in pneu box constant under shade; may require further monitoring under sun exposure.

Attachments:

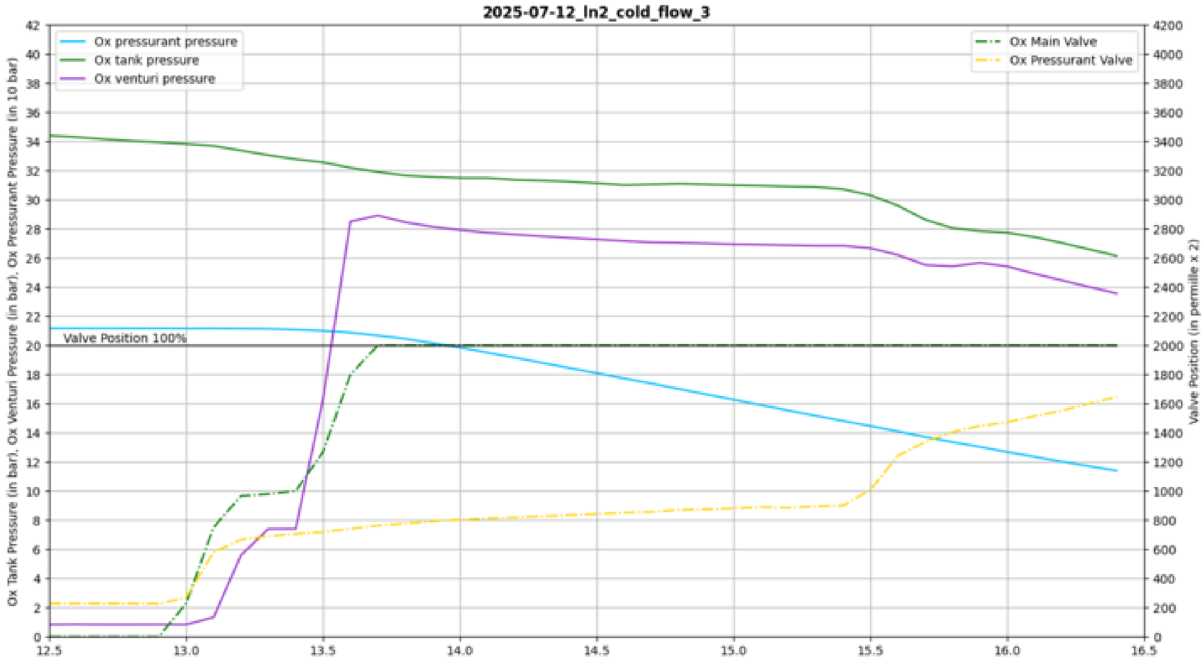
• Attachment 1: Pressure plots 2025-07-12 Coldflow 1 (Ninja V3, 40 bar target)



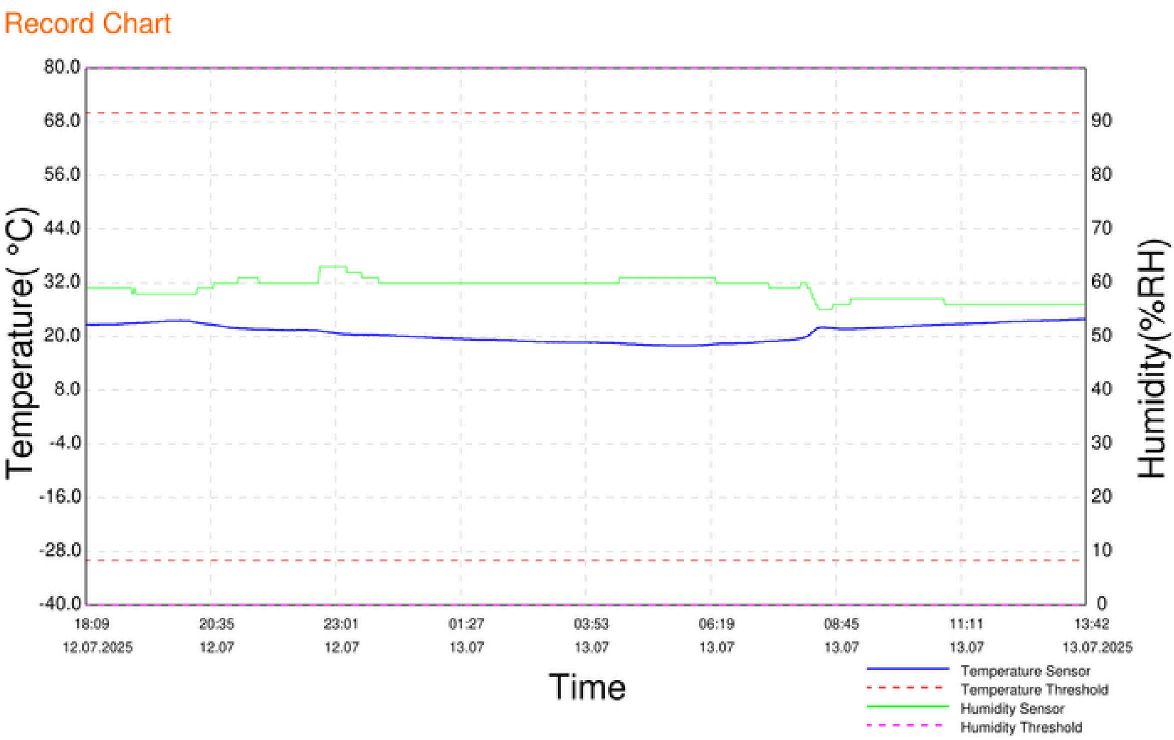
• Attachment 2: Pressure plots 2025-07-12 Coldflow 2 (Ninja V3, 32 bar target)



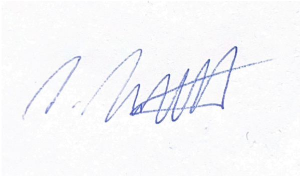
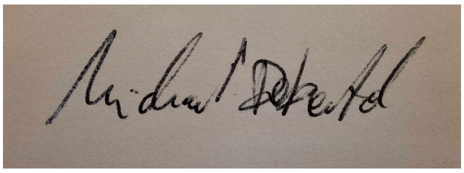
• Attachment 3: Pressure plots 2025-07-12 Coldflow 3 (Ninja V3, 32 → 38 bar target)



• Attachment 4: Pneumatic box temperature log (shaded conditions)



Signatures:


LOX Coldflows

Date / Time	2025-07-17
Participants	• Lutfi Celik (Mission Lead) • Diego Grünberger (Mission Lead Support) • Michael Debertol (Mission Control) • Raffael Rott (Documentation)
Testing purpose	• Perform LOX coldflow tests with Ninja V3 pressure regulator and new ox press valve • Validate ox system seals and overall performance under cryogenic conditions
Module	Propulsion
Component	Ox System

Preparations:

• PTFE sleeve installed on ox decoupler (removed after tanking issue)
• New ox press valve installed
• Ox press check valve removed
• Ox lines in engine bay reworked, leak points tightened
• Warm leak check before LOX tanking — nominal.
• PTFE sleeve on ox decoupler prevented filling → removed.
• Barriers added to protect ECU from icing due to ox decoupler leaks.
• Ox vent and ox decoupler thawed and cleaned between runs; radial seals greased with Krytox.

Test execution:

Test 1:
• LOX tanking possible despite strong ox decoupler radial leak.
• Ox fill check valve tight on warm check; ox vent slightly leaky under cryo.
• During sequence: major LOX leak observed in engine bay, traced to loose ox venturi sensor fitting at ox main valve. Connection tightened.

• Target pressure: 36 bar; duration 7.5 s.
• IGNITION_OX_OPEN delay: 10 ms; IGNITION_MAIN_OPEN delay: 1200 ms.

Test 2:
• LOX tanking repeated; ox decoupler still leaky, ox vent slightly leaky, ox fill check valve leaking small amounts of LOX.
• Leak observed again during sequence, likely at ox main valve stem (ice formation & visible plume).
• Ox tank pressure stable ~30 bar for ~8 s until pressurant bottle fell below 70 bar, then tank pressure decayed.
• Target pressure: 32 bar; duration 8.5 s.
• IGNITION_OX_OPEN delay: 10 ms; IGNITION_MAIN_OPEN delay: 1200 ms.

Results:

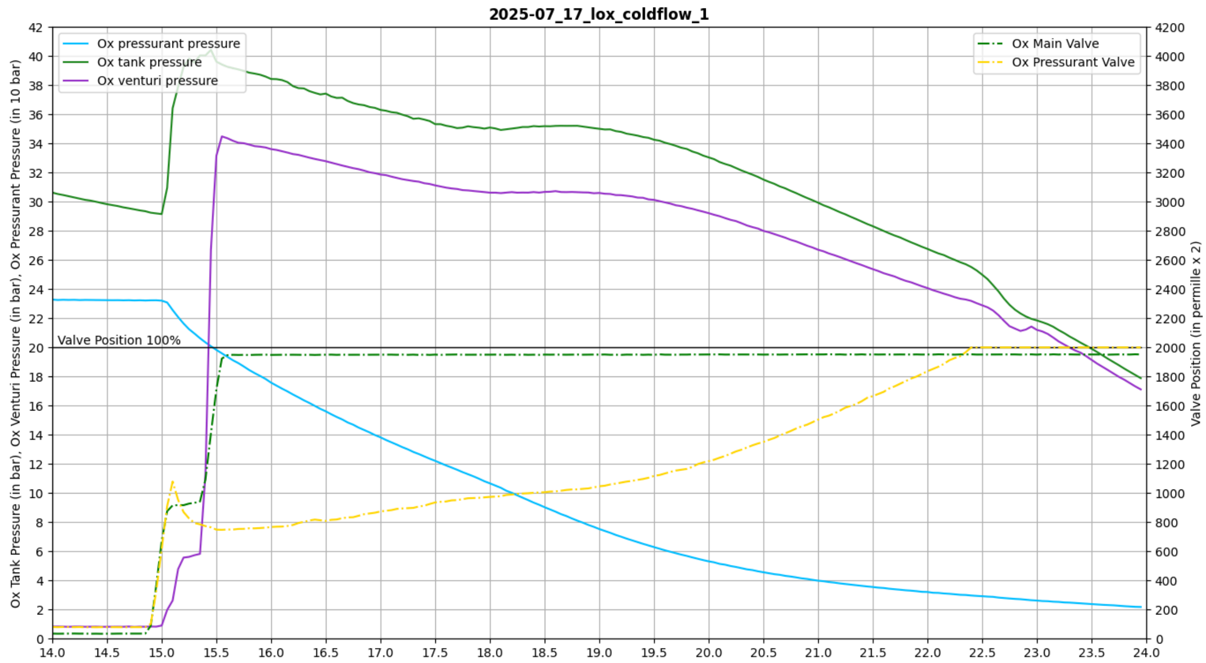
• Both coldflows executed despite multiple leaks.
• Stable LOX mass flow for ~7.5–8.5 seconds achieved.
• Ox tank pressure maintained near targets until upstream pressurant fell below ~70 bar.
• Ox decoupler, ox vent, and ox main valve stem remain unreliable under cryogenic conditions.

Learnings:

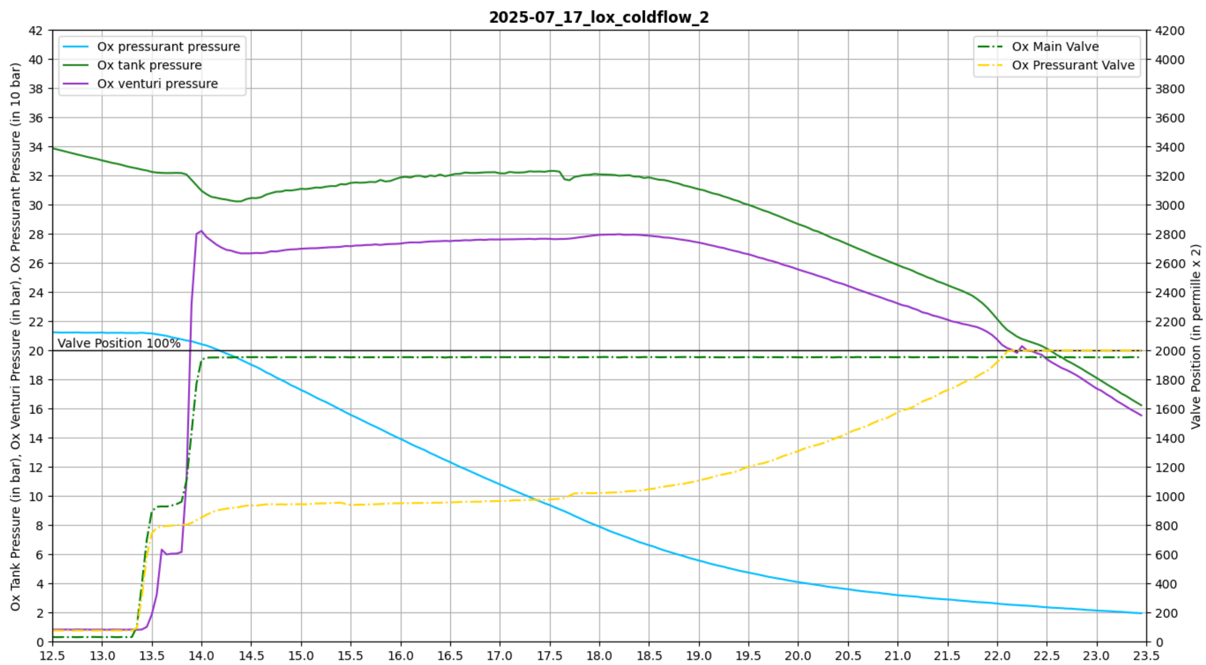
• PTFE sleeve geometry unsuitable for ox decoupler — must be reworked.
• Ox decoupler radial seal remains critical failure point, even with lubrication.
• Ox vent cryo sealing remains problematic.
• Pressurant pressure >70 bar necessary for stable ox tank regulation with Ninja V3 regulator.
• Engine bay fittings (e.g., venturi sensor, main valve stem) must be secured and inspected carefully to avoid cryo leaks.

Attachments:

• Attachment 1: Pressure plot, LOX Coldflow Test 1 (36 bar target, 7.5 s)

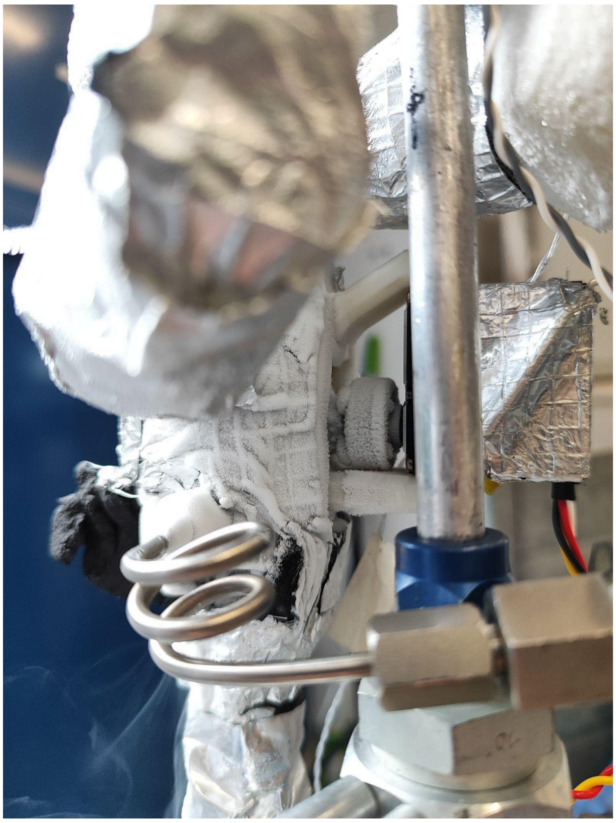


- Attachment 2: Pressure plot, LOX Coldflow Test 2 (32 bar target, 8.5 s)

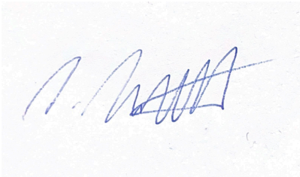


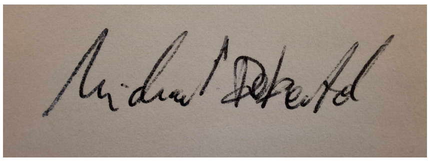
- Attachment 3: Photo – Leaky ox decoupler

• Attachment 4: Photo – Ox main valve after Test 2



Signatures:



Combined Coldflows

Date / Time	2025-07-23
Participants	• Lutfi Celik (Mission Lead) • Fabio Winkler (Support, Documentation) • Diego Grünberger (Mission Control) • Raffael Rott (Mission Control Support) • Matthias Rier (Propulsion Support) • Luis Büchi (Software / ECUI Support)
Testing purpose	• First combined coldflow test with LOX and Ethanol using internal rocket state machine • System-level validation before Wet Dress Rehearsal • Verify sealing and functionality of ox and fuel system components under cryogenic conditions
Module	Propulsion
Component	Propulsion System

Preparations:

• Ox Main Valve with new PEEK stem bearings (maintained by Michael)
• Improved Ox Press Valve (Ninja V3 regulator, modified)
• All ox system O-rings replaced and documented (Ox Vent, Ox Fill, Ox Decoupler)
• Fuel Main Valve with stem support hotfix
• Fuel Press Valve (new servo installed, not yet calibrated)
• Old Fuel Vent reassembled with new O-ring
• Ninja V2 regulator for fuel system
• Bleed valves: 0.1 mm printer nozzle (ox), 0.1 mm drilled nozzle (fuel, Oliver)
• Warm pressurization leak check on fuel and ox systems (both stable at 30 bar).
• Verified fuel vent opening pressure: ~45 bar.
• LOX system reassembled with new seals; Ox Fill, Vent, Decoupler tested.
• Ethanol manually tanked (4.1 kg for first test, 4.0 kg for second).
• LOX tanking slow due to restricted ox vent mass flow and strongly leaking ox decoupler.
• Pressurant tanks filled to 300 bar.

Test execution:

Test 1:

• Ethanol tanking nominal with new couplers and manual valve.
• Ox Main Valve servo overheated to 56°C (stuck at ~300 mA current draw until replugged).
• LOX tanking very slow; Ox Vent mass flow restricted.
• Ox Decoupler heavily leaking, ~8 kg LOX required to fill tank.
• Prepress sequence overshot to ~35 bar, stabilized.
• During combined coldflow, fuel vent opened at ~45 bar due to overpressure spike in fuel tank.
→ Cause: likely too much ethanol tanked (low gas ullage).
• Ox system coldflow nominal.

Test 2:

• Ethanol tanking repeated, reduced to 4.0 kg (100 g less).
• LOX tanking again problematic, ox decoupler leaking heavily.
• Pressurant filled, but both fuel and ox regulator low-pressure burst discs ruptured during prep.
– Fuel burst disc: likely caused by rapid tank overpressure in Test 1.
– Ox burst disc: failed unexpectedly at ~250 bar, ox press valve closed.
• Burst discs replaced.
• Internal Control sequence restarted.
• Fuel system again overpressurized, fuel vent opened.
→ Likely due to new fuel press servo: not calibrated, operating point too high, causing valve to overshoot.

Results:

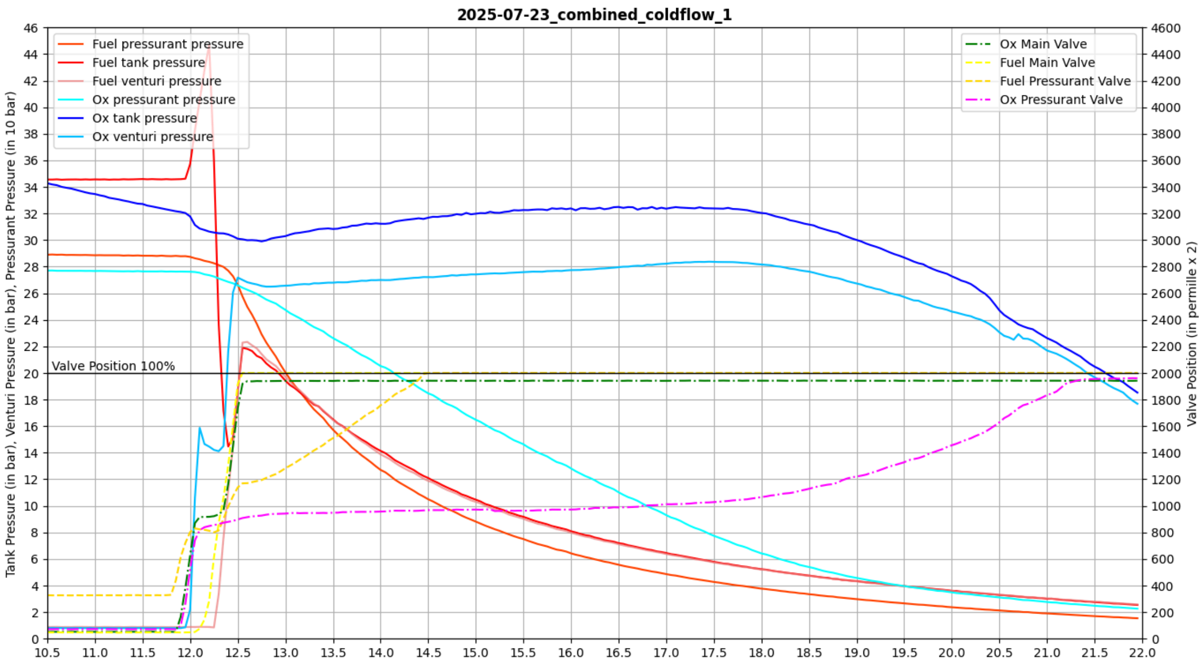
• First combined coldflow achieved partial success: ox side nominal, fuel side failed due to vent opening.
• Second combined coldflow aborted after burst disc replacements and repeat fuel overpressure.
• Data recorded, attached.

Learnings:

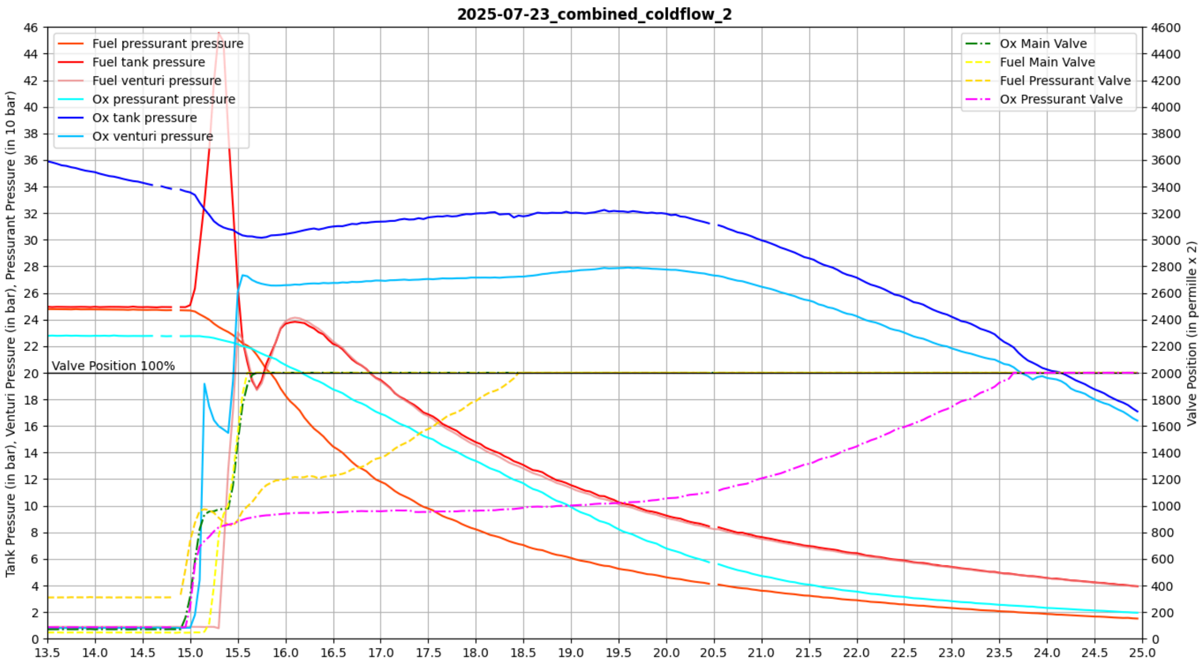
• Fuel Press Servo must be calibrated — operating point mismatch leads to ~9% offset compared to old servo.
• Ox Decoupler design remains a major leak source → requires rework.
• Ox Vent flow restriction significantly slows LOX tanking.
• Fuel vent opening pressure confirmed at ~45 bar.
• Burst discs in both regulators must be checked and replacements stocked.
• ECUI display flicker persists; software review required.
• Servo feedback between new and old models differs in sign and offset; PI controller must be adjusted.

Attachments:

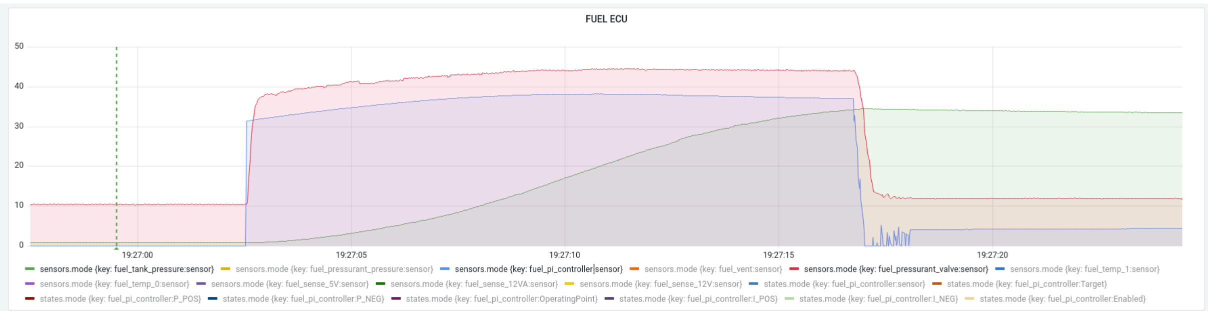
• Attachment 1: Pressure data plot, Combined Coldflow Test 1

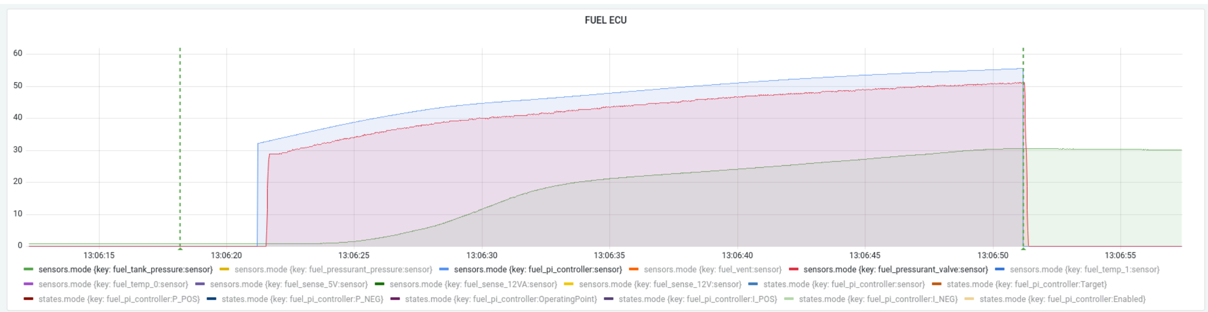


• Attachment 2: Pressure data plot, Combined Coldflow Test 2



- Attachment 3: Servo feedback comparison – new vs old





Signatures:

Ethanol Coldflows

Date / Time	2025-07-26
Participants	• Lutfi Celik (Mission Lead) • Raffael Rott (Mission Control) • Oliver Bailant (Documentation)
Testing purpose	• Characterize new fuel press valve servo (operating point, response speed) • Run ethanol coldflows with corrected servo calibration • Identify regulator and state machine parameter adjustments needed for stable operation
Module	Propulsion
Component	Fuel System

Preparations:

• New fuel press valve servo installed
• Incremental adjustments (+2, then +2 more) during testing
• PI controller gains modified (P_Pos and P_Neg)
• Timing between fuel press and fuel main open reduced to 10 ms
• ECU reflashed with updated parameters
• Leak-free system confirmed before tests
• Prepress sequence used to find gas flow threshold → confirmed consistent with old servo values (~31% feedback at 1 bar increase)
• PI controller operating point corrected by –9 points in sequences (from 25 → 16, from 38 → 29) and committed to Git
• Fuel tanking: 4 kg ethanol per run

Test execution:

Test 1 (Prepress characterization, 13:27)

• Prepress sequence with 32 bar target, operating point = 5
• Vent opened at ~35 bar

• At ~31% servo position, gas flow started (consistent with old servo)
• Adjustments confirmed

Test 2 (First ethanol coldflow, ~14:13)
• Ethanol tanked to 4 kg
• Prepress sequence to 32 bar
• Coldflow started, pressure dipped after main open, then overshot to 36 bar
• Operating point increased by +2 (to 33%)
• ECU reflashed with reduced timing (10 ms between fuel press and fuel main open)

Test 3 (Second ethanol coldflow, ~14:37)
• 4 kg ethanol tanked
• Similar pressure dip followed by overshoot
• PI gains adjusted (P_Pos = 0.5, P_Neg = 1)

Test 4–5 (Afternoon runs)
• Same behavior persisted: dip after main open, followed by overshoot
• Pressure regulation unstable ("chaotic"), likely due to faster servo response than old model

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Results:

• Servo gas flow threshold consistent with old servo (~31%)
• Operating point correction fixed vent overpressure issue from earlier combined coldflow
• However, servo response faster than old unit → introduced oscillatory pressure regulation (dip + overshoot pattern)
• PI tuning insufficient to stabilize, further state machine timing changes required

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Learnings:

• Operating point correction (–9 points) valid, but had to be increased again by +4 (final ~33%)
• New servo significantly faster than old → system behavior differs even with

identical PI parameters

• Likely need to invert or adjust order of IGNITION_FUEL_PRESSURIZE and IGNITION_FUEL_OPEN states in state machine

• Fuel system otherwise nominal; ethanol tanking and flow successful

• Random Grafana data frequency drop (100 Hz → 30 Hz) observed during testing

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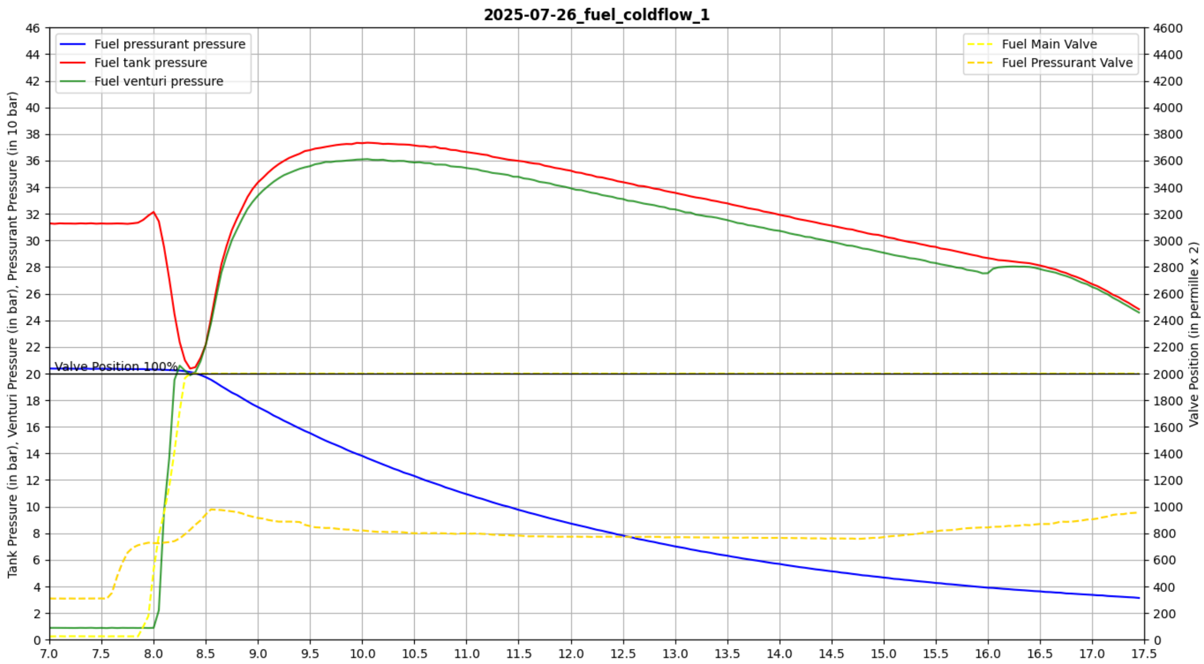
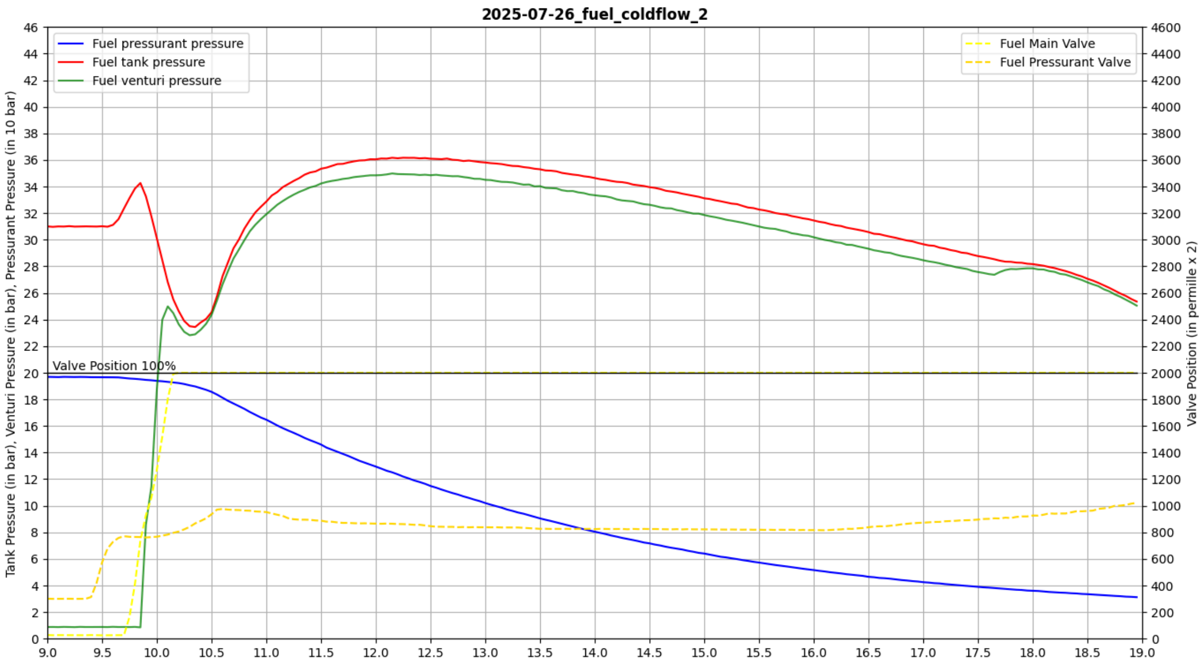
Attachments:

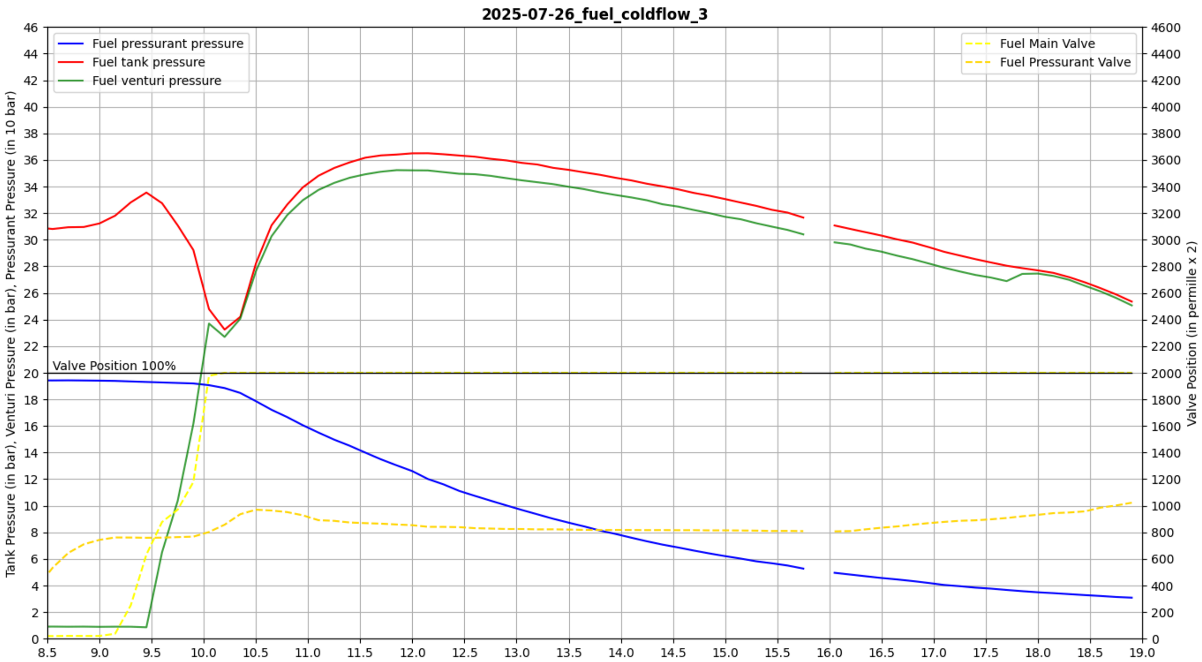
• Attachment 1: Pressure data, Fuel Coldflow 1



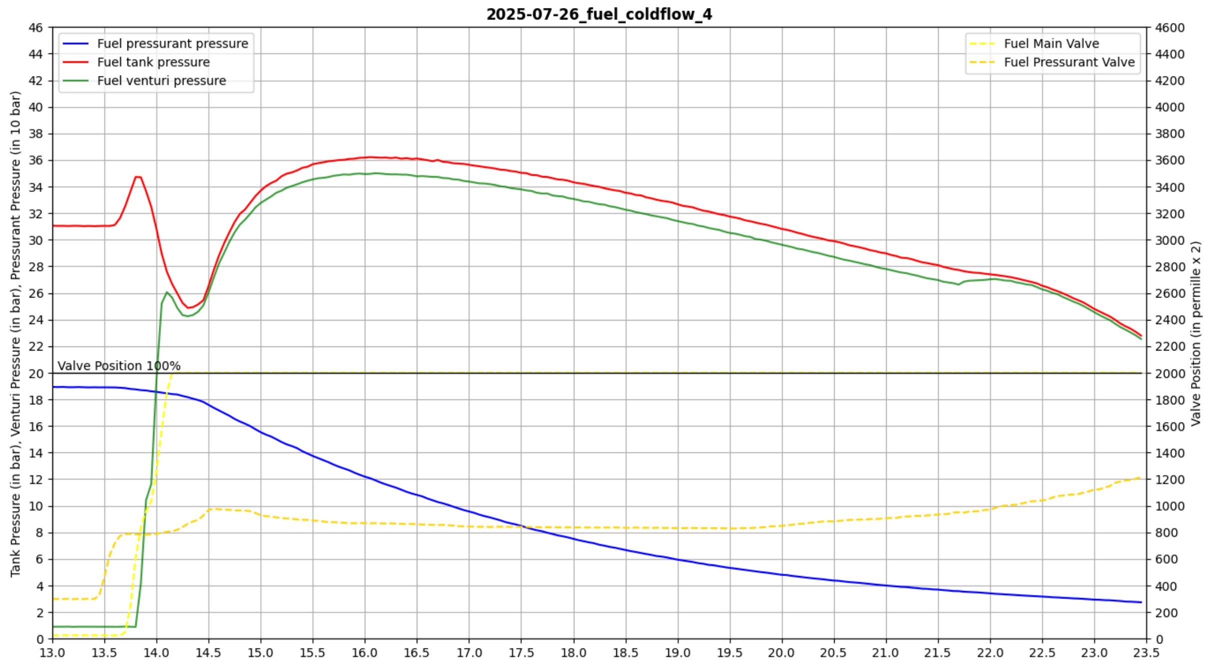
• Attachment 2: Pressure data, Fuel Coldflow 2



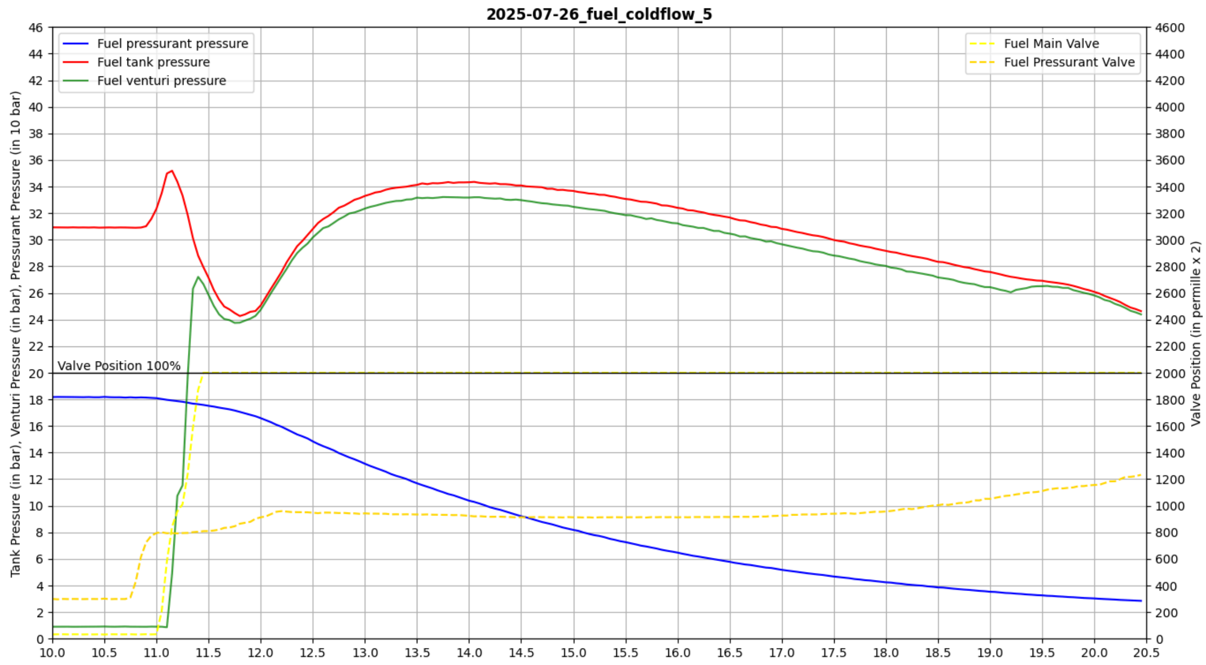
- Attachment 3: Pressure data, Fuel Coldflow 3



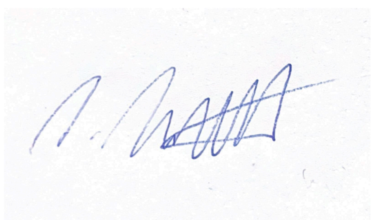
- Attachment 4: Pressure data, Fuel Coldflow 4



• Attachment 5: Pressure data, Fuel Coldflow 5



Signatures:



Combined Coldflows

Date / Time	2025-07-27
Participants	• Lutfi Celik (Mission Lead) • Fabio Winkler (Mission Lead Support) • Diego Grünberger (Mission Control) • Raffael Rott (Mission Control Support)
Testing purpose	• Evaluate combined coldflow performance with updated seals and servo calibration • Check fuel tank pressure stability • Verify Ox Decoupler axial seal performance • Monitor Ox Vent valve flow behavior
Module	Propulsion
Component	Propulsion System

Preparations:

• New axial seal installed on Ox Decoupler
• Testing with modified Ninja V3 pressure reducer
• Leak check performed prior to tests
• LOX Dewar connection found to be leaky at flange
• Ox Decoupler reinstalled with new axial seal

Test execution:

• Tanking was very slow due to LOX Dewar flange leak and restricted LOX vent flow
• During operations, Ox Decoupler failed to decouple but remained leak-tight
• Fuel tank pressure stable at ~30 bar during coldflows
• Ox tank pressure dropped significantly during firing duration
– Attributed first to possible Ox Vent leakage
– Data showed Ox Pressurant tank pressure dropped from 280 → <60 bar in ~3 seconds, inconsistent with just a leak
– Post-test inspection confirmed the Ox System low-pressure burst disk had burst (second occurrence)

Results:

• Fuel side performance stable and nominal
• Ox side unstable — could not maintain tank pressure
• Burst disk failure likely root cause of pressure collapse

Learnings:

• Ox Decoupler axial seal works well — no leaks observed
• LOX Dewar flange leak slowed operations and wasted propellant — must be fixed
• Ox Vent valve flow capacity may be too low, needs inspection
• Modified Ninja V3 pressure reducer may output too high a pressure → repeated premature burst disk failures
• No adapter available to measure outlet pressure — must be acquired for comparison against V2 regulators

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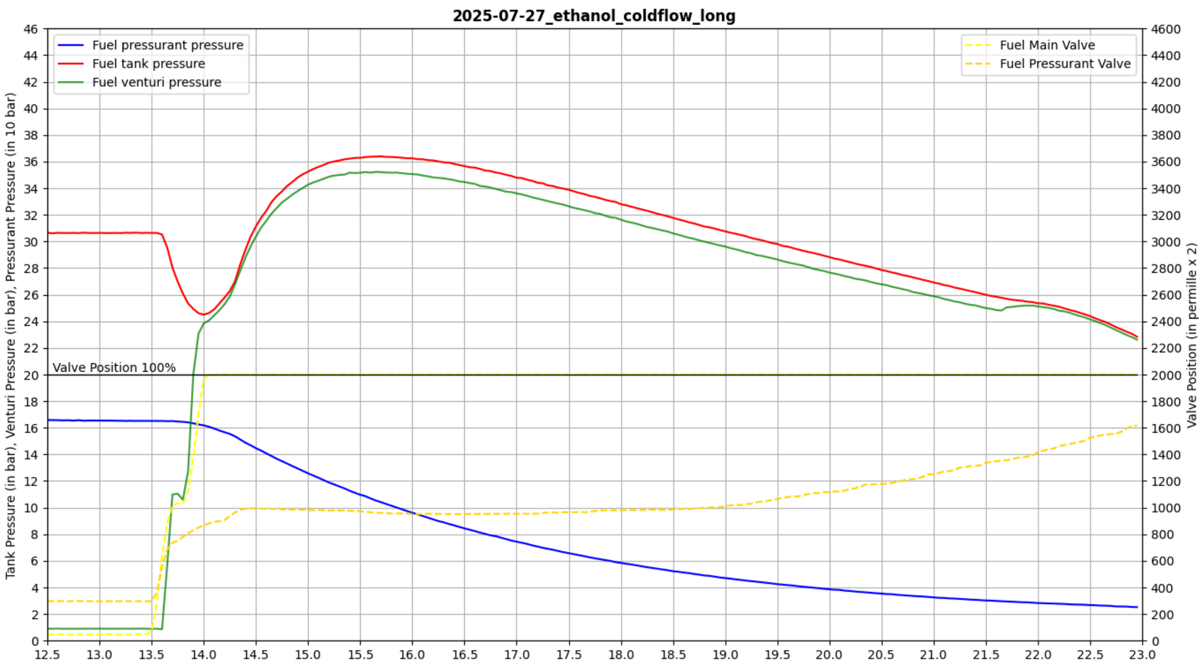
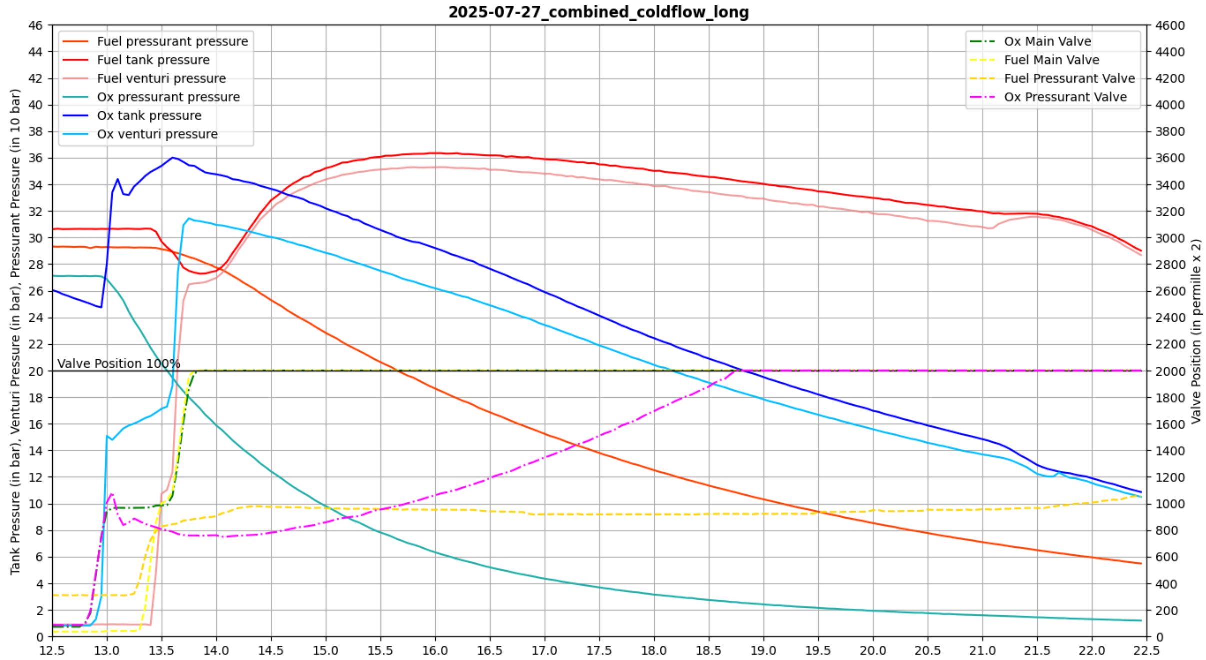
Attachments:

• Attachment 1: Fuel coldflow pressure plot



- Attachment 2: Combined coldflow pressure plot



Signatures:

Wet Dress Rehearsal

Date / Time	2025-08-01
Participants	• Lutfi Celik (lead) • Diego Grünberger (support) • Johannes Eschner (Mission Control) • Raffael Rott (support) • Matthias Rier (support)
Testing purpose	• Evaluate combined coldflow performance with updated seals and servo calibration • Check fuel tank pressure stability • Verify Ox Decoupler axial seal performance • Monitor Ox Vent valve flow behavior
Module	Propulsion/GSE/Avionics
Component	Full propulsion system and avionics except batteries

Preparations:

• New ECU breakout board with separate high-power channel supply
• Ox Vent supply voltage increased to 24 V to mitigate premature opening
• Fuel Press Servo operating point tuning carried over from 26/07 coldflows
• Warm leak check: Fuel system stable, Ox system initially nominal
• Ox Vent closed up to 35 bar warm, but opened prematurely under cryo at ~34 bar
• Breakout board swapped to allow Ox Vent high-power supply adjustment
• Pressurant bottles filled, target tank pressures set to 32 bar

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Test execution:

• Fuel system:
– Timings matched expectations, operating point stable but could be increased slightly
– Pressure regulation improved compared to July coldflows

• Ox system:
– Offset (~6%) appeared between Ox Press Valve Servo setpoint and feedback; not present in earlier tests
– Caused automatic pre-pressurization to overshoot → tank briefly peaked at 38 bar
– High pressurant consumption → Ox pressurant tank depleted before test end
– Ox Vent unexpectedly opened at ~34 bar in cryo, despite holding 35 bar in warm check
– Dynamic seal of Ox Vent showed visible leaks and icing
– Ox Press Valve intermittently stuck between 35–60% opening; partially resolved after breakout board swap

• Software / ECUI:
– During system check after LOX tanking, Ox Vent became unresponsive in ECUI
– LL Server threw error; fixed via restart, underlying bug remains

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Results:

• Fuel system stable at ~30–32 bar with improved regulator behavior
• Ox system target (32 bar) not stably maintained due to servo offset and regulator overshoot
• Pressurant consumption higher than expected
• Abort and safing worked nominally
• Video and full dataset logged

Learnings:

• Fuel system performance largely restored; minor tuning still possible
• Ox Vent premature opening under cryo must be addressed (seal, magnet, or voltage issue)
• Ox Press Valve sticking remains a risk; seat compression adjustment may reduce issue
• Pressurant system efficiency limited by regulator overshoot → verify Ninja V3 regulator outlet pressure
• LL Server bug (Ox Vent disappearing in ECUI) requires urgent fix before static fire

• No adapter available to measure outlet pressure — must be acquired for comparison against V2 regulators

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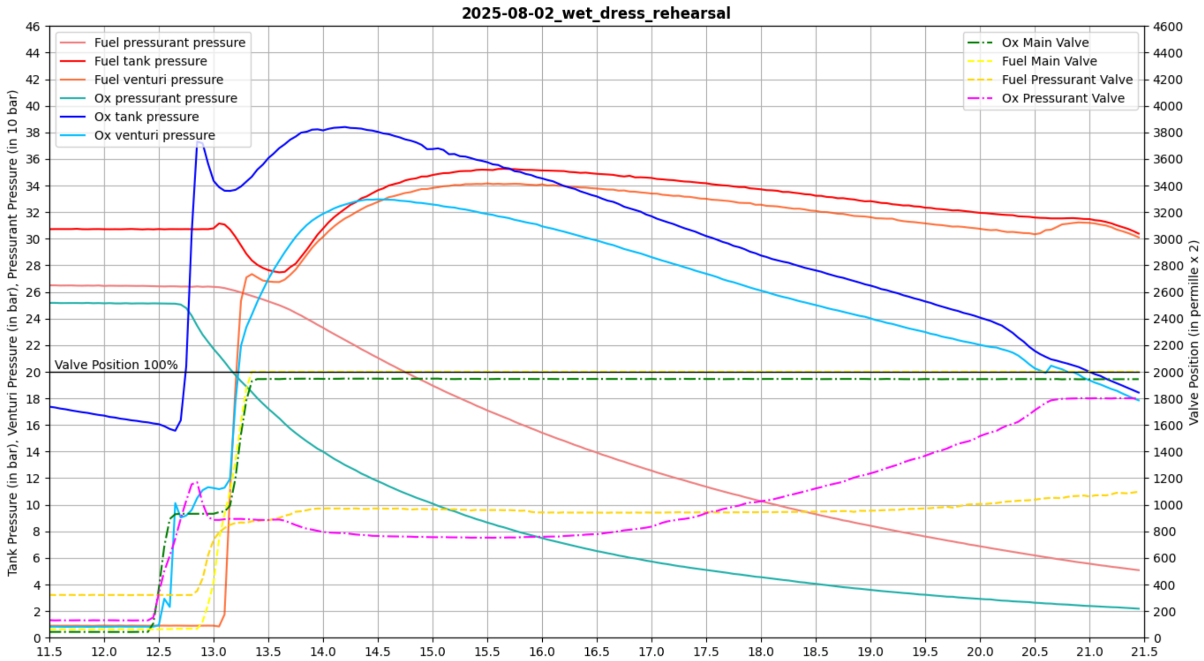
Attachments:

• Attachment 1: Pressure plots Wet Dress Rehearsal



Signatures:

Test Report

Date / Time	2025-08-30
Participants	Oliver Balint, Matthias Rier, Bernhard Hansemann
Testing purpose	Test decoupler check valve for holding working pressure
Changes	Version 1
Doc. Ref.	

Preparations:

Ox decoupler is connected to the hydrostatic test machine. Filled with water and is put onto paper towels.

Test execution:

The oxidizer decoupler is pressurized to 51 bar (1.5 times the nominal pressure). No leaks are observed. After confirming that the system is leak-free, the component remains pressurized for 30 minutes. During this period, a pressure drop of 2 bar is recorded, although no external leaks are detected.

No further testing is carried out to evaluate the characteristics of the component, as the design of all critical parts is derived from a previous version that has already undergone and passed all relevant tests. The only modification in this version is a shorter decoupler body.

Results:

The check valve is functional and works as intended. The component is ready to use.

Learnings:

Component works as intended, previous decoupler was very well designed and well thought through, is suitable for this component as well.

Attachments:

Signatures:

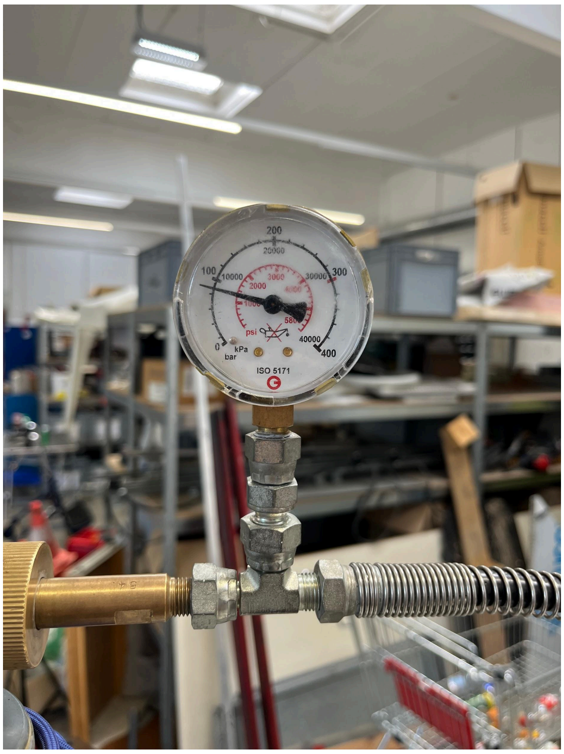
Test Report

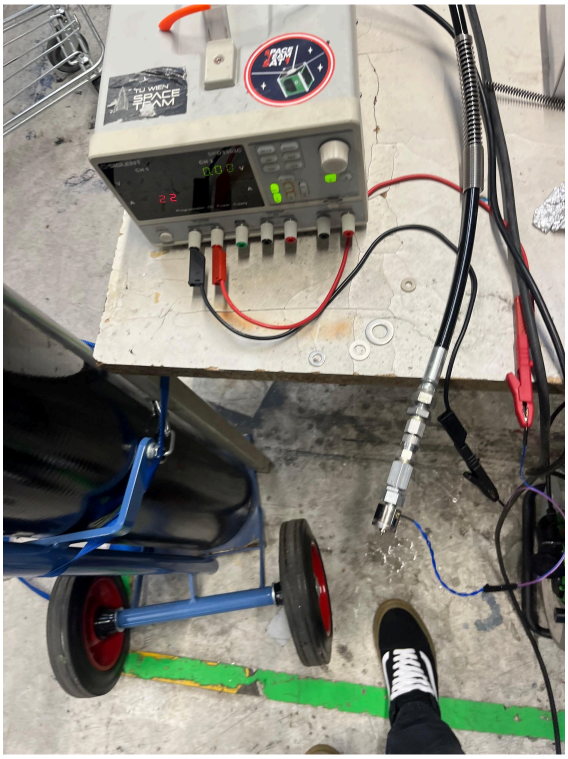
Date / Time	2025-09-02
Participants	Oliver Balint, Matthias Rier, Fabio Winkler
Testing purpose	Testing pressurante vent valve (aka. Mininoid) with working pressure and functionality with N2
Changes	Version 1
Doc. Ref.	

Preparations:

Mininoid is attached to a N2 gas bottle with around 100 bar. All the connections apart from the pressure regulator are sealed with USIT rings. Mininoid is attached to a lab power supply for actuating.

Pictures of the setup:





Test execution:

The Mininoid is set to the closed state with the PSU, and the plate on top of the magnet is adjusted so that there is a very small gap between the plate and the magnet in the closed state. The N_2 bottle is opened, and the valve is placed under pressure.

The first test fails due to a leaky seal in the Mininoid, caused by an excessive gap between the plate and the magnet.

The second test is successful: the Mininoid holds the intended pressure, and no leaks are detected using soapy water along the entire pressurized line. The gas bottle is then closed and left for 30 minutes so that the pressure gauge on the adapter shows the line pressure, where the only possible leakage path is through the valve. After 30 minutes, no pressure change is observed, even after reopening the bottle.

After confirming that the Mininoid can hold the intended pressure, the actuation test is performed. The valve is opened under working pressure and then closed again. If the system functions correctly, it vents only through the designed vent orifice and then reseals.

The first actuation test is not successful: the valve opens and vents correctly but cannot close again due to the excessive distance between the plate and the magnet.

For the second test, shims are added between the valve body and the magnet to reduce the valve travel to around 1 mm. The pressure-holding test is repeated successfully, and the actuation test is also successful: the valve opens and closes under working pressure, and the system functions as intended.

Video of actuating:
https://drive.google.com/file/d/1eHO6dFXfkXioknmrmK7k4of4TiscECCM/view?usp=drivesdk

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Results:

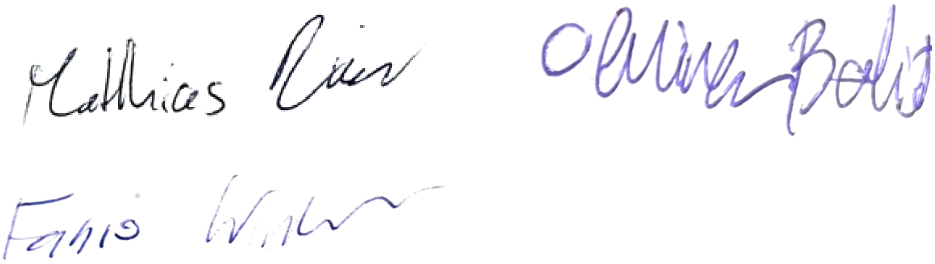
Mininoid works as intended, the sealing type is appropriate for the use case and the magnet is strong enough to keep the valve closed. Actuation is also working as intended, the pressure could be released reliably every time, no clogging or similar issue is observed.

Learnings:

Travel of the stem should be minimal so that the valve can close under pressure. Powering the magnet for 30 minutes gets it quite warm, heatsink can be considered as a counter measure.

Attachments:

Signatures:



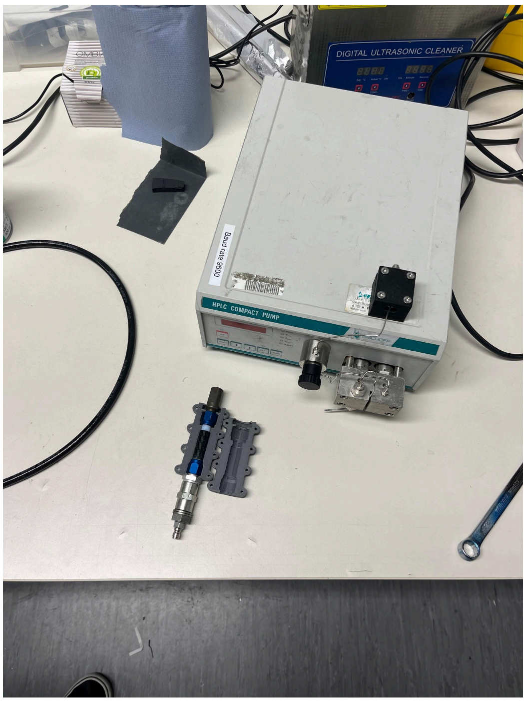
TEST REPORT

Date / Time	2025-02-07
Participants	Oliver Balint, Matthias Rier, Stefan Galavics
Testing purpose	Pressure testing the flight thermal decoupling of the Ox-Pressurization system for operating pressure; Hydrostatic
Changes	Version 1
Doc. Ref.	

Preparations:

The thermal decoupling was plugged on one end with a dummy plug and the other end was connected to the water supply. The thermal decoupling consists of a PTFE Tube, linered with another PTFE Tube which was linered again with a carbon fiber tube. The Parts without secondary ptfe tube were linered with a cut ptfe tube. The whole PTFE tube - carbon fiber tube assembly is encapsulated in a polycarbonate 3D Print, which is sized to fit perfectly the outlines of the thermal decoupling.

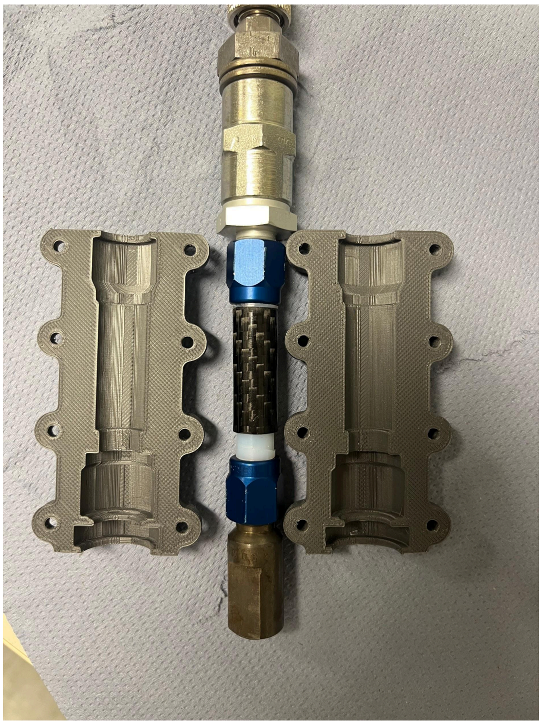
The Assembly is connected to a hydrostatic pressure testing pump. The screws which hold the 3D printed encapsulation together were tightened by hand



Test execution:

First Proof Pressure test:

The thermal decoupling ist filled with water and hooked up to the hydrostatic testing pump. Target Pressure was set to 57 Bar, which is more than the working pressure of 37 Bar times 1.5. As soon as the target pressure is reached a timer is started. Over the course of 6 minutes, which is 3 times the working time of 2 minutes, the pressure sank to 38 Bar, which is expected due to the expansion of the PTFE tubes. The Assembly is depressurized and the encapsulation gets taken off. The thermal decoupling together with the encapsulation is checked for leaks and deformation. No leakes and no deformation is detected



Between the carbon fiber tube and a fitting is a small gap, which was there before. This gap is no closed with a small piece of cut up PTFE tube

Second Proof Pressure test:

The Assembly is encapsulated with the 3D print. This time the screws get tightened with an Allen key. The target pressure is set to 57 bar and the testing pump is switched on. The target pressure is overshot to 59 bar. The timer is started. Over the course of 3 minutes the pressure dropped to 46. Over the next 3 minutes, 6 minutes in total, the pressure dropped von 46 to 43 bar. The encapsulation is disassembled and every part is checked for water. No leaks are detected and no big deformation is seen. The support ptfe tube gets removed and the inner ptfe tube is checked for deformation. Slight bulking is observed, but is in the expected range.

Results:

The thermal decoupling and the 3D printed encapsulation is tight and solid enough for the integrated static fire tests

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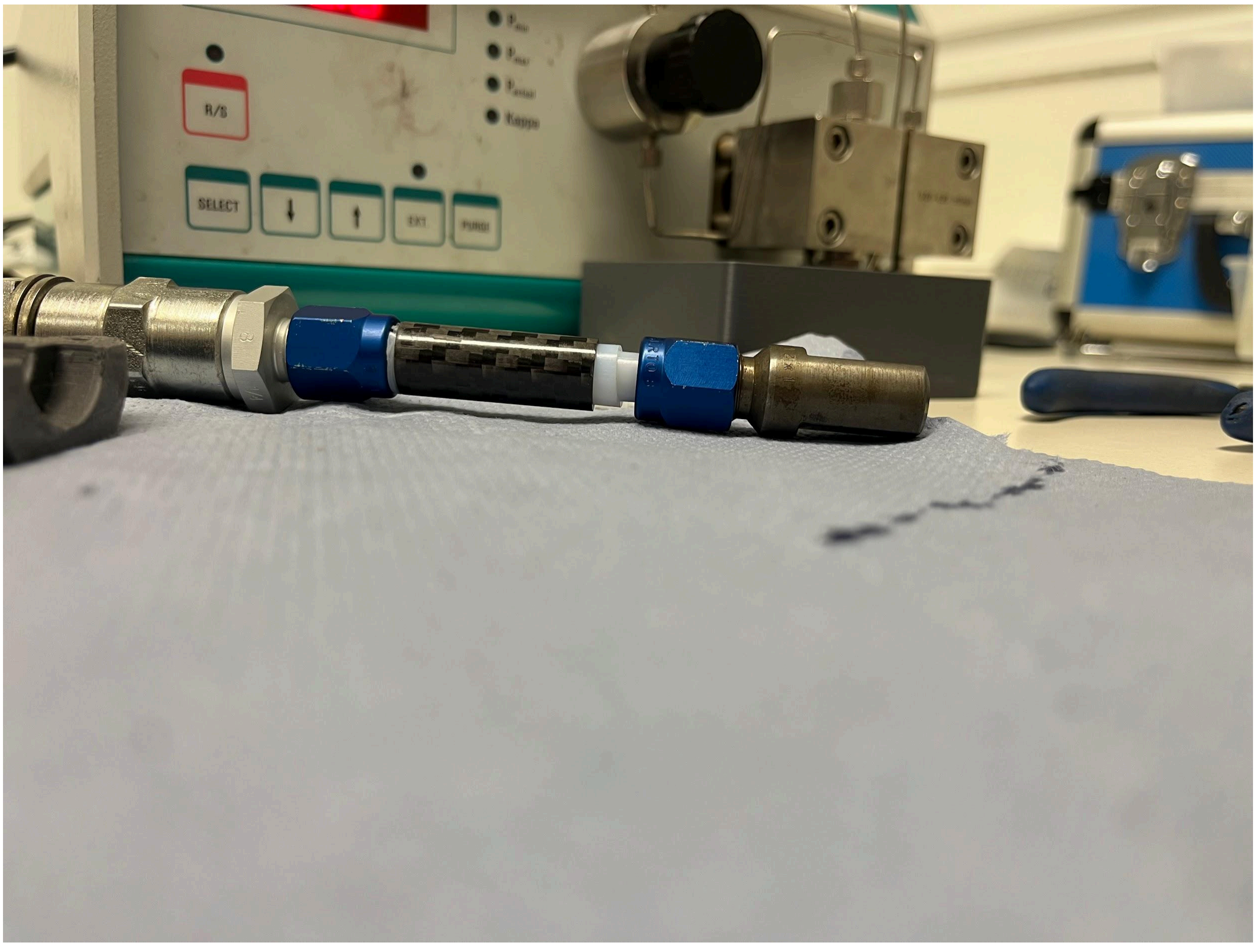
Learnings:

The inner and main PTFE Tube is, despite the cut up PTFE support tube between itself and the carbon fiber tube, slightly bulking. After several pressure Tests the PTFE tube is “used to the working pressure”, probably due to plastic deformation. This results in a slower pressure drop until the pressure almost stabilizes



Attachments:

Signatures:

A.3 Hazard analysis report:

A.3.1 Liquid Propulsion System:

- Transport and Storage
  - **Igniter**

    Hazard: The pyrotechnic igniter is highly flammable.

    Mitigation: The individual constituents of the pyrotechnics igniter mixtures are not dangerous. Once the igniter has been prepared, it is stored inside an air tight, clear plastic container to protect it from humidity and and to keep it away from potential ignition sources.

  - **Ethanol**

    Hazard: Ethanol is highly flammable with a low flash point, making ethanol vapours a considerable risk. Ethanol is also a strong skin and eye irritant.

    Mitigation: Until use, ethanol is only stored and transported in its original container, with clear warning labels indicating the substances high flammability.

  - **Liquid Oxygen**

    Hazard: Liquid oxygen is a cryogenic liquid and rapidly self pressurizes under atmospheric conditions. It's also a potent oxidizer and thus a dangerous accelerant for fires.

    Mitigation: Liquid oxygen is only transported and stored inside our dedicated, pressurized medical LOX dewar. It possesses several redundant pressure relief devices and is placed inside a custom frame in our ground support equipment to secure it from tipping or falling over. Only enough liquid oxygen is taken from the EuRoC liquid oxygen dewar as is needed to support launch preparations for a single day. All unused liquid oxygen in our dewar at the end of the day is safely vented to atmosphere and disposed of.

  - **300 bar Nitrogen Pressurant**

    Hazard: Gas bottle valve failure can lead to catastrophic injury

    Mitigation: The 300 bar nitrogen gas bottles supplied by the EuRoC are securely attached to our ground support equipment at dedicated mounting points to eliminate any risk of bottles falling over. Only after the bottles have been secured and shortly before use, the safety cap of the pressuarnt bottles are removed. When nitrogen bottles have to be moved or replaced, this is only done after the safety cap has been put back onto the bottle.

- Usage
  - **Igniter**

    Hazard: Potential igniter misfire during installation in the combustion chamber.

    Mitigation: The e-matches igniting the rocket candy are only armed shortly before the last personnel leaves the launch pad. Nevertheless, the voltage on the wires supplying the power for the e-matches is double checked before they are connected to the ignition system of the rocket. All personnel handling the pyrotechnic igniters wear appropriate PPE.

- **Ethanol**

  Hazard: Ethanol spills during tanking could pose a fire and health risk on and around the pad.

  Mitigation: Before ethanol is prepared to be fed into the rocket via our ground support equipment, all potential ignition sources are removed from the vicinity of the rocket and all personnel on the launch pad put on suitable PPE like safety goggles or visors. The pressurisation of the ethanol container for the pressure-fed tanking procedure is controlled through a normally closed, dead-man type switch. If there is a leak during tanking, letting go of the switch will immediately depressurize the entire system and abort the procedure. Water is kept at hand to dilute potentially flammable ethanol spills.

- **Liquid Oxygen**

  Hazard: Spontaneous combustions are possible when liquid oxygen comes into contact with flammable materials. Liquid oxygen trapped in an enclosed system without overpressure relief devices can catastrophically explode.

  Mitigation: All systems used to pressurize the dewar or feed liquid oxygen are meticulously ox cleaned to prevent spontaneous combustion of hydrocarbon contaminants. LOX piping system is designed in such way that liquid oxygen can never be trapped in an enclosed volume without overpressure relief devices. In addition, LOX tanking procedure is conducted fully remotely. No personnel needs to be present when liquid oxygen is fed into the rocket. The last action taken by ground crew is connecting the lox tanking feed line to the rocket. It is decoupled automatically before launch.

- **300 bar Nitrogen Pressurant**

  Hazard: Over-pressurizing pressure systems can lead to catastrophic failure. Venting of excess amounts of gas can cause hearing damage.

  Mitigation: The connectors for supplying the pneumatics system of our ground support equipment and for feeding pressurant into our pressurant tanking system are unlike, so it is impossible to mix them up. The pressure going into our pneumatics system is regulated via two sequential pressure reducers, with pressure sensors logging the pressure in the system at all times. Propellant and pressurant tanking connectors on the rocket are also unlike, so it is impossible to fill pressurant directly into the propellant tanks of the rocket. Before any pressure bottle is connected to the ground support equipment, all present personnel equip hearing protection. All gas venting exhausts of the pneumatics, propellant tanking and pressurant tanking system possess mufflers to reduce the noise generated by venting a system.

A.4 Main risks assessment:

Failure Mode	Mission Phase	Failure Probability	Mishap Severity	Critical Ranking	Comments and Justification
Coupler fincan/body tube screws loosen	During flight	1	2	2	Check tightness of all screws after final assembly, before launch
Body tube breaks at screw holes	During flight	1	2	2	A test section of the body tube material was tested with the expected force. A simulation of the expected forces was made
Fincan breaks at screw holes	During flight	1	2	2	A test section of the fincan material was tested with the expected force. A simulation of the expected forces was made
Nosecone breaks at screw holes	During flight	1	2	2	A test section of the tube material was tested with the expected force. A simulation of the expected forces was made

Coupler nosecone/body tube screws loosen	During flight	1	2	2	Check tightness of all screws
Coupler breaks	During flight	1	2	2	Forces on both couplers were simulated and tested with hardware
Railbutton breaks off body tube during holddown	During holddown	1	3	3	Holddown railbutton is tested during static fires
Fincan breaks at touchdown	During landing	2	1	2	Nozzle protrudes from fincan and should take landing shock. Since severity is low, no further avoidance attempts are made.
Railbutton gets stuck in launch rail	During launch	1	2	2	Check launch rail and railbutton for clearance and debris.
Clamp band separation mechanism triggers on ground, ejecting nose cone	Before launch	1	1	1	Clamp band is retained on the outside by a second line, which is removed shortly before launch

Clamp band coupler fails during ascent because of aerodynamics stress	During flight	1	3	3	Exhaustive stress testing on ground with analytically calculated maximum aerodynamic stress, safety margin
Clamp band release mechanism triggers during ascent	During flight	1	3	3	Sufficient ventilation of avionics bay to ensure reliable barometric data on altimeters
Clamp band release mechanism fails at apogee	Apogee	1	3	3	Redundancy, ground and flight tests confirm reliability of mechanism
Nose cone does not separate after release of the clamp band mechanism	Apogee	1	3	3	Slingshot mechanism to aid with separation of nose cone, thorough testing on ground
Drogue parachute or parachute line failure because of parachute opening shock	Apogee	1	3	3	Extremely short actuation time of release mechanism, use of shock absorbers, shock minimizing parachute design

Clamp band safety retainer is not removed before launch, no separation	Apogee	1	3	3	Rigorous adherence to check list routine, RBF tag on the retainer has to be physically attached to the list to proceed
Initial or main deployment event triggers at the wrong time because of faulty programming	During flight	1	3	3	Flight computer programming is verified by different people, testing mode is used to confirm behavior
Main release line fails because of stress, main parachute deploys above 450 m	During descent	1	2	2	Main release line dimensioned to withstand stress, tested until failure to verify specification
Main release mechanism fails	During descent	1	2	2	Main release mechanism uses same design as clamp band release, redundancy
Main parachute or parachute line failure because of parachute opening shock	During descent	1	2	2	Parachutes are dimensioned so both main and drogue suffer similar shocks, use of shock absorbers

Main parachute deployment bag gets stuck inside rocket or parachute fails to exit deployment bag	During descent	2	2	4	Slender design of parachute bag, practice of correct folding technique with deployment tests
Drogue or main parachute line fails because of shearing	During descent	1	3	3	Careful deburring and sanding of all edges on the coupler and parachute tube
Drogue or main parachute lines become tangled during integration or flight	During flight	1	2	2	Compact compartment for lines and parachutes, practiced folding technique for lines
Parachute attachment bulkhead failure because of parachute shock	During descent	1	3	3	Robust airframe and aerostructure design with generous safety margins, mechanical stress tests on ground
Burn wire mechanism causes fire in rocket, parachute line failure	During descent	1	3	3	Use of fire proof aramid braid for all parachute lines which are not meant to be cut by burn wire

Burn wire short circuit causes flight computer failure	During descent	1	2	2	Burn wire resistance is verified shortly before integration of recovery system, burn wire fails under extremely high current
Flight computers not turned on before launch or flight computer failure	During flight	1	3	3	Highly visible RBF pin and strict checklist adherence, confirm status of flight computers through beeping pattern and via telemetry
Flight computer battery voltage too low to trigger burn wire release mechanism	During descent	1	3	3	Batteries for avionics are continuously charged by ground support equipment until launch

Igniter losing quality due to air humidity	Before launch	1	3	3	Igniters will be made shortly before launch and stored in seal tight box with silica gel to reduce the effect of humidity; in the case of extremely high air humidty during launch procedures an excess igniter will be held in comparative conditions as the primary igniter and tested before launch
Leaks in Injector or fluid system	Before launch	1	3	3	Assembling of injector and fluidsystem according checklist
Igniter mount loses functionality or pyrotechnic material detaches before successful engine ignition	During launch	1	3	3	Tested thoroughly during engine tests and static fire tests

Leakage of hot gasses between liner and casing	During flight	2	1	2	Could slightly melt casing, but aluminium has high thermal conductivity and Liner is suitable for 5-8s of operation; already happened at tests, there was no damage to casing
Raw pyrotechnic components faulty or igniter not mixed properly	Before launch	1	1	1	Procedure is thoroughly tested before EuRoC, new sorbitol ordered, potassium nitrate dried beforehand and igniter's functionality is tested before shortly before launch
Blockage of Injection or fluid system with debris	During flight	1	2	2	Engine would lose performance ->could use filters in injector assembly or before tanking

Fincan or liner material burning due to hot gases or heat radiation	After Landing	1	1	1	Burning or hot glowing carbon/linermaterial could ignite vegetation after touch down ->extensive engine purge after burn out
Pressure relief valve not activating	Always	1	3	3	High quality COTS components are used and burst discs built into each system to avoid critical pressure
Pressurization valves leaking	Always	2	3	6	Propellant tanks would be overpressurized, danger of tank rupture ->use of 2 stage safety in form of pressure relief valve (custom-made normally opened relief valve and burst disc), extensive testing needed
Pressure relief valve activating at too low pressure	Always	1	2	2	Components are thoroughly tested beforehand to avoid malfunction

Lox fill not disconnecting after Lox tanking	Before launch	2	1	2	Would hinder liftoff, extensive testing needed. Maybe just waiting and letting components warm up would fix it
Thrust structure breaks	During flight	1	3	3	Tested thoroughly during static fire tests
Bolts and nuts are loose	During flight	1	1	1	Using washers and loctite bolt glue; have enough redundant bolts and nuts
LOX saturation pressure influencing LOX venturi flow	During flight	1	1	1	No safety risk but performance loss - venting to regulate ox tank pressure to required level before start sequence
Swapped LOX and pressurant pipes	Before launch	1	3	3	Due to the positioning of the propellant and LOX tanks, they cannot be swapped without realizing it. Furthermore, remote tanking mitigates the risk even more

Tab. A.2: Main risks assesment

A.5 Compliance matrix:

Requirement reference	Title	Text	Compliance	Reference	Remarks
LV-RQT-0010	Non-toxic propellants	Launch vehicles entering EuRoC shall use non-toxic propellants.	Fully compliant	A.3	Bio Ethanol and Liquid Oxygen are used
LV-RQT-0020	Air-start ignition circuit electronics	All upper stage and secondary ignition systems shall comply with the recovery systems redundant electronics and safety critical wiring requirements specified in Sections 5.1 (EuRoC-LV-RQT-0240 to EuRoC-LV-RQT-0280) and 5.4, respectively.	N/A		Hedy is a single-stage rocket.
LV-RQT-0030	Ground-start ignition circuit arming distance	All ground-started propulsion system ignition circuits/sequences shall be capable of being armed and disarmed with no personnel within 15 m of the launch vehicle.	Fully compliant	3.2.4	This is achieved by a key box, which is at least 25 m away from the rocket.
LV-RQT-0040	Clustered vehicle release system	All clustered vehicles shall have a launch release system ensuring lift-off only occurs if a minimum threshold force is met.	N/A		Hedy isn't clustered.
LV-RQT-0050	Clustered vehicle stability proof	All clustered vehicles shall be capable of performing a stable flight for any lift-off force above the minimum threshold value.	N/A		Hedy isn't clustered.
LV-RQT-0060	Clustered vehicle arming	For vehicles with a "main" and several "secondary" propulsion systems, the arming function of the secondary propulsion systems shall only be armed by launch detection (i.e., air-start).	N/A		Hedy isn't clustered.

LV-RQT-0070	Air-start ignition circuit arming	All upper stage and “secondary” (i.e., air-start) propulsion systems shall only be armed by launch detection	N/A		Hedy is a single-stage rocket.
LV-RQT-0080	COTS solid motors	All COTS solid motors shall be selected from the official EuRoC Motors List [RD02].	N/A		Hedy isn’t a solid rocket.
LV-RQT-0090	Ignition systems for solid motors	All solid motors shall use the electronic ignition system provided by EuRoC.	N/A		Hedy isn’t a solid rocket.
LV-RQT-0100	Active Pressurization	All gaseous and liquid propellant system shall be able to be externally pressurized with inert gas.	Fully compliant	2.7.4	For pressureization, a bottle of 300 bar nitrogen is used.

LV-RQT-0110	Loading lines disconnection	Systems employing any gaseous or liquid propellants shall perform propellant tank pressurization after all propellant and pressurant loading lines are disconnected.	Partially compliant	2.7.4	Due to an implemented safety feature, our pressurant tanks continuously lose pressure. As a consequence, it is necessary to fill them immediately before the launch. Due to an extensively tested, automatically retractable tanking system, we can ensure that nobody needs to go near the pressurized rocket.

LV-RQT-0120	Dissimilar connections	All loading lines, used for pressurization gases or propellants, shall feature dissimilar connectors	Fully compliant	2.7.4	This requirement is fulfilled by a mixture of the different types of connectors and locations on the rocket.
LV-RQT-0130	Remote-controlled loading mechanism and respective emergency release mechanism	Any remote-controlled loading mechanism for gases or liquid propellants shall feature a clearly marked and labelled, single-action, hand-actuated, “Emergency Release Mechanism”.	Partially compliant	2.7.4	For an emergency situation, it is possible, but it shouldn’t be done during the normal process.
LV-RQT-0140	Filling/ loading/ unloading connections	Any filling/ loading/ unloading connections for fluid propellants shall be readily accessible from the ground when the rocket is in vertical launch position.	Non-compliant	2.7.4	
LV-RQT-0150	Filling/ loading/ unloading timing	Teams shall demonstrate that the filling/ loading/ unloading of the liquid fuels can be done to be ready for the launch window (maximum 90 minutes for liquid propellant loading, including pressurization).	Fully compliant	see test report "Liquid Propelant loading and Unloading"	During our test, the 90-minute limit was never once nearly reached.
LV-RQT-0160	Venting	For hybrid and liquid motors, teams shall facilitate oxidizer tank venting to prevent over-pressure situations.	Fully compliant	2.2.1	At least three countermeasures to prevent an overpressure are implemented per tank.

LV-RQT-0170	Passive PRD in isolated sections of pressurized lines	All isolated sections of pressurized lines (including pressure vessels) shall incorporate a passive pressure relief device (PRD) with an opening set point below the maximum tested pressure of that line section.	Fully compliant	2.2	
LV-RQT-0180	PRD discharge coefficient	All pressure relief devices shall have a discharge coefficient equal to or higher than any other fluid interface on the respective pressurized section in which they are installed.	Fully compliant	2.2	
LV-RQT-0190	Propellant offloading after launch abort	Hybrid and liquid propulsion systems shall implement a means for remotely controlled venting or offloading of all liquid and gaseous propellants in the event of a launch abort.	Fully compliant	2.2 2.7 2.6	Depending on the process's current progress, it is possible to unload or vent the fuels and pressurant gases at any time.
LV-RQT-0200	Combustion chamber pressure test	SRAD and modified COTS propulsion system combustion chambers shall be designed and tested according to the SRAD pressure vessel requirements defined in Sections 0 and 6.3, respectively.	Partially compliant	2.2.1	
LV-RQT-0210	Combustion chamber leak proof	Combustion chambers shall be designed allowing to be closed off in a leak-tight manner for testing at any section between the throat and the exit section of the nozzle.	Fully compliant	A.2.4	

LV-RQT-0220	Hybrid and liquid tanking test	SRAD and modified COTS propulsion systems using liquid propellant(s) shall successfully (without significant anomalies) have completed a propellant loading and offloading test in "launch configuration", prior to the competition.	Fully compliant	see test report "Liquid Propelant loading and Unloading"	During our extensive test campaigns, we loaded and unloaded our propellants multiple times without any problems.
LV-RQT-0230	Static hot-fire test	SRAD propulsion systems shall successfully (without significant anomalies) complete an instrumented (chamber pressure and/or thrust), full-scale (including system working time) static hot-fire test prior to EuRoC.	Partially compliant	A.2.5	
LV-RQT-0240	Redundant recovery system electronics	Launch vehicles shall implement fully redundant recovery system electronics, including sensors/flight computers and ëlectric initiators", with a separate power supply (i.e., battery).	Fully compliant	2.2.1 2.6.1	To secure a complete redundancy of the recovery electronics, two completely electrically independent COTS flight computers are used.
LV-RQT-0250	Redundant COTS recovery electronics	At least one redundant recovery system electronics subsystem shall implement a COTS flight computer.	Fully compliant	2.2.1	The primary and backup flight computers are both COTS.

LV-RQT-0260	Recovery electronics access panel	All electronics switches or connectors that need to be manually operated shall be accessible from outside the vehicle via either access panels or direct mounting on the outer skin.	Fully compliant	2.6.2	Due to the chosen design approach, this requirement is fulfiled.
LV-RQT-0270	Recovery electronics location	All electronics switches or connectors that need to be manually operated shall be readily accessible from the ground, when the rocket is in vertical launch position.	Partially compliant	2.6.2	The rocket can be set in a safe status from the ground.
LV-RQT-0280	Recovery electronics access	All electronics switches or connectors that need to be manually operated shall be mounted on the vehicle side opposite to the launch rail.	Fully compliant	2.6.2	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0290	Recovery system energetic devices	All stored-energy devices (i.e., energetics) used in recovery systems shall comply with the energetic device requirements defined in Section 6.1 of this document.	Fully compliant	2.4.4	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0300	Onboard power systems	All onboard systems shall be free of batteries with either lithium-polymer or lithium (non-rechargeable) chemistry.	Fully compliant	2.6.2	Only rechargeable lithium-ion batteries are used. In the form factor of 21700 assembled to custom battery packs.

LV-RQT-0310	Onboard power systems access	Onboard batteries shall be readily accessible from the ground, when the rocket is in vertical launch position.	Partially compliant	2.6.2	The batteries will be charged while the rocket is in the launch rail.
LV-RQT-0320	Launch rail standby time	Onboard power systems shall have at least six hours of battery lifetime on the launch rail.	Fully compliant	2.6.2	Battery lifetime without charging is at least 7 hours.
LV-RQT-0330	Non-parachute/ parafoil recovery systems	Teams exploring other recovery methods (i.e., non-parachute or parafoil-based) shall mention it in the dedicated field of the Technical Questionnaire [RD04].	N/A		A regular drogue and main parachute recovery system is used.
LV-RQT-0340	Dual deployment recovery	Each independently recovered launch vehicle body, anticipated to reach an apogee above 450 m above ground level (AGL), shall follow a dual deployment recovery operations concept.	Fully compliant	2.4	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0350	Initial deployment event altitude	The initial deployment event shall occur at or near apogee.	Fully compliant	2.6.2	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0360	Initial deployment event descent velocity	The initial deployment event shall result in a descent velocity between 23 and 46 m/s.	Fully compliant	2.4.2	Due to the chosen design approach, this requirement is fulfilled.

LV-RQT-0370	Main deployment event altitude	The main deployment event shall occur at an altitude no higher than 450 m AGL.	Fully compliant	2.4.5	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0380	Main deployment event descent velocity	The main deployment event shall result in a descent velocity of less than 9 m/s.	Fully compliant	2.4.2	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0390	Ejection gas protection	The recovery system shall implement adequate protection (e.g., fire-resistant material, pistons, baffles, etc.) to prevent hot ejection gases (if implemented) from causing burn damage to retaining chords, parachutes, and other vital components as the specific design demands.	N/A		The designed recovery system is pyroless. Due to that, no protection is necessary.
LV-RQT-0400	Parachute swivel links	The recovery system rigging (e.g., parachute lines, risers, shock chords, etc.) shall implement swivel links at any connections, including single-threaded anchors.	N/A		Due to over 80 successful rocket launches in the past without them and the approval of Reinhard, we decided not to use them.
LV-RQT-0410	Dual deployment parachute coloration	Dual deployment parachutes shall be visually highly dissimilar.	Fully compliant	2.4.2	Parachute shapes are dissimilar

LV-RQT-0420	Parachute coloration	Utilised parachutes shall use colours providing a clear contrast to a blue sky, a grey/white cloud cover, and ground vegetation (i.e., avoiding certain shades of green and brown, as well as black).	Fully compliant	2.4.2	Main chute is red/white, drogue is solid red
LV-RQT-0430	Mandatory system	Launch vehicle stages and deployable payloads shall feature a mandatory operational CATS Vega Flight Computer for official altitude logging and landing site tracking purposes.	Fully compliant	2.4.5	The Cats Vega is used as a secondary flight computer.
LV-RQT-0440	CATS transmitter call-sign	Teams shall assign to each transmitter a “call-sign” (referred to in the CATS User Manual as the tele_link_phrase telecommand) respecting a specific string format to be found in Appendix D.	Fully compliant	2.4.5	Will be done.
LV-RQT-0450	CATS Vega firmware update	Teams will be required to fly a specific firmware version in each mandatory CATS flight computer, mandated by the EuRoC organization.	Fully compliant	2.4.5	Will be flashed when available.
LV-RQT-0460	CATS receiver	The CATS Ground Station shall be used for telemetry and tracking in conjunction with the mandatory system.	Fully compliant	2.4.5	Will be done.
LV-RQT-0470	CATS electronics	CATS devices shall comply with the electronics general electronics requirements EuRoC-LV-RQT-0260 0260, EuRoC-LV-RQT-0270, and EuRoC-LV-RQT-0280.	Fully compliant	2.6.2	Due to the chosen design approach, this requirement is fulfilled.

LV-RQT-0480	Cable management	All safety-critical wiring shall implement a cable management solution (e.g., wire ties, wiring, harnesses, cable raceways).	Partially compliant	2.6.4	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0490	Secure connections	All safety-critical wiring/cable connections shall be sufficiently secure as to prevent de-mating due to expected launch loads.	Fully compliant	2.6.4	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0500	Cryo-compatible wire insulation	In case of propellants with a boiling point of less than -50°C, any wiring or harness passing within close proximity of a cryogenic device (e.g., valve, piping, etc.) or a cryogenic tank (e.g., a cable tunnel next to a LOX tank) shall utilize safety-critical wiring with cryo-compatible insulation (i.e., Teflon, PTFE variants, etc.).	Fully compliant	2.6.4	Only Teflon cables will be used in the rocket.
LV-RQT-0510	Electronics thermal testing	Teams shall thermally test the electronics to know the reliable operational temperature range, implement cooling or venting provisions, and monitor at least one temperature sensor representative of the electronics temperature.	Partially compliant	2.6 A.2.3	Tests have been carried out without any major problems.
LV-RQT-0520	Recovery system ground test demonstration	All recovery system mechanisms shall be successfully (without significant anomalies) tested prior to EuRoC, either by flight testing, or through one or more ground tests of key subsystems.	Fully compliant	2.4.6 A.2.2	Tests have been carried out without any major problems.

LV-RQT-0530	Energetic device safing and arming	All energetics shall be “safed” until the rocket is in the launch position, at which point they may be ärmed".	Fully compliant	2.2.4 2.6.2	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0540	Arming device access	All energetic device arming features shall comply with the requirements EuRoC-LV-RQT-0260, EuRoC-LV-RQT-0270 and EuRoC-LV-RQT-0280.	Fully compliant	2.6.2	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0550	Arming device location	All energetic device arming features shall be located on the airframe.	Fully compliant	2.6.2 2.6.10	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0560	Burst discs	Each SRAD pressure vessel and every propellant tank shall implement an over-pressure safety measure, in the form of a (replaceable) burst disc, with a diaphragm orifice diameter of no less than 6 millimetres. The burst (or rupture) disc solution can be either COTS or SRAD.	Fully compliant	2.2.1	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0570	Burst disc pressure	Burst discs (COTS or SRAD) shall be selected or calibrated to rupture at a pressure no higher than 1,25 times the nominal tank pressure.	Fully compliant	2.2.1	Due to the chosen design approach, this requirement is fulfilled.

LV-RQT-0580	Burst disc marking	Burst disc orifices (the body which determines the rupture pressure) shall be clearly and permanently marked with the average rupture pressure determined by testing, along with a unique identifier, tracing each burst disc orifice to an associated test report.	Fully compliant	2.2.1	COTS
LV-RQT-0590	Burst discs material	All SRAD burst discs shall come from the same stock material sheet, both for flight, testing and rupture pressure characterization.	N/A		Only COTS burst discs are used.
LV-RQT-0600	Relief device	SRAD pressure vessels shall implement an additional relief device, set to open in the range of 1,10 to 1,20 times the nominal operating pressure.	Partially compliant	2.2.3	The system was designed for higher pressures.
LV-RQT-0610	Designed burst pressure for metallic pressure vessels	SRAD and modified COTS pressure vessels constructed entirely from isotropic materials (e.g., metals) shall be designed to a burst pressure no less than 2 times the maximum expected operating pressure.	Fully compliant	2.2.1	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-0620	Designed burst pressure for composite pressure vessels	All SRAD and modified COTS pressure vessels either constructed entirely from non-isotropic materials (e.g., fibre reinforced plastics (FRP), composites) or implementing composite overwrap of a metallic vessel (i.e., composite overwrapped pressure vessels (COPV)), shall be designed to a burst pressure no less than 3 times the maximum expected operating pressure.	N/A		Our SRAD Tanks are made out of aluminium.

LV-RQT-0630	Burst discs testing	Individual test reports are required for each SRAD burst disc orifice, tied to its unique identifier or serial number. Each burst disc orifice test report must contain a minimum of five consecutive rupture tests, preferably using a data logging system and a pressure transducer for optimum rupture pressure documentation. The burst disc sheet metal must also be specified in detail.	N/A		Only COTS burst discs are used.
LV-RQT-0640	Proof pressure testing	SRAD and modified COTS pressure vessels shall be proof pressure tested successfully (without significant anomalies) to 1,5 times the maximum expected operating pressure for no less than twice the maximum expected system working time, using the intended flight article(s) (e.g., the pressure vessel(s) used in proof testing must be the same one(s) flown at EuRoC).	Partially compliant	2.2.1	
LV-RQT-0650	Restricted control functionality	Launch vehicle active flight control systems, if implemented, can only be implemented for pitch and/or roll stability augmentation, for aerodynamic braking, guided recovery systems, precision landing, or guided deployable loads.	N/A		No active flight control system
LV-RQT-0660	Unnecessary for stable flight	Flight vehicles implementing active flight controls shall be naturally stable without these controls being implemented.	N/A		No active flight control system

LV-RQT-0670	Designed to fail safe	Control Actuator Systems shall be designed to Fail Safe in any abnormal condition or during an active flight abort (if such functionality is implemented).	N/A		No active flight control system
LV-RQT-0680	Boost phase dormancy	Control Actuator Systems shall be designed with a field-adjustable boost dormancy capability, which will disable them in the initial period of the flight.	N/A		No active flight control system
LV-RQT-0690	Active flight control system electronics	All electronics shall comply with the recovery systems redundant electronics and safety critical wiring specified in Sections 5.1 (EuRoC-LV-RQT-0240 and EuRoC-LV-RQT-0260 to EuRoC-LV-RQT-0280) and 5.4, respectively.	N/A		No active flight control system
LV-RQT-0700	Active flight control system energetics	All stored-energy devices used in an active flight control system (i.e., energetics) shall comply with the energetic device requirements defined in Section 6.1 of this document.	N/A		No active flight control system
LV-RQT-0710	Venting	All non-pressurized compartments of the airframe shall be vented in such a way that the pressures during flight are never above 1,05 times the atmospheric pressure at that point in the flight.	Fully compliant	2.3.2	There are holes in the bodytube.

LV-RQT-0720	Material selection	PVC (and similar low-temperature polymers) Public Missiles Ltd. Quantum Tube components shall not be used in any structural (i.e., load-bearing) capacity, most notably as load-bearing eyebolts, launch vehicle airframes, or propulsion system combustion chambers.	N/A		Such material are not used.
LV-RQT-0730	Load bearing eyebolts type	All load bearing eyebolts shall be of the closed-eye, forged type.	N/A		Not used in the rocket
LV-RQT-0740	Load bearing eyebolts and U-bolts material	All load bearing eyebolts and U-bolts shall be steel or stainless steel.	N/A		Not used in the rocket
LV-RQT-0750	Coupling tubes	Airframe joints which implement coupling tubes shall be designed such that the coupling tube extends no less than one body calibre (1D) on either side of the joint — measured from the separation plane.	N/A		Not used in the rocket
LV-RQT-0760	Launch lugs mechanical attachment	Launch lugs (i.e., rail guides) shall implement hard points for mechanical attachment to the launch vehicle airframe.	Fully compliant	2.2.5	The Railbuttons were extensively tested.
LV-RQT-0770	Aft launch lug support	The aft-most launch lug shall support the launch vehicle's fully loaded launch weight while vertical	Fully compliant	2.2.5	The Railbuttons were extensively tested.

LV-RQT-0780	RF transparency	Any internally mounted RF transmitter, receiver or transceiver, not having the applicable antenna(s) mounted externally on the airframe, shall employ “RF windows in the airframe shell plating (typically glass fibre panels).	Fully compliant	2.3.1 2.4.5	The complete nosecone is made out of glass fibre. In the nosecone are all RF and GNSS-related parts.
LV-RQT-0790	RF windows dimensioning	RF windows in the flight vehicle shell shall be a 360° circumference and be at least two body calibres in length.	Fully compliant	2.3.1 2.4.5	The complete nosecone is made out of glass fibre. In the nosecone are all RF and GNSS-related parts.
LV-RQT-0800	RF windows material	RF windows shall be of a material other than carbon fibre.	Fully compliant	2.3.1 2.4.5	The complete nosecone is made out of glass fibre. In the nosecone are all RF and GNSS-related parts.
LV-RQT-0810	RF antennas’ location	RF antennas shall be kept as far away as possible from wiring and metallic structural elements	Fully compliant	2.3.1 2.4.5	Next to the antennas is mainly glass fibre.

LV-RQT-0820	Internal RF antennas' location	The internally mounted RF antenna(s) shall be placed at the midpoint of the RF window section.	Fully compliant	2.3.1 2.4.5	The complete nosecone is made out of glass fibre. In the nosecone are all RF and GNSS-related parts.
LV-RQT-0830	Identifying markings	The Team ID shall be clearly and prominently displayed on the launch vehicle airframe, visible on all four quadrants of the vehicle, as well as fore and aft, and on all components that separate from the vehicle, such as deployable payloads.	Fully compliant	2.3.4	
LV-RQT-0840	Payloads	Teams are required to carry payload(s) on the vehicle.	Fully compliant	2.5	
LV-RQT-0850	Payload form factor	ayloads shall fulfil one of the following basic form factors: • CanSat: cylindrical shape with 115 mm height and 66 mm diameter; • CubeSat: cubic shape with one CubeSat Unit (1U) being defined as a 100 mm x 100 mm x 100 mm cubic structure; • PocketSat: cubic shape with 50 mm x 50 mm x 50 mm.	Fully compliant	2.5	1 x 4units Picosat
LV-RQT-0860	Payload minimum mass	The launch vehicle shall carry no less than 1000 g of payload, with no requirement applicable to the upper limit.	Fully compliant	2.5	exactly 1kg

LV-RQT-0870	Payload mass factor	Payloads shall fulfil one of the following basic mass increments: • A single CanSat-type payload has a mass between 300 g and 350 g; • A single CubeSat-type payload has a mass between 1000 g and 1330 g; • A single PocketSat-type payload has a mass between 200 g and 250 g	Fully compliant	2.5	1 x 4units Picosat with 1 kg
LV-RQT-0880	Independent payload functionality	The payload functionality must be completely independent of the launch vehicle and at the same time payloads cannot be a part of the launch vehicle functionality (e.g., a guidance and control system).	Fully compliant	2.5	The payload has no impact of the mission.
LV-RQT-0890	Payload removal for weigh-in	Teams must ensure that the payloads shall not be inextricably connected to other launch vehicle associated components (e.g., recovery system, internal structure, or airframe) while being weighed	Fully compliant	2.5	The payload has no impact of the mission.
LV-RQT-0900	Payload materials	Payloads shall not contain significant quantities of lead or any other hazardous materials, and in case of payloads with potential biohazards such as seeds or living beings, those must not contain invasive species. The use of radioactive materials is not permitted.	Fully compliant	2.5	There are no hazardous materials inside the payload.
LV-RQT-0910	Payload energetic devices	All stored-energy devices (i.e., energetics) used in payload systems shall comply with the energetic device requirements defined in Section 6.1 of this document.	Fully compliant	2.5	There are only Lithium-ion batteries in it.

LV-RQT-0920	Recovery system	Deployable payloads shall have its own independent recovery system.	N/A		Payload is non deployable
LV-RQT-0930	Unique recovery system	If teams plan to develop a deployable payload that requires a specific unique recovery system, they shall contact the EuRoC organization well in advance of the event to clarify if the payload satisfies all requirements.	N/A		Payload is non deployable
LV-RQT-0940	Descent velocity	Deployable payloads shall incorporate an independent recovery system, reducing the payload's descent velocity to less than 9 m/s before it descends through an altitude of 450 m AGL.	N/A		Payload is non deployable
LV-RQT-0950	Recovery system electronics	Payloads implementing independent recovery systems shall comply with the launch vehicle redundant electronics requirements defined in Section 5.1 (EuRoC-LV-RQT-0240 to EuRoC-LV-RQT-0280).	N/A		Payload is non deployable
LV-RQT-0960	Payload safety critical wiring	Payloads implementing independent recovery systems shall comply with the launch vehicle safety critical wiring requirements defined in Section 5.4.	N/A		Payload is non deployable
LV-RQT-0970	Recovery system testing	Payloads implementing independent recovery systems shall comply with the launch vehicle recovery system testing requirements defined in Section 0.	N/A		Payload is non-deployable
LV-RQT-0980	Payload tracking	All deployable payloads shall feature the mandatory altitude logging and tracking system (see Section 5.3).	N/A		Payload is non deployable

LV-RQT-0990	Payload tracking call-sign	Teams shall assign to each transmitter a call-sign respecting the format described in Appendix D.	N/A		Payload is non-deployable
LV-RQT-1000	Launch azimuth and elevation	Launch vehicles shall nominally launch at an elevation angle of 84°±1° and a launch azimuth defined by the organisation at EuRoC.	Fully compliant	2.7.1	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-1100	Rail take-off velocity	The vehicle shall be capable of achieving a rail departure speed higher than 30 m/s on the intended launch rail's length.	Fully compliant	flight simulation	Due to the chosen design approach, this requirement is fulfilled.
LV-RQT-1020	Hold-down system	All vehicles using at least one liquid propellant shall employ a hold-down system that will release the rocket only after sufficient thrust for stable flight is achieved.	Fully compliant	2.7.2	An extensively tested hold-down is integrated into the launch rail.
LV-RQT-1030	Stability margin	Launch vehicles shall maintain a static stability margin of at least 1,5 calibres throughout the whole flight phase (upon leaving the launch rail), regardless of CG movement due to depleting consumables and shifting CP location due to wave drag effects (which may become significant as low as 0,5 Mach).	Fully compliant	flight simulation	Due to the chosen design approach, this requirement is fulfilled.

SE-RQT-0010	Operational range	All team provided launch control systems shall be electronically operated and have a maximum operational range of no less than 750 metres from the launch rail.	Fully compliant	2.7.5	Mission control and GSE are connected per point-to-point radio link.
SE-RQT-0020	Fault tolerance and arming	All team provided launch control systems shall be at least single fault tolerant by implementing a removable safety interlock (i.e., a jumper or key to be kept in possession of the arming crew during arming) in series with the launch switch.	Fully compliant	2.6.2	There are multiple safety switches like monostable key switches and RBF switches.
SE-RQT-0030	Safety critical switches	All team provided launch control systems shall implement ignition switches of the momentary, normally open (also known as dead man) type so that they will remove the signal when released.	Fully compliant	2.6.2 2.6.10	There are multiple safety switches like monostable key switches and RBF switches.
SE-RQT-0040	Launch rail fit check	Teams using EuRoC launch rails shall perform a launch rail fit check as part of the Flight Readiness Review, before going to the launch range.	N/A		We use our own launch rail.
SE-RQT-0050	Launch rail bottom spacer	Teams shall provide their own bottom spacer to define their vehicles' vertical position on the rail.	N/A		We use our own launch rail.
SE-RQT-0060	Launch rail nominal elevation	Team provided launch rails shall be able to implement a nominal launch elevation of 84°+-1°.	Fully compliant	2.7.1	Due to the chosen design approach, this requirement is fulfilled.

SE-RQT-0070	Launch rail elevation range	Team provided launch rails with adjustable elevation shall only allow inclinations between 70° and 85°.	Fully compliant	2.7.1	Due to the chosen design approach, this requirement is fulfilled.

A.6 Checklists:

A.6.1 Launch Checklist:

The launch checklist is a work-in-progress document. The final launch checklist will be based on the static fire checklist. See A.6.2 for our latest static fire checklist.

A.6.2 Static Fire Checklist:

LAMARR
Static Fire Test

Event General	
Event	Static Fire Test
Date	18.08.2025
Participants	Lamarr Team
Checklist Version	1.1
Mission Control	
ECUI	http://192.168.0.7
Grafana	http://192.168.0.7:3000

Tools

Name	Description
Cryo Safety Gear	Insulated Cryo safety gloves, face shield
Electrical Cabinet Key	A key to open the GSE Electrical cabinet and the GSE pneumatics cabinet
Eye Wash	Stored in personal safety equipment cabinet
Manual Valve Actuator	A long (1.5 m) stick
Pressure Safety Gear	Hearing protection, safety glasses
Spanner Wrench Set	A full set of spanner wrenches

Index	Checklist Item	I	V	Comment
1.	Initial Setup			
1.1	Trailer Setup			
1.1.1	Move the trailer to the test location	☐	☐	Position it over the red markings on the ground
1.1.2	Verify hand break is pulled and trailer support jacks are down	☐	☐	
1.1.3	Verify the power cable supplying the server cabinet is connected	☐	☐	
1.1.4	Remove all potential fire hazards from the vicinity of the trailer	☐	☐	Clothing, cardboard, flammable liquids, etc.
1.1.5	Set up the laboratory power supply to power the rocket	☐	☐	Place it on the back of the trailer below the bed
1.1.6	Bring three 300 bar nitrogen bottles and fix them to the trailer on their dedicated mounting positions	☐	☐	
1.1.7	Verify the connector of the pressurant bottles is pointing towards the pressurant tanking system	☐	☐	
1.2	IBC Container Setup			
1.2.1	Fill the two $1000\,\mathrm{L}$ IBC containers with water until they are at least three quarters full	☐	☐	
1.2.2	Position the IBC containers next to the trailer with equal distance to the launch rail	☐	☐	
1.2.3	Bring a CO2 bottle and strap it to the far right side of the rightmost IBC container	☐	☐	
1.2.4	Point the CO2 line towards the engine bay and fix it to the IBC container using zip ties	☐	☐	
1.3	Equipment Setup			
1.3.1	Setup the pavilion outside on the Assembly wall opposite of the launch rail trailer	☐	☐	
1.3.2	Secure the feet of the pavilion with weights	☐	☐	
1.3.3	Set up two foldable tables under the pavilion	☐	☐	

Index	Checklist Item	I	V	Comment
1.3.4	Verify cold flow tools, ethanol tanking and pressure regulator Auerboxes are ready	☐	☐	
1.3.5	Verify Launch Rail case is ready	☐	☐	
1.3.6	Verify aluminium truss is ready	☐	☐	
1.3.7	Verify launch rail extension segment is ready	☐	☐	
1.3.8	Bring the flame trench to the test location	☐	☐	
1.3.9	Bring the immersion pump to the test location	☐	☐	
1.3.10	Move the antenna to the blue container and fix it using ratchet straps	☐	☐	
1.3.11	Set up Mission Control Computer in Lamarr Container	☐	☐	
1.3.12	Set up Mission Lead Laptop in Assembly	☐	☐	Also bring an additional screen
1.4	**Rocket and GSE Setup**			Do this after "Trailer Setup"
1.4.1	Verify laboratory power supply is turned off	☐	☐	
1.4.2	Using the gray power cable, connect the M12 plug on the rocket labeled "12 V Power" with the laboratory power supply and secure it with a clamp	☐	☐	Red on red, black on black
1.4.3	Verify that the M12 plug on the rocket labeled "CAN" is connected with the port on the GSE server cabinet labeled "rocket"	☐	☐	
1.4.4	Using a white Ethernet cable, connect the Ox Press System network camera to the GSE server cabinet	☐	☐	
1.4.5	Verify antenna is connected to the GSE server cabinet port labeled "antenna"	☐	☐	
1.4.6	Verify that the CAN cable and the ethernet cable are secured with retaining clamps	☐	☐	
1.4.7	Verify GSE electrical cabinet, GSE pneumatics cabinet and LCB are connected to the GSE server cabinet with orange CAN cabes	☐	☐	
1.4.8	Verify pressurant tanking pressure sensor is conenctred to GSE Electrical Cabinet	☐	☐	

	Index	Checklist Item	I	V	Comment
	1.4.9	Verify dewar scale load cell and thrust measurement load cell are connected to GSE Electrical Cabinet	☐	☐	
	1.4.10	Verify the feed system mounts are fixed tightly to the launch rail	☐	☐	
	1.4.11	Verify the feed system is secured to the steel mount with zip ties	☐	☐	
	1.4.12	Connect and engage ox and fuel pressurant tanking quick disconnect	☐	☐	
	1.4.13	Tie down the ox pressurant tanking line to the aluminum profile of the camera using zip ties	☐	☐	
	1.4.14	Tie the ox decoupler to the camera aluminium profile with a piece of string	☐	☐	
	1.4.15	Connect the second aluminium truss to the launch rail with one strap and shackle pointing to each IBC container	☐	☐	
	1.4.16	Hook the big ratchet straps into the shackles	☐	☐	
	1.4.17	Extend the launch rail using 3 slot nuts and two rail-to-truss connectors	☐	☐	
	1.4.18	Erect the launch rail and secure it using the two support bars	☐	☐	
	1.4.19	Strap the launch rail down to the IBC containers	☐	☐	
	1.4.20	Verify the engine mounting flange is slotted into the launch rail and arrested with the hold down lever	☐	☐	
	1.4.21	Fix an emergency stop for the engine mounting flange on the rail above the highest point of the flange	☐	☐	
	1.4.22	Slot the holddown emergency blocker behind the holddown lever	☐	☐	
	1.4.23	Connect the submersible pump to the deluge system and place the pump in the IBC container with the cap	☐	☐	
	1.4.24	Connect ox decoupler to "ox decoupler" channel on the GSE electrical cabinet	☐	☐	
	1.4.25	Set up network cameras filming engine bay and rocket	☐	☐	
	1.4.26	Prepare igniters	☐	☐	

Index	Checklist Item	I V	Comment
1.5	Mission Briefing		
1.5.1	Define mission objectives	☐ ☐	
1.5.2	Safety briefing	☐ ☐	
1.5.3	Assign mission lead	☐ ☐	
1.5.4	Assign mission lead support	☐ ☐	
1.5.5	Assign mission control	☐ ☐	
1.5.6	Assign mission control support	☐ ☐	
1.5.7	Assign fire safety officer	☐ ☐	
1.5.8	Assign range safety officer 1	☐ ☐	Left side of the assembly (gas cage side)
1.5.9	Assign range safety officer 2	☐ ☐	Door from the hallway to the test area
1.5.10	Assign range safety officer 3	☐ ☐	Right side of the assembly (parking spots side)

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2.	Prepare Systems			
2.1	Power up rocket			
2.1.1	Turn on laboratory power supply, set voltage on channel 1 to $12\,\mathrm{V}$, set current limit to $5\,\mathrm{A}$	☐	☐	
2.1.2	Verify power cable connected to channel 1 of power supply with correct polarity	☐	☐	Red on red, black on black
2.1.3	Turn on channel 1 of power supply and verify status of Fuel ECU, Ox ECU and Engine ECU via status LEDs.	☐	☐	Blue LED = status good
2.1.4	Connect Ox Vent power cable to channel 2 of laboratory power supply and set Voltage to 16 V.	☐	☐	Blue LED = status good
2.1.5	Verify GSE electrical cabinet, GSE pneumatics cabinet and LCB are connected to the GSE server cabinet with orange CAN cabes	☐	☐	
2.1.6	Plug one of the power cables coming from the GSE server cabinet into the bottom of the GSE electrical cabinet	☐	☐	
2.1.7	Plug the other power cable into the bottom of the GSE pneumatics cabinet	☐	☐	
2.1.8	Open a browser window with the ECUI on the mission control laptop	☐	☐	ECUI Config: Lamarr_hedy Server restart command: docker compose restart llserver-ecui
2.1.9	Start the axis streaming assistant	☐	☐	
2.1.10	Start OBS and select the "Lamarr Testsetup" profile	☐	☐	3 Network camera feeds should be visible
2.1.11	Verify Mission Control is Master in their ECUI instance	☐	☐	
2.1.12	Set GSE electrical cabinet warning light to green	☐	☐	
2.2	Pressurize pneumatics system			
2.2.1	Verify pneumatics gas bottle is secured tightly	☐	☐	Pneumatics bottle is labeled and marked with a red cord
2.2.2	Remove safety cap of pneumatics gas bottle and attach pneumatics pressure regulator to bottle	☐	☐	

Index	Checklist Item	I	V	Comment
2.2.3	Connect the pneumatics tube from the pressure regulator to the pneumatics cabinet using the quick disconnect connector on the bottom	☐	☐	
2.2.4	Verify needle valve of pressure regulator is closed	☐	☐	
2.2.5	Verify pressure regulator is set to minimum	☐	☐	
2.2.6	Slowly open pneumatics bottle one revolution and note down pressure	☐	☐	Bottle Pressure:
2.2.7	Gently open pneumatics bottle all the way and finally turn it back one revolution	☐	☐	
2.2.8	Adjust pressure regulator until output pressure is $10\,\text{bar}$	☐	☐	
2.2.9	Close pneumatics manual vent valve	☐	☐	
2.2.10	Slowly open pressure regulator needle valve	☐	☐	
2.2.11	Open GSE pneumatics cabinet	☐	☐	Tools: Electrical Cabinet Key
2.2.12	Verify pneumatics system is airtight	☐	☐	
2.2.13	Verify bottom pressure regulator inside cabinet for dewar pressurisation is set to $1.0\,\text{bar}$ to $1.4\,\text{bar}$	☐	☐	
2.2.14	Verify hold down solenoid valve is disconnected from pneumatics ECU BOB 1	☐	☐	
2.2.15	Verify manual valve supplying the dewar press line is open	☐	☐	
2.2.16	Verify input pressure of the pneumatics system is between $10\,\text{bar}$ to $12\,\text{bar}$	☐	☐	
2.2.17	Verify valve terminal pressure it between $7.5\,\text{bar}$ to $8.5\,\text{bar}$	☐	☐	
2.2.18	Verify dewar pressurization line pressure it between $1.0\,\text{bar}$ to $1.4\,\text{bar}$	☐	☐	
2.2.19	Close GSE pneumatics cabinet	☐	☐	Tools: Electrical Cabinet Key

Index	Checklist Item	I	V	Comment
2.3	Verify ECÙI, rocket and GSE are fully operational			
2.3.1	Verify all pressures ambient	☐	☐	Propellant tanks, pressurant tanks, venturi lines, chamber pressure and pressurant tanking line
2.3.2	Verify spoofing resistor is connected to the Engine ECU pressure channel 2 and chamber pressure is simulated at 60 bar	☐	☐	
2.3.3	Verify all five rocket temperature sensors working	☐	☐	
2.3.4	Verify rocket ECU states visible and status "pad idle"	☐	☐	
2.3.5	Verify GSE supply voltages nominal	☐	☐	Pneumatics and Electrical ECU nominal voltage range: $11.5\,\mathrm{V}$ to $12.6\,\mathrm{V}$, Elec BoB nominal voltage: $24\,\mathrm{V}$
2.3.6	Verify rocket supply voltages nominal	☐	☐	Ox, Fuel and Engine ECU nominal voltage range: $11.5\,\mathrm{V}$ to $12.6\,\mathrm{V}$
2.3.7	Actuate pressurant tanking valve	☐	☐	
2.3.8	Actuate pressurant vent valve	☐	☐	
2.3.9	Actuate LOX tanking valve	☐	☐	
2.3.10	Actuate dewar pressurization valve	☐	☐	
2.3.11	Actuate ox pressurant valve	☐	☐	
2.3.12	Actuate ox vent	☐	☐	
2.3.13	Actuate ox main valve	☐	☐	
2.3.14	Actuate fuel pressurant valve	☐	☐	
2.3.15	Actuate fuel vent	☐	☐	
2.3.16	Actuate fuel main valve	☐	☐	
2.3.17	Test ox decoupler	☐	☐	
2.3.18	Check LCB functionality	☐	☐	Press down on the LOX dewar scale
2.3.19	Test water deluge system	☐	☐	

	Index	Checklist Item	I	V	Comment
	2.3.20	Lift submersible pump out of the water to stop the water from flowing out of the pump	☐	☐	
	2.3.21	Verify "prepress_fuel" sequence parameters are correct	☐	☐	Target pressure: 30 bar to 34 bar
	2.3.22	Verify "prepress_ox" sequence parameters are correct	☐	☐	Target pressure: 30 bar to 34 bar
	2.3.23	Verify "prepress_fuel" sequence runs nominally	☐	☐	
	2.3.24	Test abort scenario of "prepress_fuel" sequence and verify functionality of abort signal	☐	☐	Reset abort state when finished
	2.3.25	Verify "internal_control_and_lox_prepress" sequence runs nominally	☐	☐	
	2.3.26	Test abort scenario of "internal_control_and_lox_prepress" sequence and verify functionality of abort signal	☐	☐	Reset abort state when finished
	2.3.27	Test one set of igniters by connecting them to the Engine ECU and starting the "internal_control_and_lox_prepress" sequence	☐	☐	
	2.3.28	Note down rocket current draw on laboratory power supply	☐	☐	Current draw:
	2.3.29	Unplug and replug Ox Main valve servo	☐	☐	

Index	Checklist Item	I	V	Comment
3.	Fuel and Ox System Leak Check			
3.1	Connect and purge pressurant bottle			Tools: Pressure Safety Gear
3.1.1	Put on hearing protection and safety glasses	☐	☐	
3.1.2	Hoist yellow safety status flag	☐	☐	
3.1.3	Set GSE electrical cabinet warning light to red	☐	☐	
3.1.4	Verify pressurant bottle is secured tightly	☐	☐	
3.1.5	Remove safety cap of pressurant gas bottle	☐	☐	Pressurant bottle is labeled and marked with a blue cord
3.1.6	Connect pressurant bottle to pressurant tanking system	☐	☐	
3.1.7	Open pressurant tanking valve	☐	☐	
3.1.8	Open pressurant tanking gas throttle all the way	☐	☐	
3.1.9	Open pressurant tanking line in the middle	☐	☐	
3.1.10	Firmly hold upstream fuel pressurant tanking line and slightly open and close pressurant bottle for two seconds	☐	☐	
3.1.11	Verify bottle is closed	☐	☐	
3.1.12	Close pressurant tanking valve	☐	☐	
3.1.13	Close pressurant tanking gas throttle	☐	☐	
3.1.14	Reconnect pressurant tanking line	☐	☐	
3.2	Pressurant filling			
3.2.1	Vacate all non-essential personnel from test area	☐	☐	
3.2.2	Hoist red safety status flag	☐	☐	
3.2.3	Verify pressurant tanking line connected	☐	☐	
3.2.4	Verify pressurant tanking gas throttle is completely closed, then set to 0.5	☐	☐	
3.2.5	Verify pressurant tanking valve is closed	☐	☐	
3.2.6	Slowly open pressurant bottle one quarter revolution and note down pressure	☐	☐	Bottle pressure:

Index	Checklist Item	I	V	Comment
3.2.7	Verify fuel pressurant valve is closed	☐	☐	
3.2.8	Verify ox pressurant valve is closed	☐	☐	
3.2.9	Close pressurant vent valve	☐	☐	
3.2.10	Open pressurant tanking valve	☐	☐	Call out pressurant tank pressure every 10 bar
3.3	Pressurize fuel and ox system			
3.3.1	Run fuel pre-pressurization sequence and wait for sequence to terminate	☐	☐	Call out fuel tank pressure every 5 Bar
3.3.2	Verify pre-pressurization sequence terminated nominally and fuel pressurant valve is closed	☐	☐	
3.3.3	Run ox pre-pressurization sequence and wait for sequence to terminate	☐	☐	Call out ox tank pressure every 5 Bar
3.3.4	Verify pre-pressurization sequence terminated nominally and ox pressurant valve is closed	☐	☐	
3.3.5	Close pressurant bottle	☐	☐	
3.3.6	Wait two minutes	☐	☐	
3.3.7	Verify fuel tank pressure is stable and around 30 bar to 34 bar	☐	☐	
3.3.8	Verify ox tank pressure is stable and around 30 bar to 34 bar	☐	☐	
3.3.9	Verify there are no leaks in the system	☐	☐	
3.3.10	Verify pressurant bottle is closed	☐	☐	
3.3.11	Open pressurant vent valve	☐	☐	
3.3.12	Wait for all the gas in the pressurant tanking system to escape	☐	☐	
3.3.13	Close pressurant tanking valve	☐	☐	
3.4	Fuel and ox system depressurizing			
3.4.1	Step away from the rocket	☐	☐	

Index	Checklist Item	I	V	Comment
3.4.2	Open fuel vent and wait for pressure to sink to ambient pressure	☐	☐	
3.4.3	Slowly open fuel pressurant valve to depressurize the fuel pressurant tank	☐	☐	
3.4.4	Open ox vent and wait for pressure to sink to ambient pressure	☐	☐	
3.4.5	Slowly open ox pressurant valve to depressurize the fuel pressurant tank	☐	☐	
3.4.6	Verify all pressures ambient	☐	☐	
3.4.7	Call out hearing protection can be removed	☐	☐	
3.4.8	Close fuel pressurant valve	☐	☐	
3.4.9	Close ox pressurant valve	☐	☐	
3.4.10	Verify pressurant vent valve is open	☐	☐	
3.4.11	Verify pressurant tanking valve is closed	☐	☐	
3.4.12	Verify pressurant tanking line pressure is ambient	☐	☐	
3.4.13	Hoist yellow safety status flag	☐	☐	

Index	Checklist Item	I	V	Comment
4.	Fuel Tanking			
4.0.1	Prepare eye wash	☐	☐	Tools: Eye Wash
4.0.2	Put on safety glasses	☐	☐	
4.0.3	Verify fuel pressurant valve closed	☐	☐	
4.0.4	Verify fuel main valve closed	☐	☐	
4.0.5	Verify fuel vent open and not stuck in the closed position	☐	☐	
4.0.6	Verify canister is at least half full	☐	☐	
4.0.7	Verify fuel tanking cap is in place	☐	☐	
4.0.8	Place fuel tanking canister on top of scale	☐	☐	
4.0.9	Using a 8 mm pneumatics tube, connect fuel canister riser to rocket fuel tanking nipple	☐	☐	
4.0.10	Using a 8 mm pneumatics tube, connect fuel canister pressurization connector to ethanol canister pressurization valve	☐	☐	
4.0.11	Open ethanol canister pressurization valve	☐	☐	
4.0.12	Open manual ethanol tanking valve	☐	☐	
4.0.13	Close manual ethanol tanking when $4\,\mathrm{kg}$ are reached Until then: call out tanked mass every $500\,\mathrm{g}$	☐	☐	
4.0.14	Close ethanol canister pressurization valve	☐	☐	
4.0.15	Disconnect fuel tanking line making sure no ethanol splashes on the electronics	☐	☐	
4.0.16	Move fuel tanking canister out of the way	☐	☐	

Index	Checklist Item	I	V	Comment
5.	Engine and Igniter Preparation			
5.0.1	Fix engine to the engine flange	☐	☐	
5.0.2	Loop steel cable around ox venturi line and launch rail truss	☐	☐	
5.0.3	Connect ox and fuel venturi line to injector	☐	☐	
5.0.4	Connect chamber pressure sensor to engine ECU pressure sensor channel 3	☐	☐	
5.0.5	Verify spoofing resistor is connected to the Engine ECU pressure channel 2 and chamber pressure is simulated at 60 bar	☐	☐	
5.0.6	Verify chamber pressure sensor is operational	☐	☐	
5.0.7	Connect fire suppression system to CO2 bottle	☐	☐	
5.0.8	Mount igniter mount to launch rail profile	☐	☐	
5.0.9	Connect igniter ematches to igniter key switch box	☐	☐	
5.0.10	Verify igniter key switches are in the open position	☐	☐	
5.0.11	Connect igniter key switch box to engine ECU high power channel 1 and 2	☐	☐	
5.0.12	Place igniter key switch box next to Mission Lead Laptop	☐	☐	
5.0.13	Insert igniter into the combustion chamber and fix it in place	☐	☐	
5.0.14	Place flame diverter under combustion chamber and secure it in place	☐	☐	
5.0.15	Send range safety officers to check points	☐	☐	
5.0.16	Hoist red safety status flag	☐	☐	
5.0.17	Range safety is now in effect, test area is closed off	☐	☐	

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6.	LOX tanking			
6.1	Set up LOX tanking			
6.1.1	Put on face shield or safety glasses	☐	☐	Tools: Cryo Safety Gear
6.1.2	Verify dewar scale is connected to the GSE electrical cabinet port labeled ”dewar weight”	☐	☐	
6.1.3	Verify dewar scale is operational	☐	☐	Lightly press on the dewar scale and check the ECUI for feedback
6.1.4	Tare dewar scale	☐	☐	
6.1.5	Place LOX dewar on dewar scale	☐	☐	
6.1.6	Verify dewar flange bolts are secured	☐	☐	
6.1.7	Remove blind plug from the LOX dewar riser	☐	☐	
6.1.8	Connect the LOX dewar riser to the right of the LOX tanking valve using the long Swagelok pipe assembly	☐	☐	Tools: Spanner Wrench Set
6.1.9	Connect the left of the LOX tanking valve to the LOX decoupler braided hose using the short Swagelok pipe assembly	☐	☐	Tools: Spanner Wrench Set
6.1.10	Connect the LOX decoupler assembly to the left of the LOX tanking valve	☐	☐	Tools: Spanner Wrench Set
6.1.11	Plug the white PTFE tube coming from the dewar press solenoid into the LOX dewar pressurisation connection	☐	☐	
6.2	Final Equipment Check			
6.2.1	Verify Mission Lead Laptop is connected to GSE Access Point network	☐	☐	
6.2.2	Verify Mission Lead Laptop is running and ECUI is open	☐	☐	
6.2.3	Verify OBS is open on camera feedback is coming in	☐	☐	
6.2.4	Verify submersible pump cable is ready at Mission Lead table	☐	☐	
6.2.5	Verify Key Box is connected to Igniter Box and keys are in place	☐	☐	
6.2.6	Verify respirator mask is ready	☐	☐	

Index	Checklist Item	I	V	Comment
6.2.7	Verify Action Cam is mounted to launch rail	☐	☐	
6.2.8	Verify fire suppression system ball valve is open	☐	☐	
6.2.9	Verify BFI plot is clear of bystanders	☐	☐	
6.3	LOX Tanking			
6.3.1	Note down time	☐	☐	
6.3.2	Restart llserver	☐	☐	restart command: docker compose restart llserver-ecui
6.3.3	Verify "internal_control_and_lox_prepress" parameters are correct	☐	☐	
6.3.4	Note down dewar mass	☐	☐	Dewar mass:
6.3.5	Engage ox decoupler	☐	☐	
6.3.6	Push the ox decoupler into the ox tanking connection	☐	☐	
6.3.7	Verify ox decoupler is secured in place	☐	☐	
6.3.8	Put additional insulation over the exposed areas of the LOX tanking assembly	☐	☐	Right on top of the dewar, etc.
6.3.9	Verify ox main valve is closed	☐	☐	
6.3.10	Verify ox pressurant valve is closed	☐	☐	
6.3.11	Verify ox vent is open and not stuck in the closed position	☐	☐	Tools: Manual Valve Actuator
6.3.12	Step away from the rocket	☐	☐	
6.3.13	Open LOX tanking valve	☐	☐	
6.3.14	Open dewar pressurization solenoid and call out if tanking is underway	☐	☐	
6.3.15	Close LOX tanking valve when LOX starts coming out of the ox vent	☐	☐	
6.3.16	Close dewar pressurisation solenoid valve	☐	☐	
6.3.17	Disengage ox decoupler	☐	☐	
6.3.18	Note down dewar mass	☐	☐	Dewar mass:

Index	Checklist Item	I	V	Comment
7.	System Check			
7.1	Check rocket sensor and actuator function			
7.1.1	Verify all rocket pressure sensors are working nominally	☐	☐	Pressurant tank sensors, propellant tanks sensors and venturi line sensors
7.1.2	Note down rocket current draw on power supply	☐	☐	Current draw:
7.1.3	Actuate ox pressurant valve	☐	☐	
7.1.4	Actuate ox vent	☐	☐	
7.1.5	Open and close ox main valve for a short moment	☐	☐	
7.2	Ox System Leak Check			
7.2.1	Put on hearing protection and face shield	☐	☐	
7.2.2	Verify ox pressurant tanking line connected	☐	☐	
7.2.3	Verify pressurant tanking valve is closed	☐	☐	
7.2.4	Verify pressurant tanking gas throttle is completely closed, then set to 0.5	☐	☐	
7.2.5	Slowly open pressurant bottle one quarter revolution	☐	☐	
7.2.6	Verify ox pressurant valve is closed	☐	☐	
7.2.7	Verify fuel pressurant valve is closed	☐	☐	
7.2.8	Close pressurant vent valve	☐	☐	
7.2.9	Open pressurant tanking valve	☐	☐	
7.2.10	Run ox pre-pressurization sequence	☐	☐	Call out ox tank pressure every 5 bar
7.2.11	Verify pre-pressurization sequence terminated nominally and ox pressurant valve is closed	☐	☐	
7.2.12	Open ox vent and wait for pressure to sink to ambient pressure	☐	☐	
7.2.13	Test thrust measurement load cell	☐	☐	
7.2.14	Tare thrust measurement load cell	☐	☐	
7.2.15	Verify Mission Lead Laptop is ready	☐	☐	

Index	Checklist Item	I	V	Comment
8.	Static Fire Test			
8.1	Fully pressurize rocket	☐	☐	
8.1.1	Clear Assembly	☐	☐	
8.1.2	Verify igniter box keys are with test personnel	☐	☐	
8.1.3	Verify fire extinguishers are in place	☐	☐	
8.1.4	Run fuel pre-pressurization sequence and wait for sequence to terminate	☐	☐	Call out fuel tank pressure every 5 Bar
8.1.5	Verify pre-pressurization sequence terminated nominally and fuel pressurant valve is closed	☐	☐	
8.1.6	Verify fuel tank pressure is stable between 30 bar to 34 bar	☐	☐	
8.1.7	Close pressurant bottle	☐	☐	
8.1.8	Open pressurant vent valve	☐	☐	
8.1.9	Wait for all the gas in the pressurant tanking system to escape	☐	☐	
8.1.10	Start Action cam recording	☐	☐	
8.1.11	Switch pressure regulator to high pressure bottle	☐	☐	
8.1.12	Verify pressurant tanking valve is closed	☐	☐	
8.1.13	Verify pressurant tanking gas throttle is completely closed, then set to 0.5	☐	☐	
8.1.14	Slowly open pressurant bottle one quarter revolution	☐	☐	
8.1.15	Verify ox pressurant valve is closed	☐	☐	
8.1.16	Close pressurant vent valve	☐	☐	
8.1.17	Open pressurant tanking valve	☐	☐	Call out pressurant tank pressure every 10 bar
8.1.18	Wait for ox pressurant pressure to stabilize	☐	☐	
8.1.19	Open pressurant tanking gas throttle all the way	☐	☐	
8.1.20	Open pressurant bottle all the way	☐	☐	

	Index	Checklist Item	I	V	Comment
	8.1.21	All personnel clear test area	☐	☐	
	8.1.22	Request Master in ECUI on Mission Lead Laptop	☐	☐	
	8.1.23	Select "internal_control_and_lox_prepress" sequence	☐	☐	
	8.1.24	Start network camera recording	☐	☐	
	8.2	Initiate Go or No-Go poll:	☐	☐	
	8.2.1	Mission Control Go or No-Go	☐	☐	
	8.2.2	Fire Safety Officer Go or No-Go	☐	☐	
	8.2.3	Range Safety Officer 1 Go or No-Go	☐	☐	
	8.2.4	Range Safety Officer 2 Go or No-Go	☐	☐	
	8.2.5	Range Safety Officer 3 Go or No-Go	☐	☐	
	8.3	Proceed with static fire test	☐	☐	
	8.3.1	Start deluge system pump	☐	☐	
	8.3.2	Verify water is coming out of the flame trench	☐	☐	
	8.3.3	Verify test area is clear	☐	☐	
	8.3.4	Close igniter key switch circuit	☐	☐	
	8.3.5	Run "internal_control_and_lox_prepress" sequence	☐	☐	

Index	Checklist Item	I	V	Comment
9.	Depressurize rocket			
9.0.1	Check camera feedback for fire	☐	☐	
9.0.2	Stop submersible pump	☐	☐	
9.0.3	Verify ox tank pressure is ambient	☐	☐	
9.0.4	Verify ox pressurant tank pressure is ambient	☐	☐	
9.0.5	Verify ox main valve is open	☐	☐	
9.0.6	Verify ox vent is open	☐	☐	
9.0.7	Verify fuel tank pressure is ambient	☐	☐	
9.0.8	Verify fuel pressurant tank pressure is ambient	☐	☐	
9.0.9	Verify fuel main valve is open	☐	☐	
9.0.10	Verify fuel vent is open	☐	☐	
9.0.11	Verify fuel pressurant tank pressure is ambient	☐	☐	
9.0.12	Approach trailer	☐	☐	
9.0.13	Close the pressurant bottle	☐	☐	
9.0.14	Open the pressurant vent valve	☐	☐	
9.0.15	Open the pressurant tanking valve to depressurize the pressurant tanking line	☐	☐	
9.0.16	Verify pressurant tanking line pressure is ambient	☐	☐	
9.0.17	Close pressurant tanking valve	☐	☐	
9.0.18	Close ox main valve	☐	☐	
9.0.19	Close fuel main valve	☐	☐	
9.0.20	Stop network camera recordings via OBS	☐	☐	
9.0.21	Hoist green safety status flag	☐	☐	
9.0.22	Set GSE electrical cabinet warning light to green	☐	☐	

A.6.3 Ox Cleaning Checklist:

OxClean (All Parts EXCEPT SERTO Aluminum Parts)

1. Ox Cleaning shall only be done in thoroughly cleaned room with closed doors and no open windows, make sure to wear fresh and clean gloves, do not use paper towels, clean working station in advance
2. Gather all parts in contact with oxidizer ☐
3. Disassemble all parts to base components ☐
4. Remove all visible debris (especially threads) ☐
5. Rough cleaning with water ☐
6. Cleaning with distilled water and a fresh tooth brush ☐
7. Clean with LOCTITE and seperate Toothbrush ☐
8. Soak parts for 10 minutes in LOCTITE:Water (1:4) solution ☐
9. Put in Ultra-Sonic cleaner cont. LOCTITE Solution for $5\,\mathrm{min}$ at $50\,^{\circ}\mathrm{C}$ ☐
10. Rinse off in distilled water ☐
11. Let parts dry on drying rack ☐
12. After parts are completly dry, wrap single parts in fresh aluminum foil or cover exposed areas of assembled parts with fresh aluminum foil. ☐

OxClean (Aluminum SERTO Parts)

1. Ox Cleaning shall only be done in thoroughly cleaned room with closed doors and no open windows, make sure to wear fresh and clean gloves, do not use paper towels, clean working station in advance
2. Gather all parts in contact with oxidizer ☐
3. Disassemble all parts to base components ☐
4. Remove all visible debris (especially threads) ☐
5. Rough cleaning with water ☐
6. Cleaning with distilled water and a fresh tooth brush ☐
7. Clean with IPA and seperate Toothbrush ☐
8. Soak parts for 10 minutes in IPA ☐
9. Put in Ultra-Sonic cleaner cont. IPA for $5\,\mathrm{min}$ at $50\,^{\circ}\mathrm{C}$ ☐
10. Rinse off in distilled water ☐
11. Let parts dry on drying rack ☐
12. After parts are completly dry, wrap single parts in fresh aluminum foil or cover exposed areas of assembled parts with fresh aluminum foil. ☐

OxClean (Big parts, long pipes)

1. Cleaning shall only be done in thoroughly cleaned room with closed doors and no open windows, make sure to wear fresh and clean gloves, do not use paper towels, clean working station in advance
2. Gather all parts in contact with oxidizer ☐
3. Disassemble all parts to base components ☐
4. Remove all visible debris (especially threads) ☐
5. Rough cleaning with water ☐
6. Cleaning with distilled water and a fresh tooth brush ☐
7. Clean with LOCTITE and seperate Toothbrush ☐
8. Fill parts with cleaning soultion and let it soak for 10 minutes ☐
9. Rinse thoroughly with distilled water ☐
10. Let parts dry on drying rack ☐
11. After parts are completly dry, cover openings with fresh aluminum foil or cover exposed areas of assembled parts with fresh aluminum foil. ☐

A.6.4 Propulsion assembly check:

LAMARR
Engine Assembly Checklist

Injector
Tools
14mm, 19mm Wrenches
2mm, 3mm Allen Key
Lox8

Components
Engine Head
Pintle Sleeve
Orifice Plate
Injector Shim
Pintle
PTFE O-Ring 58mm x 2mm
fillister head screw M3x10
6x countersunk head screw M5x10
2x PTFE O-Ring 11,11mm x 1,78mm
2x SERTO G1/4 fitting (without O-Ring)
SERTO G1/8 pressure line fitting (part of thermal decoupling assembly)
3mm stainless steel tube (part of thermal decoupling assembly)
SERTO G 1/8 pressure sensor fitting (part of thermal decoupling assembly)

Injector Assembly Checklist

- ☐ 1. put Orifice Plate in to Engine Head
- ☐ 2. apply Lox8 grease to PTFE O-Ring (52x2)
- ☐ 3. put PTFE O-Ring 58mm x 2mm in to Engine Head
- ☐ 4. put Shim in to Pintle Sleeve(chamfer oriented upstream)
- ☐ 5. slide Pintle in Sleeve
- ☐ 6. hold Pintle and Sleeve tight together and rotate 180°
- ☐ 7. put M3x10 screw on to allen key
- ☐ 8. screw M3x10 through Pintle Sleeve into Pintle
- ☐ 9. slide Pintle Sleeve in to Engine-Head
- ☐ 10. insert 6 countersunk head screws M5
- ☐ 11. tighten them loosely
- ☐ 12. tighten srcews in a alternating manner
- ☐ 13. apply Lox8 grease to PTFE O-Ring 11,11mm x 1,75mm
- ☐ 14. slide PTFE O-Ring 11,11mm x 1,75mm on to G 1/4 SERTO fitting (over table)
- ☐ 15. screw fitting with PTFE O-Ring in to Ox side by hand
- ☐ 16. tighten it with 19mm wrench

Injector Assembly Checklist

- [ ] 17. apply Lox8 grease to PTFE O-Ring 11,11mm x 1,75mm
- [ ] 18. slide PTFE O-Ring 11,11mm x 1,75mm on to G 1/4 SERTO fitting (over table)
- [ ] 19. screw fitting with PTFE O-Ring in to Ox side by hand
- [ ] 20. tighten it with 19mm wrench
- [ ] 21. apply Lox8 to SERTO seal faces
- [ ] 22. screw SERTO G1/8 pressure fitting by hand in to EngineHead (clean seal faces)
- [ ] 23. tighten it with 14mm wrench
- [ ] 24. apply Lox8 to SERTO seal faces of pressure fitting
- [ ] 25. put thermal decoupler on Serto pressure fitting and tighten loosely
- [ ] 26. tighten it with 8mm wrench for 1/4 turn
- [ ] 27. cover every inlet and outlet with aluminiumfoil

Thrust Chamber
Tools
2x 8mm wrench
Vaseline

Components
Injector (assembled)
Casing
Retainer
Chamber Liner
Nozzle
4x Thrust Pillars
1x PTFE O-Ring 95 x 3mm
4x FKM O-Ring 76mm x 2mm
12x hex head screws M5 x 30
12x M5 screw nut

Thrust Chamber Assembly Checklist

- ☐ 1. fix injector assembly upside down (Pintle up)
- ☐ 2. apply LOX8 to PTFE 95x3mm O-ring and burning chamber sealing groove
- ☐ 3. insert o-ring into groove
- ☐ 4. put Chamber Casing in injector
- ☐ 5. put washer (12xM5) on screws(12x M5x30) and insert them in every hole through the casing and lightly screw them in
- ☐ 6. apply vaseline to the FKM 76x2mm o-rings and their respective grooves in chamber liner and nozzle
- ☐ 7. fit the o-rings into their grooves
- ☐ 8. cover the outside of liner and nozzle in vaseline as well as the top of the liner which touches the injector
- ☐ 9. insert nozzle into liner
- ☐ 10. insert liner together with nozzle into chamber casing
- ☐ 11. push liner and nozzle in until they fit onto the injector
- ☐ 12. check if liner is tight on the injector
- ☐ 13. tighten all M5 screws by hand
- ☐ 14. tighten all M5 screws with 8mm wrench in an alternating manner until PTFE o-ring is fully compressed
- ☐ 15. screw on retainer nut on to the casing and tighten it
- ☐ 16. rotate assembly by 180°

Thrust Chamber Assembly Checklist
☐ 17. put all 4 thrust pillars on the screws in their respective positions at 45°, 135°, 225° and 315°
☐ 18. put 8x M5 washer and 8x M5 nuts on screws over thrust pillars and tighten them by hand
☐ 19. put 4x M5 washer and 4x M5 nuts on the remaining screws ant tighten them by hand
☐ 20. tighten the nuts next to the thrust pillars with an 8mm wrench

Main Lines

Tools

17mm wrench
piece of clean PTFE
Bullet
SERTO M14x1 pilot Tool
Chuck

Fuel Main Line

Fuel Line
Fuel Venturi 3,1mm
PTFE O-Ring 6mm x 1mm
2x SERTO support shell 8mm
2x SERTO clamping ring 10mm
2x SERTO union nut 10mm

Ox Main Line

OX Line
OX Venturi 3,7mm
PTFE O-Ring 6mm x 1mm
2x SERTO support shell 8mm
2x SERTO clamping ring 10mm
2x SERTO union nut 10mm

	Main Line Assembly Checklist (same for both)
☐	1. apply LOX8 on Bullet tip, on Venturi uptream end and the PTFE o-ring 6x1mm and both 8mm SERTO support shells
☐	2. stick bullet on to venturi at the upstream end
☐	3. slide PTFE o-ring over bullet onto the venturi, press it into the respective groove and massage it rolling between finger tips
☐	4. stick venturi with upstream end into the downstream end of the main line)
☐	5. use a clean PTFE piece to press the venturi in to the main line
☐	6. press 2x 8mm SERTO support shells in to both ends of the main line
☐	7. apply LOX8 to 2x 10mm SERTO union nuts outside and inside
☐	8. Clamp SERTO Pilot tool in a chuck and apply LOX8
☐	9. fit 10mm union nut and 10mm clamping ring on one end of main line and screw union nut on to the pilot tool by hand
☐	10. tighten union nut with 17mm wrench for 1 and 3/4 turns
☐	11. repeat the clamping of shell and union nut on other side of main line

Fuel Pressurant system

Tools

13mm, 14mm, 17mm, 19mm, 22mm, 32mm wrench

Components
Pressurant tank
Pressure adapter
Pressure reducer
Fuel pressure manifold
Serto G1/4 fitting
Pressure sensor
Magnetic vent valve
Servo
Burst disc

Injector Assembly Checklist
☐ 1. screw pressure adapter in to pressurant tank and tighten with wrench
☐ 2. screw burst disc with G1/4 USIT ring into fuel pressure manifold
☐ 3. screw pressure sensor in to manifold
☐ 4. mount magnetiv vent valve on to manifold)
☐ 5. mount servo onto fuel pressure manifold
☐ 6. screw serto G1/4 fitting into manifold
☐ 7. screw pressure reducer into manifold
☐ 8. screwpressure reducer with manifold into pressure adapter

Ox Pressurant System
Tools
13mm, 14mm, 17mm, 19mm, 22mm, 32 wrench
Lox8

Components
Pressurant tank
Pressure adapter
Pressure reducer
Upper Ox pressure manifold
Serto G1/4 fitting with PTFE o-ring
Pressure sensor
magnetic vent valve
Servo
Burst disc

Injector Assembly Checklist

☐	1. put Orifice Plate in to Engine Head
☐	2. apply Lox8 grease to PTFE O-Ring (52x2)
☐	3. put PTFE O-Ring 52mm x 2mm in to Engine Head
☐	4. put Shim in to Pintle Sleeve(chamfer oriented upstream)
☐	5. slide Pintle in Sleeve
☐	6. hold Pintle and Sleeve tight together and rotate 180°
☐	7. put M3x10 screw on to allen key
☐	8. screw M3x10 through Pintle Sleeve into Pintle
☐	9. slide Pintle Sleeve in to Engine-Head
☐	10. insert 6 countersunk head screws M5
☐	11. tighten them loosely
☐	12. tighten srcews in a alternating manner
☐	13. apply Lox8 grease to PTFE O-Ring 11,11mm x 1,75mm
☐	14. slide PTFE O-Ring 11,11mm x 1,75mm on to G 1/4 SERTO fitting (over table)
☐	15. screw fitting with PTFE O-Ring in to Ox side by hand
☐	16. tighten it with 19mm wrench

Injector Assembly Checklist

- ☐ 17. apply Lox8 grease to PTFE O-Ring 11,11mm x 1,75mm
- ☐ 18. slide PTFE O-Ring 11,11mm x 1,75mm on to G 1/4 SERTO fitting (over table)
- ☐ 19. screw fitting with PTFE O-Ring in to Ox side by hand
- ☐ 20. tighten it with 19mm wrench
- ☐ 21. apply Lox8 to SERTO seal faces
- ☐ 22. screw SERTO G1/8 pressure fitting by hand in to EngineHead (clean seal faces)
- ☐ 23. tighten it with 14mm wrench
- ☐ 24. apply Lox8 to SERTO seal faces of pressure fitting
- ☐ 25. put thermal decoupler on Serto pressure fitting and tighten loosely
- ☐ 26. tighten it with 8mm wrench for 1/4 turn
- ☐ 27. cover every inlet and outlet with aluminiumfoil

Tanks
Tools
19mm, 32mm wrench
Lox8
lower ox pressure manifold
Components
tank
1x Serto G1/4 fitting with PTFE o-ring
2x Serto G1/4 fitting with FKM o-ring
1x Serto G1/4 adjustable adapter union

Injector Assembly Checklist	
☐	1. apply lox 8 on Serto G1/4 fitting with PTFE o-ring and sealing face on tank
☐	2. screw fitting into one tanks side by hand
☐	3. tighten fitting until o-ring is fully compressed
☐	4. screw lower ox pressurant manifold into the other side of the tank by hand
☐	5. tighten the manifold with a wrench until o-ring is fully compressed

A.7 Launch support Equipment:

A.7.1 Launch Support Equipment List

- Launch Rail
- Tanking structure
- LOX dewar
- Nitrogen bottle at 300 bar
- Nitrogen bottle at >50 bar
- Electronics cabinet
- Pneumatics cabinet
- Server cabinet with server, UPS and networking equipment
- Additional cameras
- Bottle pressure regulator
- Ethanol tanking container
- Tools:
  - Spanner set
  - Hex key set
  - Torx key set
  - Crescent wrench
  - Pipe wrench
  - Screwdriver set
  - Utility knife
  - Hose cutter
  - Multimeter
  - Scale
  - hydraulic jack
- PPE:
  - Gloves
  - Hearing protection
  - Face shields
  - Cryogenic gloves
- Spare parts:
  - Assorted pneumatic components

- Pneumatic hose
- Spare LOX tanking valve
- Spare insulation material

A.7.2 Launch Support Equipment simple operational manual

Before Launch

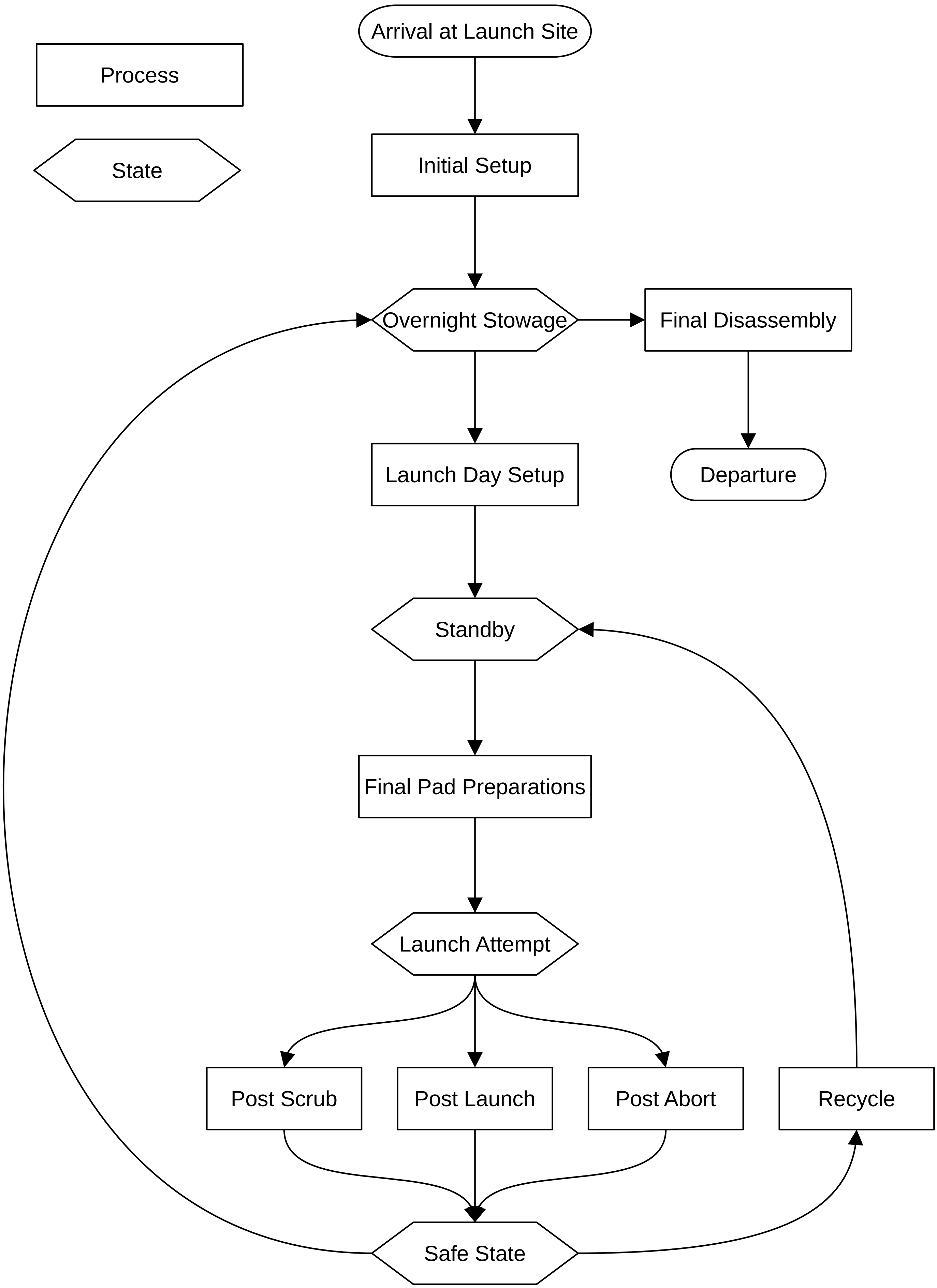
1. Cars and trailer arrive at the launch site, rocket and materials needed for rocket preparations and mission control are loaded off at the teams preparation site.
2. Mission control is set up.
3. Trailer with launch support equipment is transported to the launch area.
4. Server rack and tanking structure is unloaded.
5. Server and networking (including IP-cameras) and additional cameras are set up, meanwhile...
6. Launch rail trusses are unloaded and arranged for assembly.
7. Trailer is aligned with launch azimuth and leveled.
8. Launch rail trusses are assembled in horizontal position, guy wires are attached to the top.
9. Launch rail is aligned and fastened.
10. Launch rail is erected to launch elevation.
11. Corner brakes are fastened in place.
12. Guy wires are fixed in place with earth anchors.
13. Tanking structure is put on the trailer, electrical and pneumatic cabinets are mounted.
14. Filled LOX dewar is transported to the launch site and lifted into place in the tanking structure.
15. Both nitrogen bottles are transported to the launch site and fixed to the trailer with ratchet straps.
16. Electrical and pneumatic connections are made and double checked.
17. Bottle pressure regulator is connected to the pneumatics nitrogen bottle, pneumatic cabinet is connected to the pressure regulator.
18. Bottle pressure regulator is set to 12 bar.

19. In the pneumatics cabinet, top pressure regulator (pneumatics) is set at 8 bar, bottom pressure regulator (dewar pressurization) is set at 1.4 bar.
20. Pneumatics are pressurized, and actuator/hold-down position is checked. Actuation is checked with the manual override on the solenoid valves.
21. Connection with mission control is established.
22. Server is connected to the electronics.
23. Valve actuation by electronics is checked.
24. Dewar pressurization system is purged and connected to the LOX dewar.
25. Dewar is connected to the LOX tanking valve.
26. 300 bar nitrogen bottle is connected to the HPN2 tanking system.
27. (With hearing protection and face shields) Nitrogen bottle is slowly opened.
28. Leaks and bottle pressure >=300 bar is checked.
29. Bottle is closed and pressure vented.
30. Rocket and igniters arrive on pad.
31. Rocket is mounted on the launch rail, hold-down is actuated manually.
32. LOX and HPN2 disconnects are connected to the rocket, and disconnection and retraction is tested.
33. Non-essential personnel vacated the launch pad.
34. Ethanol is tanked into the rocket.
35. LOX and HPN2 disconnects are connected to the rocket.
36. 300 bar nitrogen bottle is opened, all pressure regulators are checked.
37. Additional cameras are started.
38. Igniter is inserted into the engine and connected to the launch structure.
39. Igniter channel is checked for zero-potential.
40. Igniter is connected to the electronics.
41. All personnel vacates the pad.

After Launch

1. Pad is approached carefully.
2. Pressurant nitrogen bottle is closed.
3. HPN2 tanking system is vented by opening the tanking valve.
4. Pneumatics nitrogen bottle is closed.
5. Pneumatics are vented by the manual venting valve.
6. Pad is disassembled in the reverse order to the pre-launch manual.

GSE Lifecycle during the Competition



A.7.3 Launch Support Equipment details

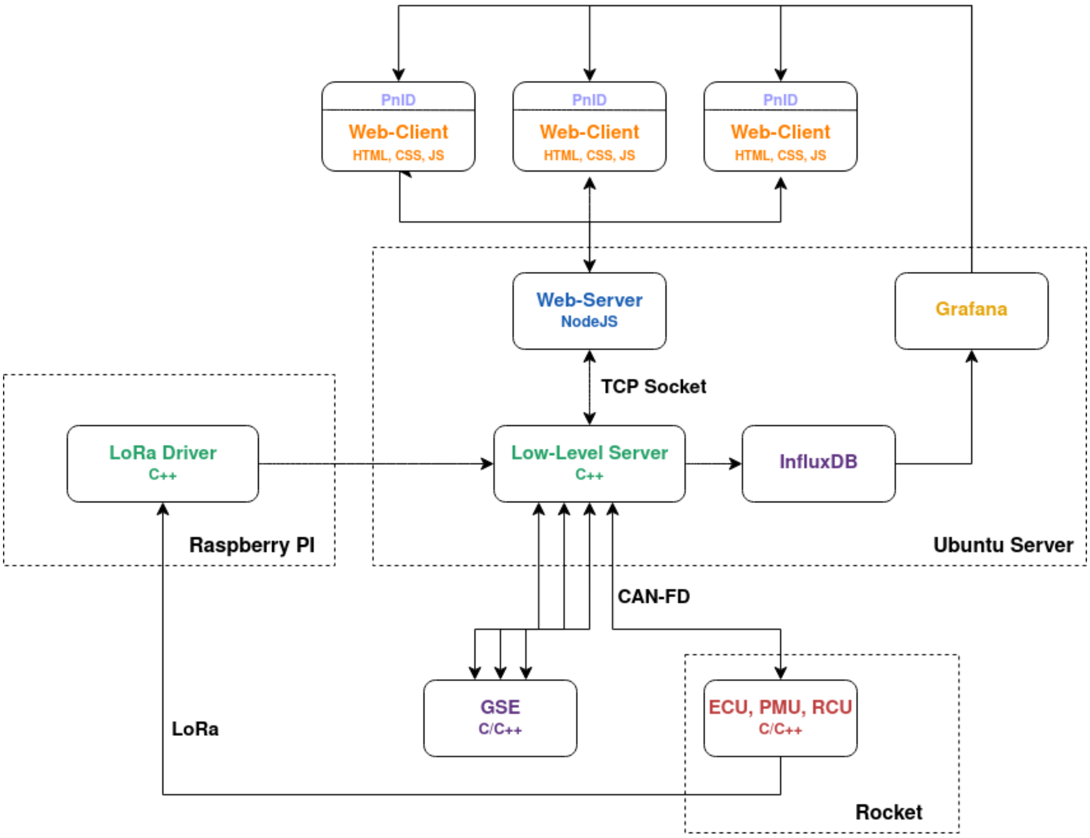


Fig. A.1: Software Architecture

Detailed Software Architecture:

Mission Control Our Mission Control operators interface with the hardware via an in-house developed software stack as depicted in figure A.1. The Mission Control setup consists of a PC or laptop running a web application inside a web browser (see A.2 for a sample image). This web application serves as the interface between the operator and the rocket, as well as the Ground Support Equipment. It displays the current state of the rocket, all measured data and actuators in a self-developed interactive Piping and Instrumentation Diagram (P&ID/PnID). Every value for each P&ID element gets validated and any outside of nominal range are highlighted by a change in color. This way, the operator doesn't have to check each number in detail but rather only has to watch for color changes, which are much more apparent. All commands such as tanking, pressurization and launch are sent through the web-application to the rocket.

Ubuntu Server The Ubuntu Server uses a PCIe CAN bus extension card with four CAN Channel ports. All communication to the Rocket and GSE electronics, i.e. GSE, ECUs and RCU, is sent through it. The server is connected to Mission Control either via a long Ethernet cable or a directed radio link depending on the necessary safety distance of the Mission Control from the pad.

Low-Level Server Written in C++, this is the software that directly communicates with the Rocket and GSE via CAN. Sensor data and all user interactions are recorded and

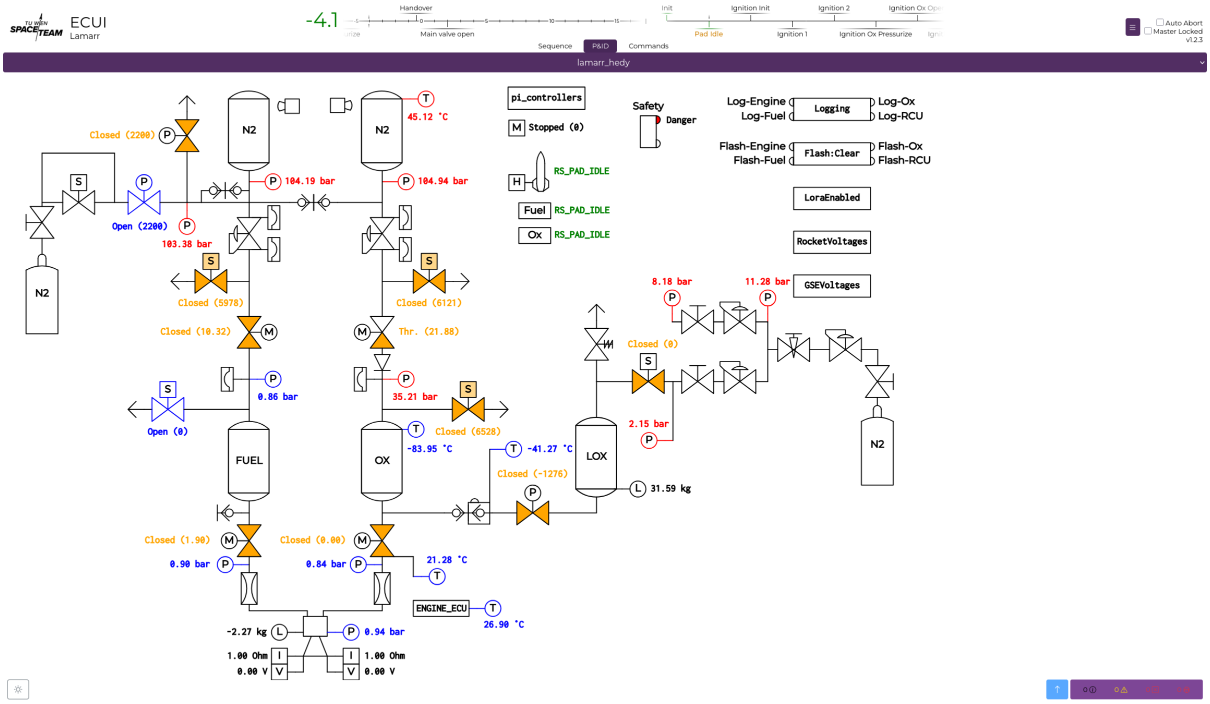


Fig. A.2: The web interface used to control the rocket and GSE

the current system state is synchronized with the web server. Additionally, time-sensitive operations, such as the launch sequence, are executed through the Low-Level Server.

Web-Server The web server's main function is to support our web application by hosting web clients with NodeJS and synchronizing data between them and the Low-Level Server.

InfluxDB and Grafana InfluxDB is a time series database for logging sensor data and user inputs. Grafana is used for real-time plots and gauges on the web-client. It is also used for post-launch procedures and data analysis.

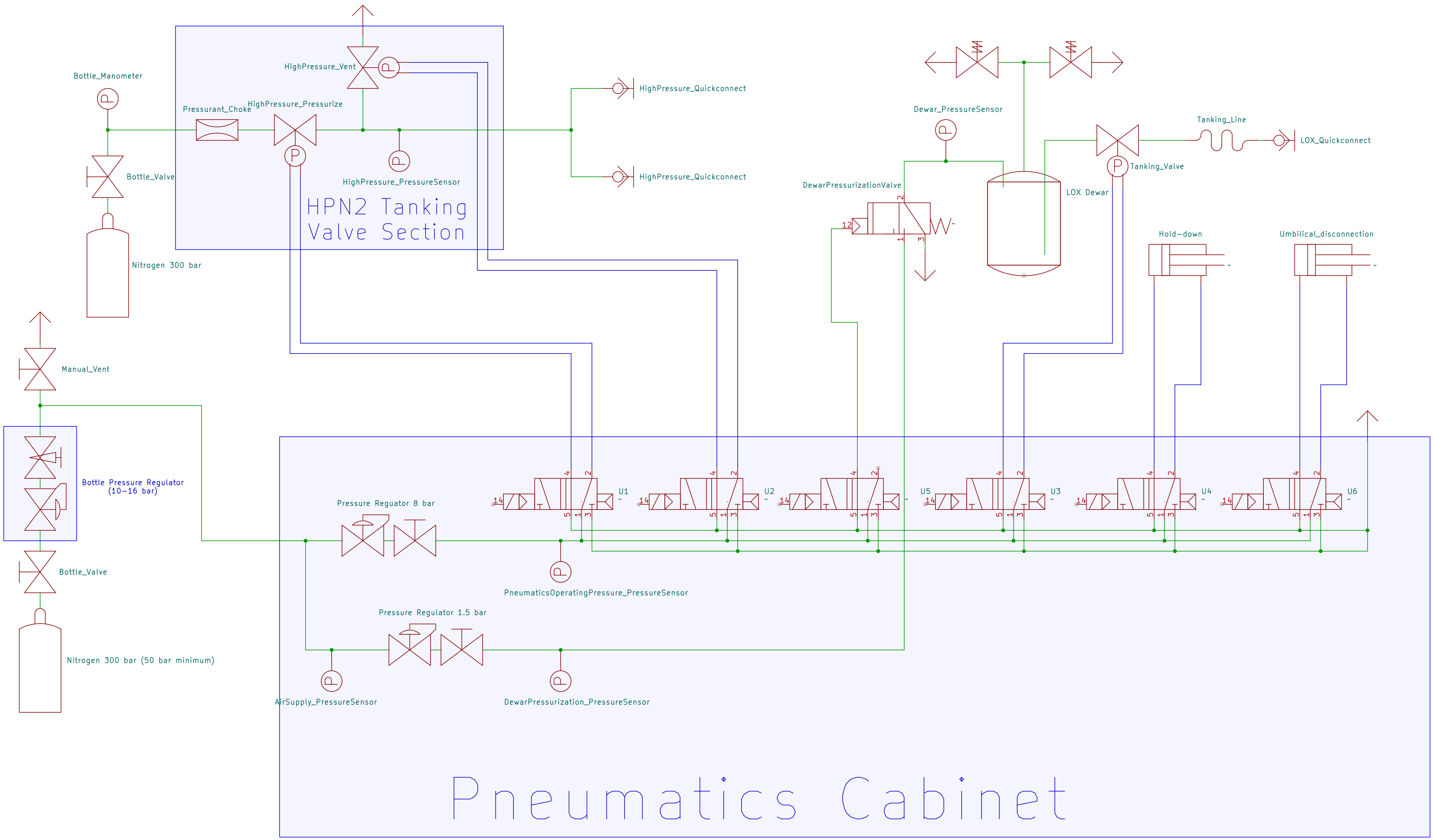
LoRa Raspberry Pi The RCU regularly sends the status updates of the rocket via LoRa to the ground. A self-developed LoRa receiver hat is connected to a Raspberry Pi, which forwards the messages over UDP to the Ubuntu Server. There, they are processed like normal CAN messages and ingested into our system. This enables us to receive accurate sensor readouts during flight, ensuring that the rocket is in a safe state before recovery.

Detailed Electrical Architecture This section overlaps with information on the Mission Control Software, so if interactions are unclear, it is advised to read from the appendices, which cover the software architecture. Similarly to the rocket, the electronics in the launch pad are connected to the main Ubuntu Server via CAN Bus and are controlled via the same Low-Level Server and Mission Control data flow as the rocket.
The GSE electronics consists out of:

- Two ECUs (Engine Control Units) in IOBs
- Four ECUs (Engine Control Units) in BOBs
- One LCB (Load Cell Board)

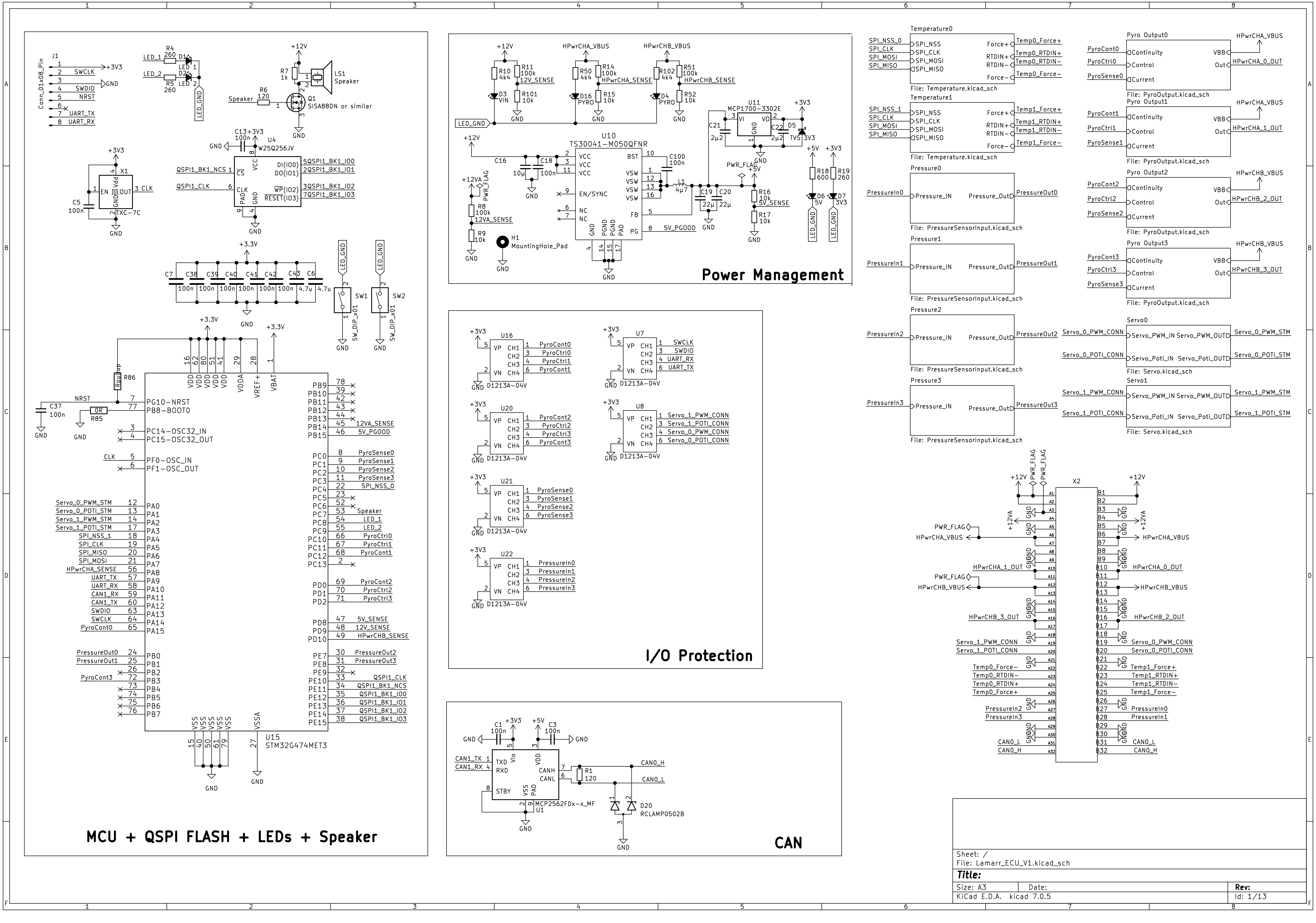
The launch pad is wired to the Ubuntu Server in a mobile rack with a CAN cable. A directed radio link connects The server rack to the Mission Control. In the server rack, connected directly to the server via LAN, a Raspberry Pi single-board computer with a LoRa shield is used for the 868 MHz radio connection to the rocket during flight. Mobile power generators power the entire GSE. During launch preparations, the electronics umbilical also provides power to the rocket, keeping the internal batteries charged until automatic disconnect at lift-off.

A.8 Detailed Hydraulic/Fluid Architecture



Bottle_Manometer
Pressurant_Choke
HighPressure_Pressurize
HighPressure_Vent
HighPressure_PressureSensor
Bottle_Valve
Nitrogen 300 bar
HPN2 Tanking
Valve Section
HighPressure_Quickconnect
HighPressure_Quickconnect
Dewar_PressureSensor
DewarPressurizationValve
LOX Dewar
Tanking_Line
LOX_Quickconnect
Tanking_Valve
Hold-down
Umbilical_disconnection
Manual_Vent
Bottle Pressure Regulator
(10-16 bar)
Bottle_Valve
Nitrogen 300 bar (50 bar minimum)
U1
U2
U5
U3
U4
U6
Pressure Regulator 8 bar
PneumaticsOperatingPressure_PressureSensor
Pressure Regulator 1.5 bar
AirSupply_PressureSensor
DewarPressurization_PressureSensor
Pneumatics Cabinet

A.9 Engineering drawings:



MCU + QSPI FLASH + LEDs + Speaker
Power Management
I/O Protection
CAN
U15 STM32G474MET3
U10 TS30041-M050QFNR
U11 MCP1700-3302E
U4 W25Q256JV
U1 MCP2562FDx-x_MF
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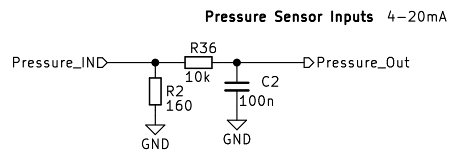

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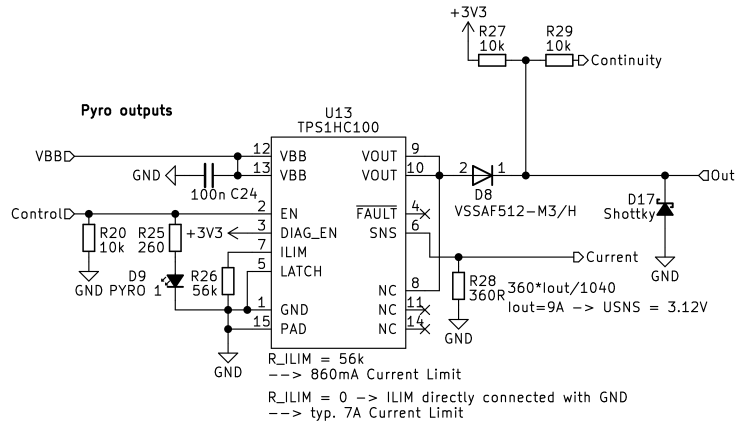
Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 2/13



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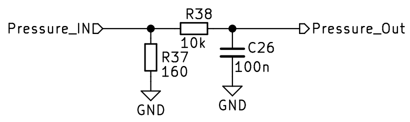
File: PyroOutput.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 3/13

Pressure Sensor Inputs 4–20mA



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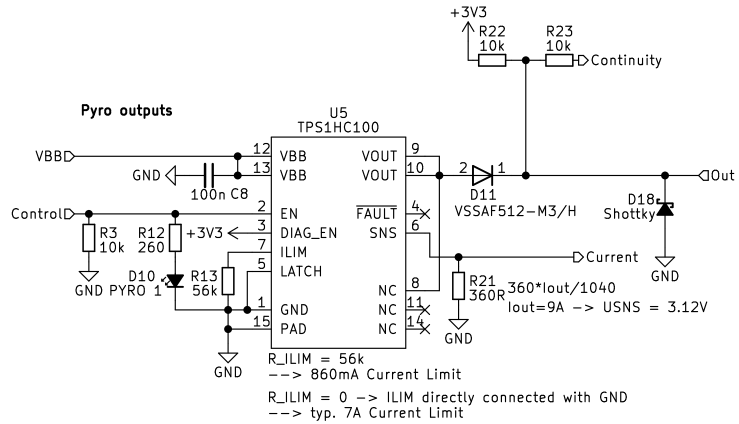
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 4/13

Pyro outputs



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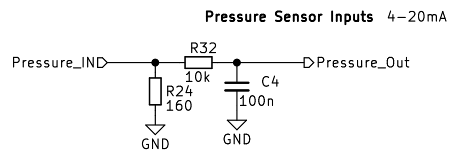
Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 5/13



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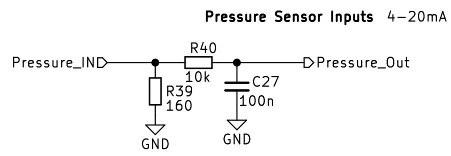
Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 6/13



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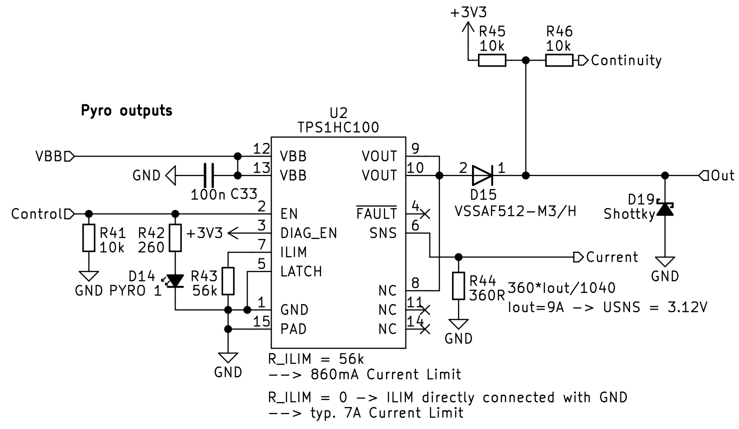
File: PressureSensorInput.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 7/13

Pyro outputs



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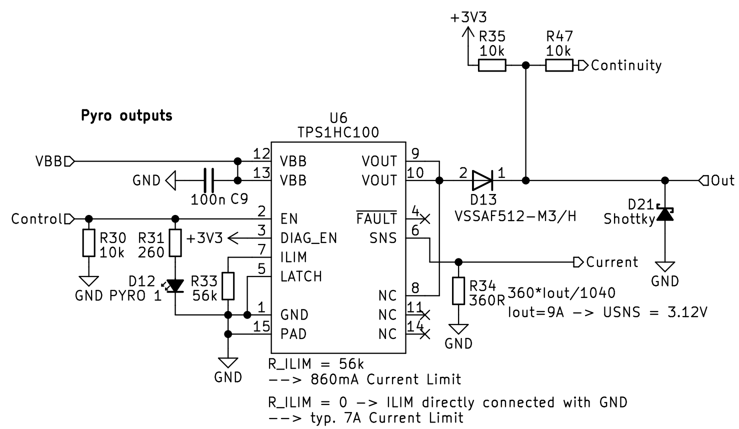
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 8/13

Pyro outputs



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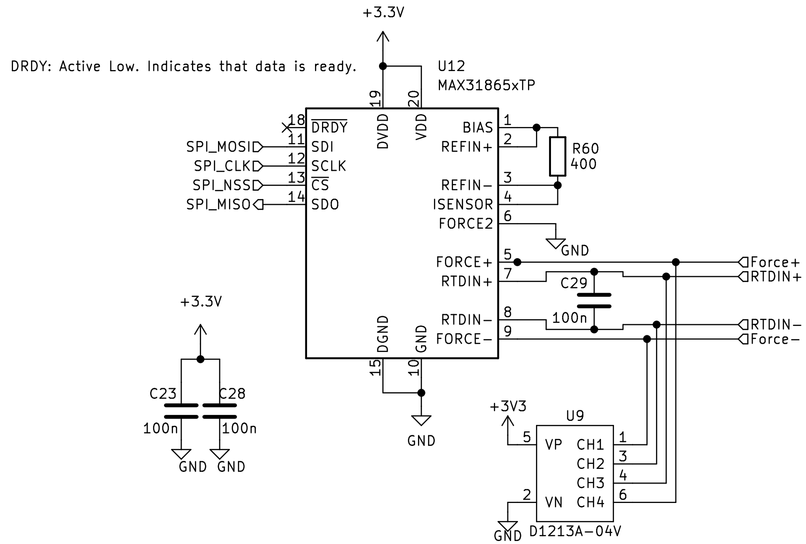
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 9/13



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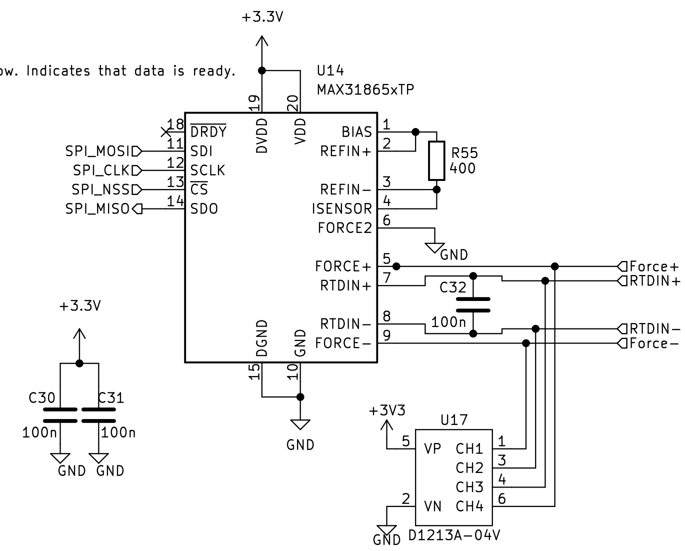
KiCad E.D.A. kicad 7.0.5		Id: 10/13



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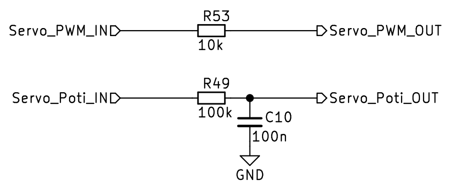
Size: A4 Date: Rev:
KiCad E.D.A. kicad 7.0.5 Id: 11/13



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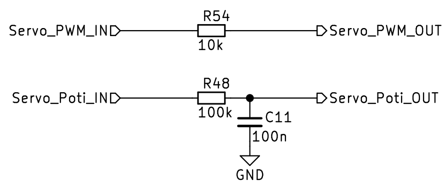
Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 12/13



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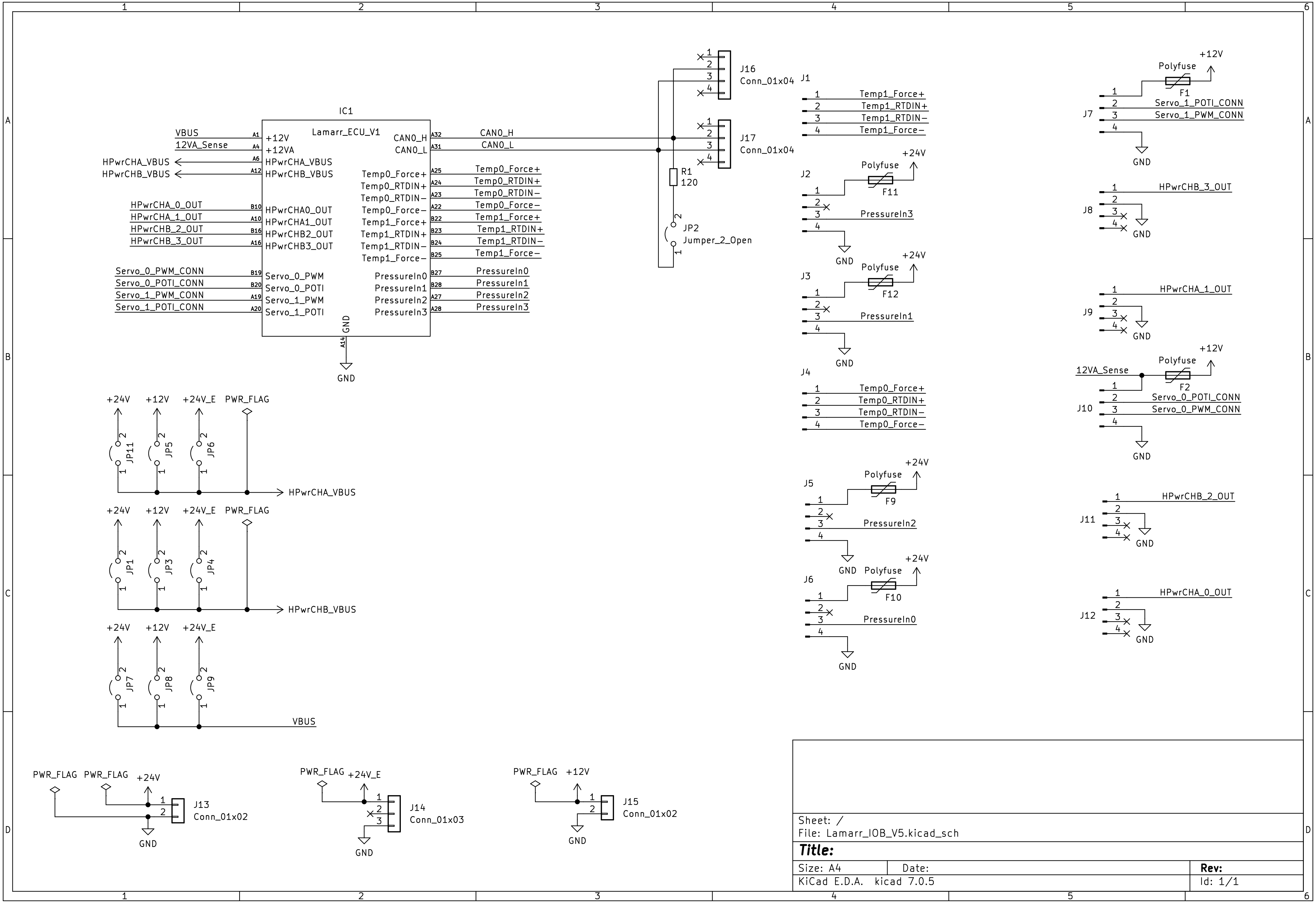
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. kicad 7.0.5		Id: 13/13


IC1
Lamarr_ECU_V1
VBUS
12VA_Sense
HPwrCHA_VBUS
HPwrCHB_VBUS
+12V
+12VA
HPwrCHA_0_OUT
HPwrCHA_1_OUT
HPwrCHB_2_OUT
HPwrCHB_3_OUT
HPwrCHA0_OUT
HPwrCHA1_OUT
HPwrCHB2_OUT
HPwrCHB3_OUT
Servo_0_PWM_CONN
Servo_0_POTI_CONN
Servo_1_PWM_CONN
Servo_1_POTI_CONN
Servo_0_PWM
Servo_0_POTI
Servo_1_PWM
Servo_1_POTI
CAN0_H
CAN0_L
Temp0_Force+
Temp0_RTDIN+
Temp0_RTDIN−
Temp0_Force−
Temp1_Force+
Temp1_RTDIN+
Temp1_RTDIN−
Temp1_Force−
PressureIn0
PressureIn1
PressureIn2
PressureIn3
GND
J16
Conn_01x04
J17
Conn_01x04
R1
120
JP2
Jumper_2_Open
J1
J2
J3
J4
J5
J6
Polyfuse
F11
F12
F9
F10
+24V
J7
J8
J9
J10
J11
J12
F1
F2
HPwrCHB_3_OUT
HPwrCHA_1_OUT
HPwrCHB_2_OUT
HPwrCHA_0_OUT
+24V_E
PWR_FLAG
JP11
JP5
JP6
JP1
JP3
JP4
JP7
JP8
JP9
J13
Conn_01x02
J14
Conn_01x03
J15
Conn_01x02
Sheet: /
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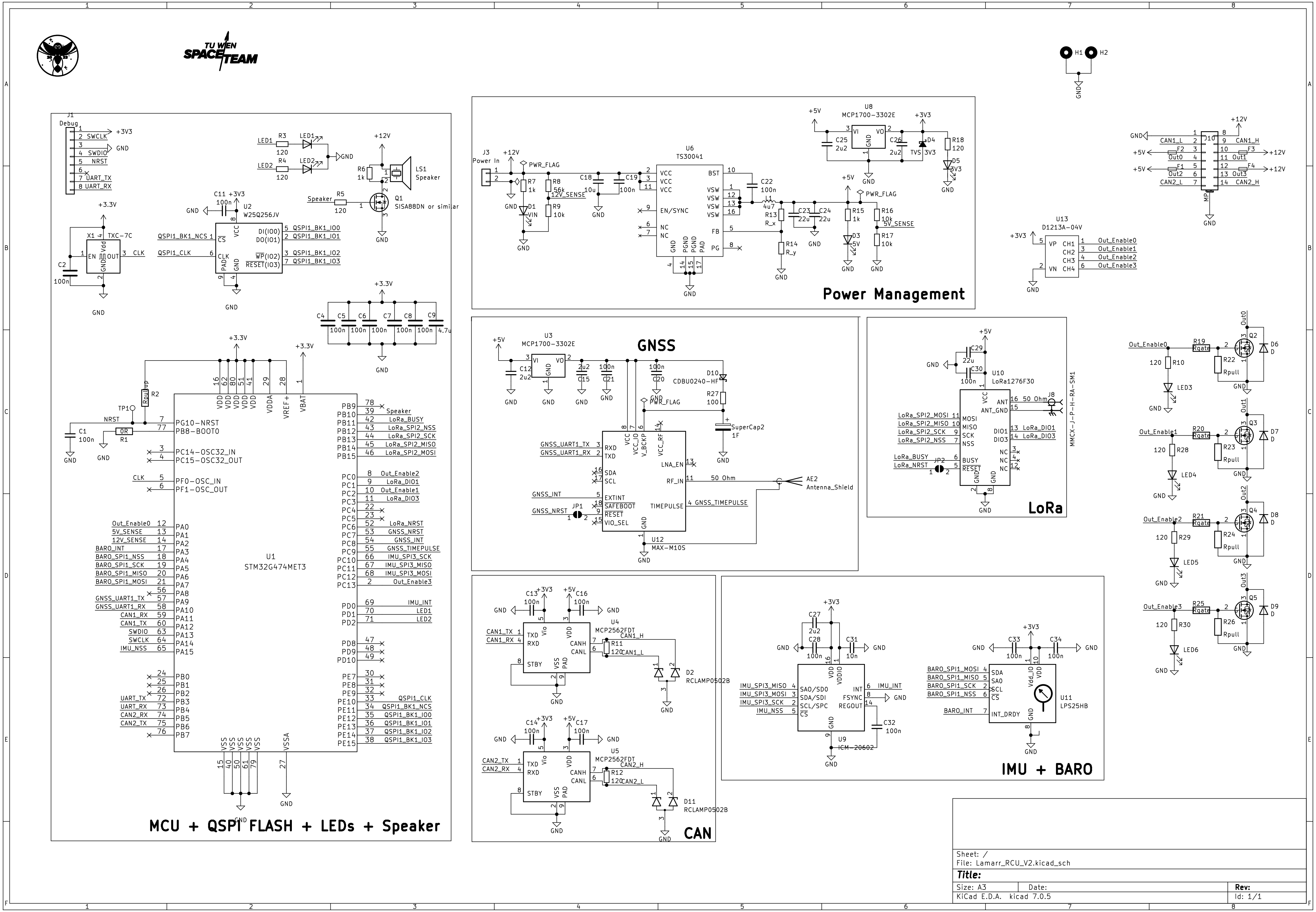
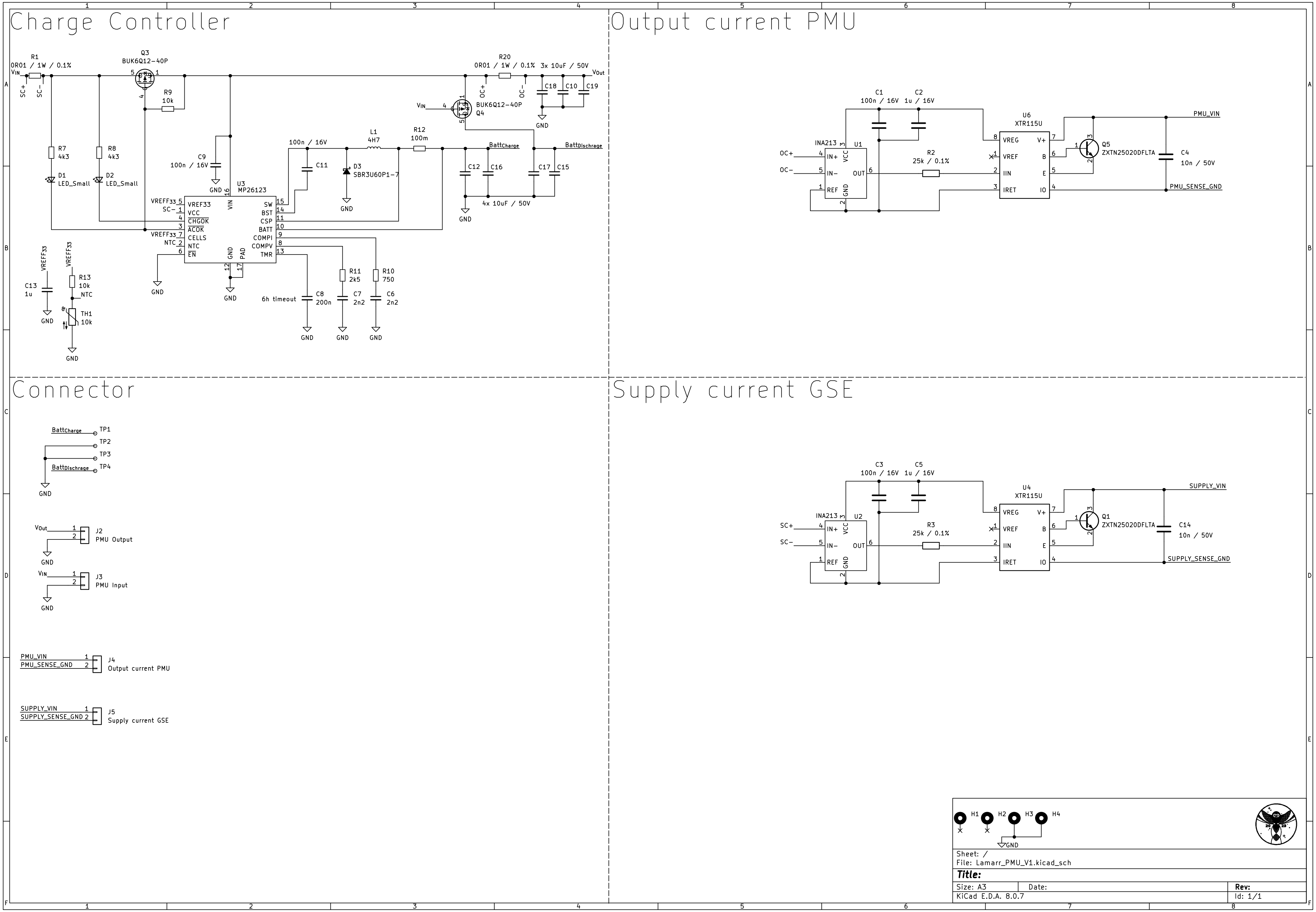
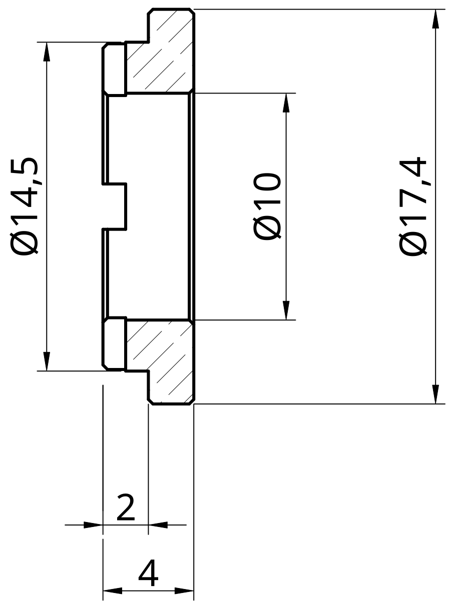
Title:
Size: A4
Date:
Rev:
KiCad E.D.A. kicad 7.0.5
Id: 1/1


MCU + QSPI FLASH + LEDs + Speaker
Power Management
GNSS
LoRa
CAN
IMU + BARO
STM32G474MET3
W25Q256JV
TXC-7C
SISA88DN or similar
TS30041
MCP1700-3302E
MAX-M10S
LoRa1276F30
MMCX-J-P-H-RA-SM1
MCP2562FDT
RCLAMP0502B
ICM-20602
LPS25HB
D1213A-04V
Sheet: /
File: Lamarr_RCU_V2.kicad_sch
Title:
Size: A3
Date:
Rev:
KiCad E.D.A. kicad 7.0.5
Id: 1/1

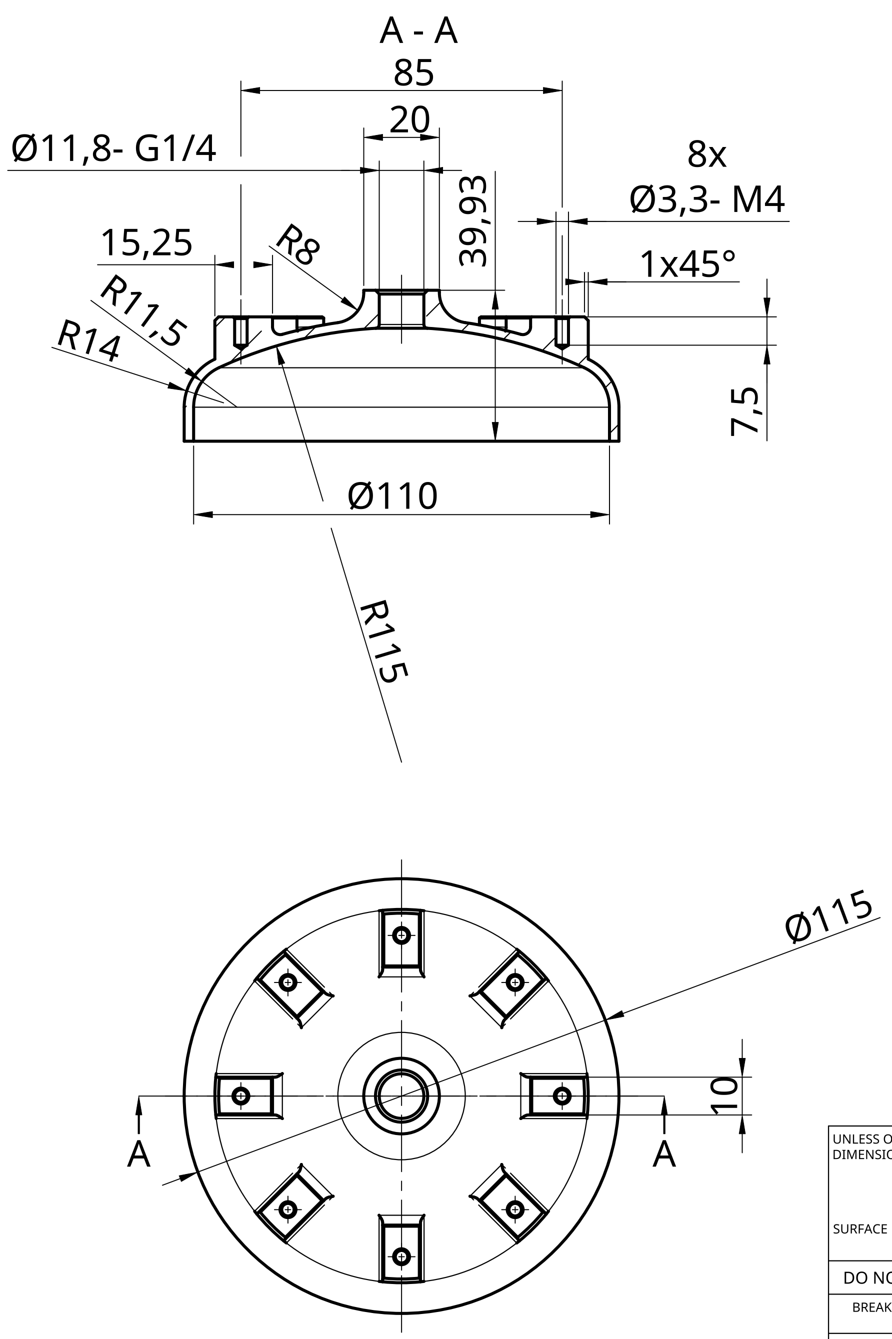


Charge Controller
Output current PMU
Connector
Supply current GSE
R1 0R01 / 1W / 0.1%
Q3 BUK6Q12-40P
R9 10k
R7 4k3
R8 4k3
D1 LED_Small
D2 LED_Small
C9 100n / 16V
U3 MP26123
VREF33 VCC CHGOK ACOK CELLS NTC EN
SW BST CSP BATT COMPI COMPV TMR
VIN GND PAD
C11 100n / 16V
L1 4H7
D3 SBR3U60P1-7
R12 100m
R20 0R01 / 1W / 0.1%
Q4 BUK6Q12-40P
3x 10uF / 50V
C18 C10 C19
C12 C16 C17 C15
4x 10uF / 50V
Batt_Charge
Batt_Dischrage
Vout
VIN
SC+ SC- OC+ OC-
VREFF33
NTC
C13 1u
R13 10k
TH1 10k
R11 2k5
R10 750
C8 200n
C7 2n2
C6 2n2
6h timeout
GND
TP1 TP2 TP3 TP4
J2 PMU Output
J3 PMU Input
J4 Output current PMU
J5 Supply current GSE
PMU_VIN
PMU_SENSE_GND
SUPPLY_VIN
SUPPLY_SENSE_GND
C1 100n / 16V
C2 1u / 16V
U1 INA213
IN+ IN- REF VCC GND OUT
R2 25k / 0.1%
U6 XTR115U
VREG VREF IIN IRET V+ B E IO
Q5 ZXTN25020DFLTA
C4 10n / 50V
C3 100n / 16V
C5 1u / 16V
U2 INA213
R3 25k / 0.1%
U4 XTR115U
Q1 ZXTN25020DFLTA
C14 10n / 50V
H1 H2 H3 H4
Sheet: /
File: Lamarr_PMU_V1.kicad_sch
Title:
Size: A3
Date:
Rev:
KiCad E.D.A. 8.0.7
Id: 1/1



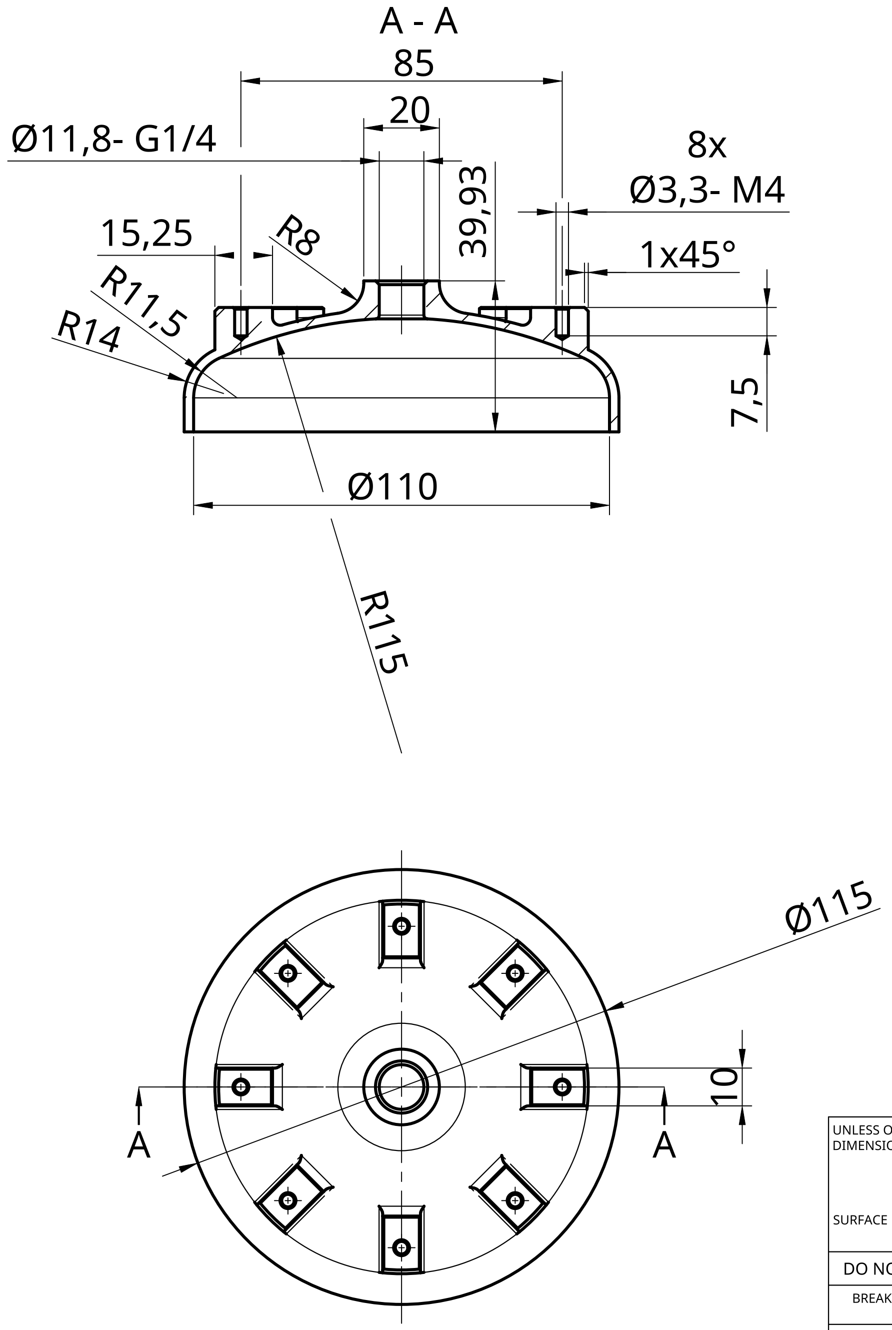
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE
	DRAWN	OLIVER BALINT		2025-08-23
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL		FINISH	

TITLE			
SIZE A4	DWG NO.		REV.
SCALE 3:1	WEIGHT	SHEET 1 of 1	



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± °		NAME	SIGNATURE	DATE
	DRAWN	MATTHIAS RIER		2024-07-01
SURFACE FINISH	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL: AW EN 6082		FINISH	

TITLE: Bulk head Propellant Tank Propulsion			
SIZE: A4	DWG NO.		REV.
SCALE: 1:2	WEIGHT	SHEET: 1 of 1	

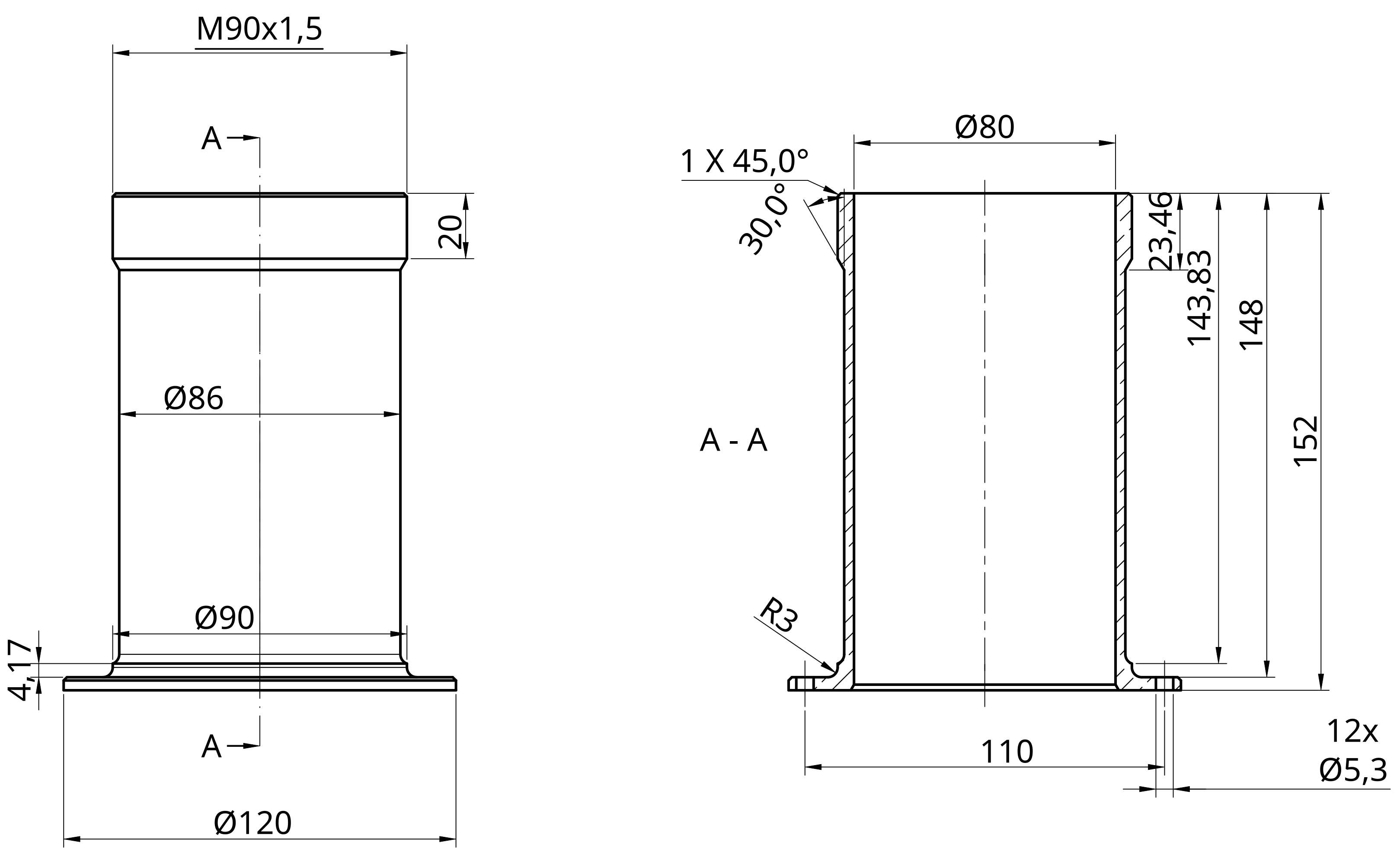


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± °		NAME	SIGNATURE	DATE
	DRAWN	MATTHIAS RIER		2024-07-01
SURFACE FINISH	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL AW EN 6082		FINISH	

TITLE
Bulk head
Propellant Tank
Propulsion

SIZE	DWG NO.	REV.
A4		

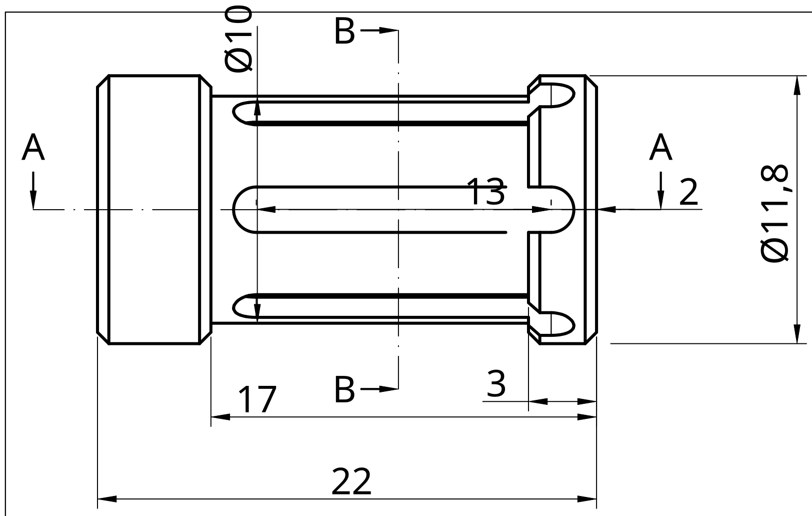
SCALE	WEIGHT	SHEET
1:2		1 of 1

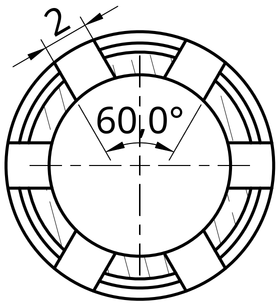


M90x1,5
Thread depth internal thread: 0,91mm

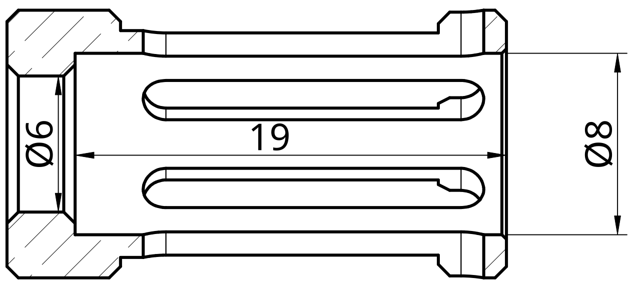
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE
	DRAWN	MATTHIAS RIER		2024-09-16
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL		FINISH	

TITLE	Casing Thrust Chamber Propulsion		
SIZE A4	DWG NO.		REV.
SCALE 1:2	WEIGHT	SHEET 1 of 1	



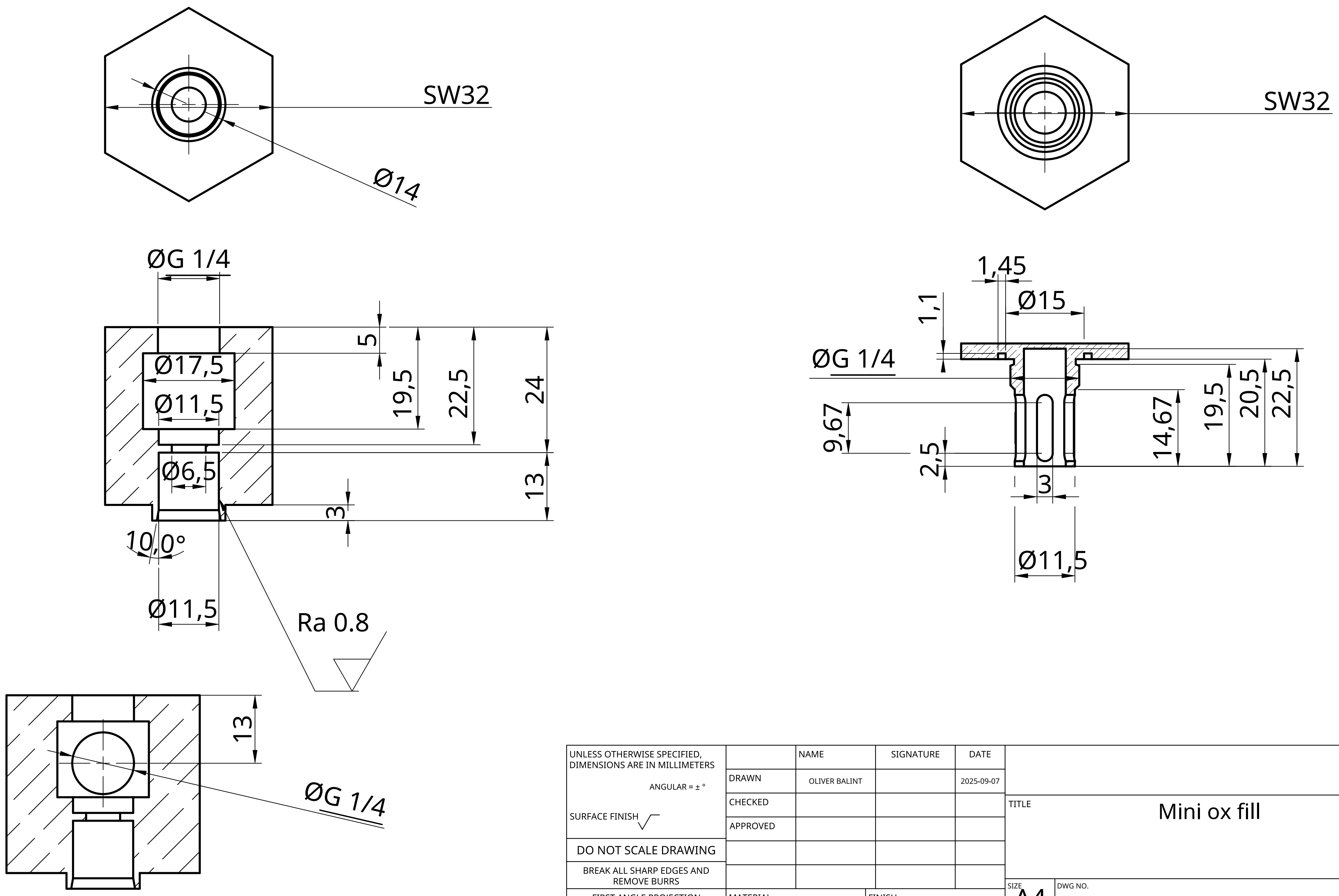


B - B

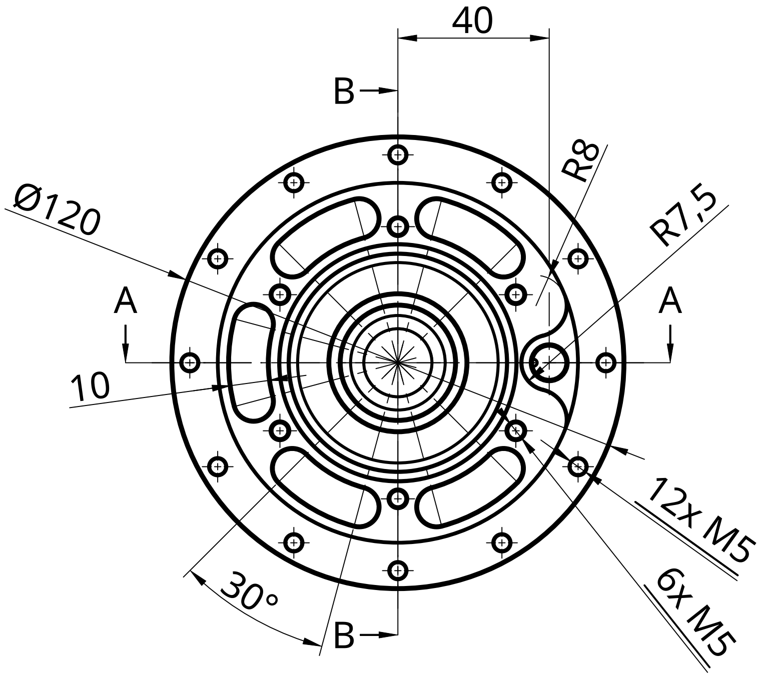


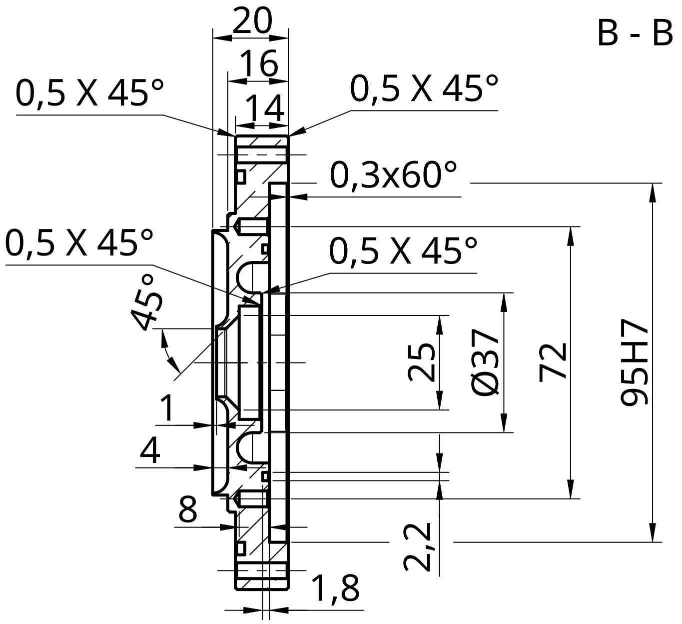
A - A

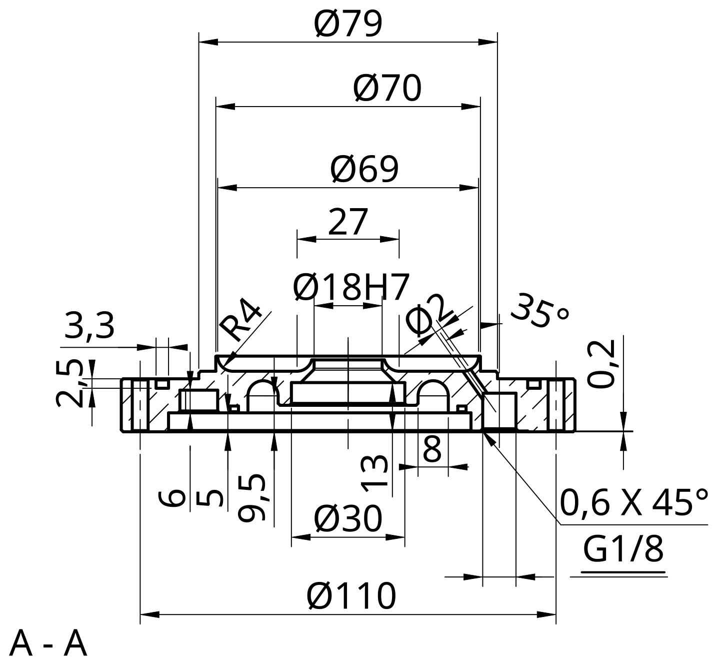
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	OLIVER BALINT		2025-08-08	
	CHECKED				TITLE
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4
FIRST ANGLE PROJECTION	MATERIAL		FINISH		DWG NO.
					REV.
					SCALE 3:1
					WEIGHT
					SHEET 1 of 1

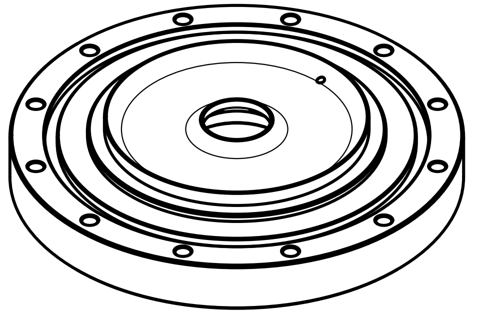


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	OLIVER BALINT		2025-09-07	
	CHECKED				TITLE Mini ox fill
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 | DWG NO. | REV.
FIRST ANGLE PROJECTION	MATERIAL 6061 SW 32 Aluminium		FINISH		SCALE 1:1 | WEIGHT | SHEET 1 of 1



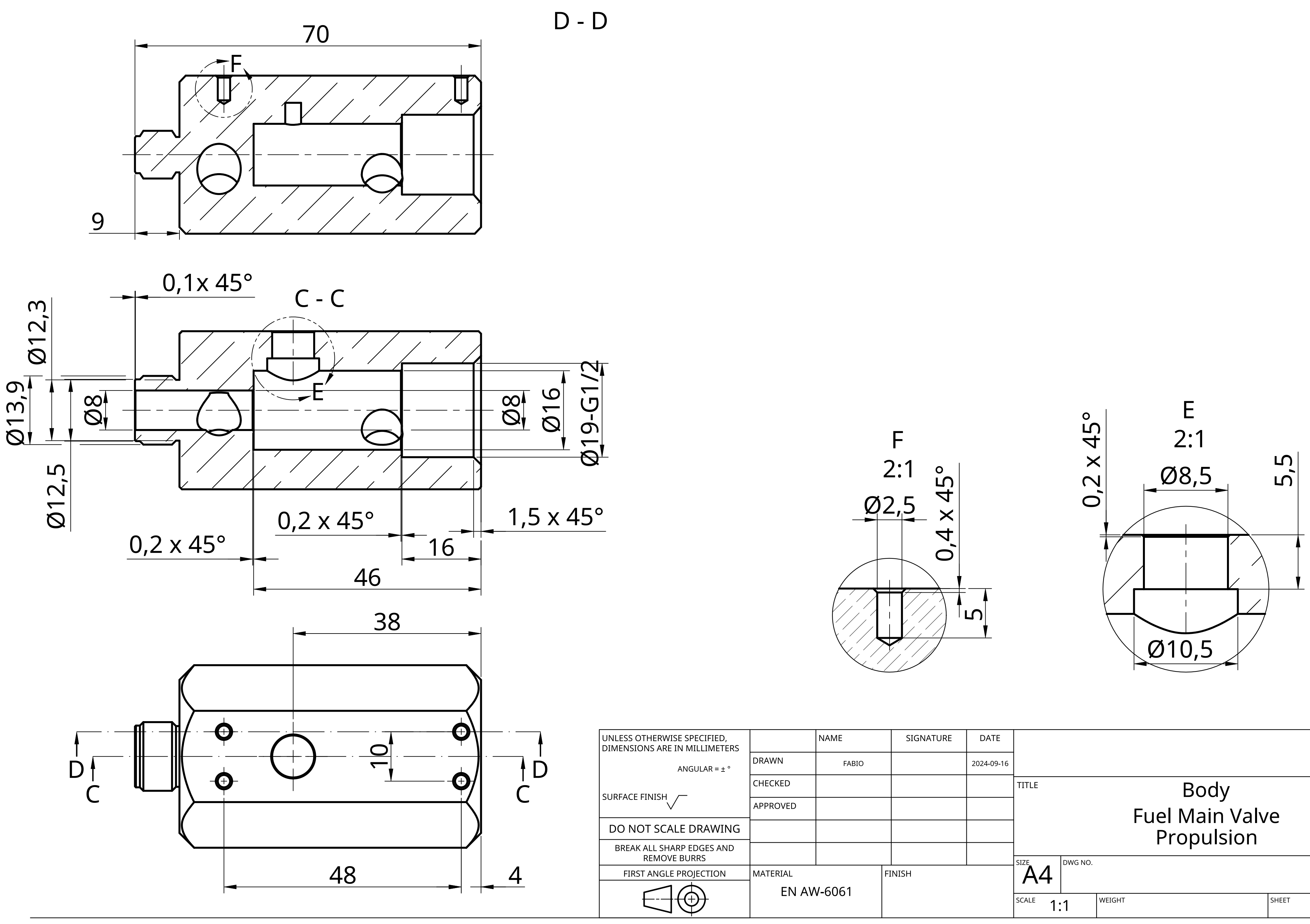




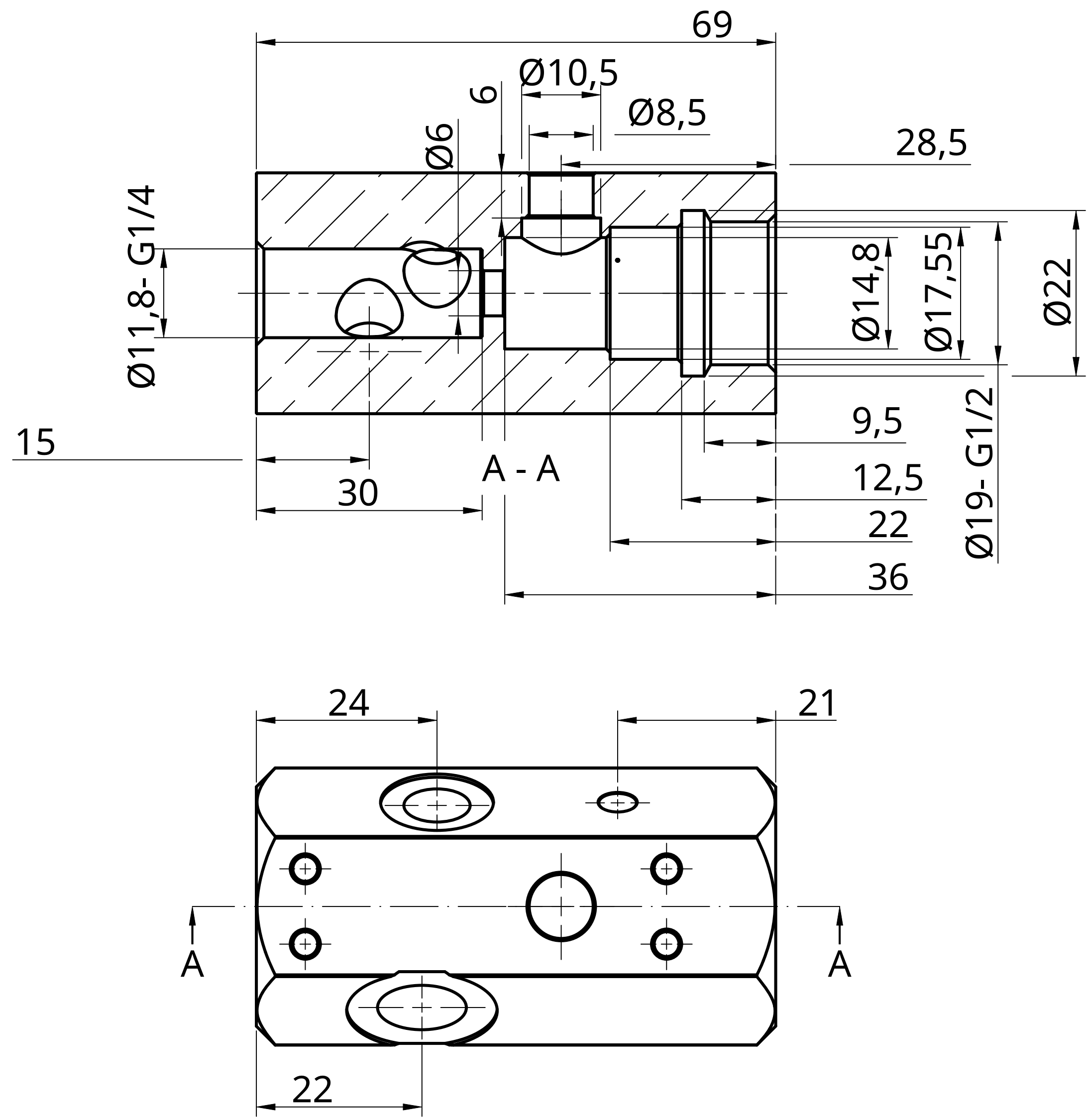


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE
ANGULAR = ± °	DRAWN	MATTHIAS RIER		2024-09-16
SURFACE FINISH	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL		FINISH	

TITLE	Enginehead Injector Propulsion
SIZE	A4
DWG NO.	
REV.	
SCALE	1:2
WEIGHT	
SHEET	1 of 1



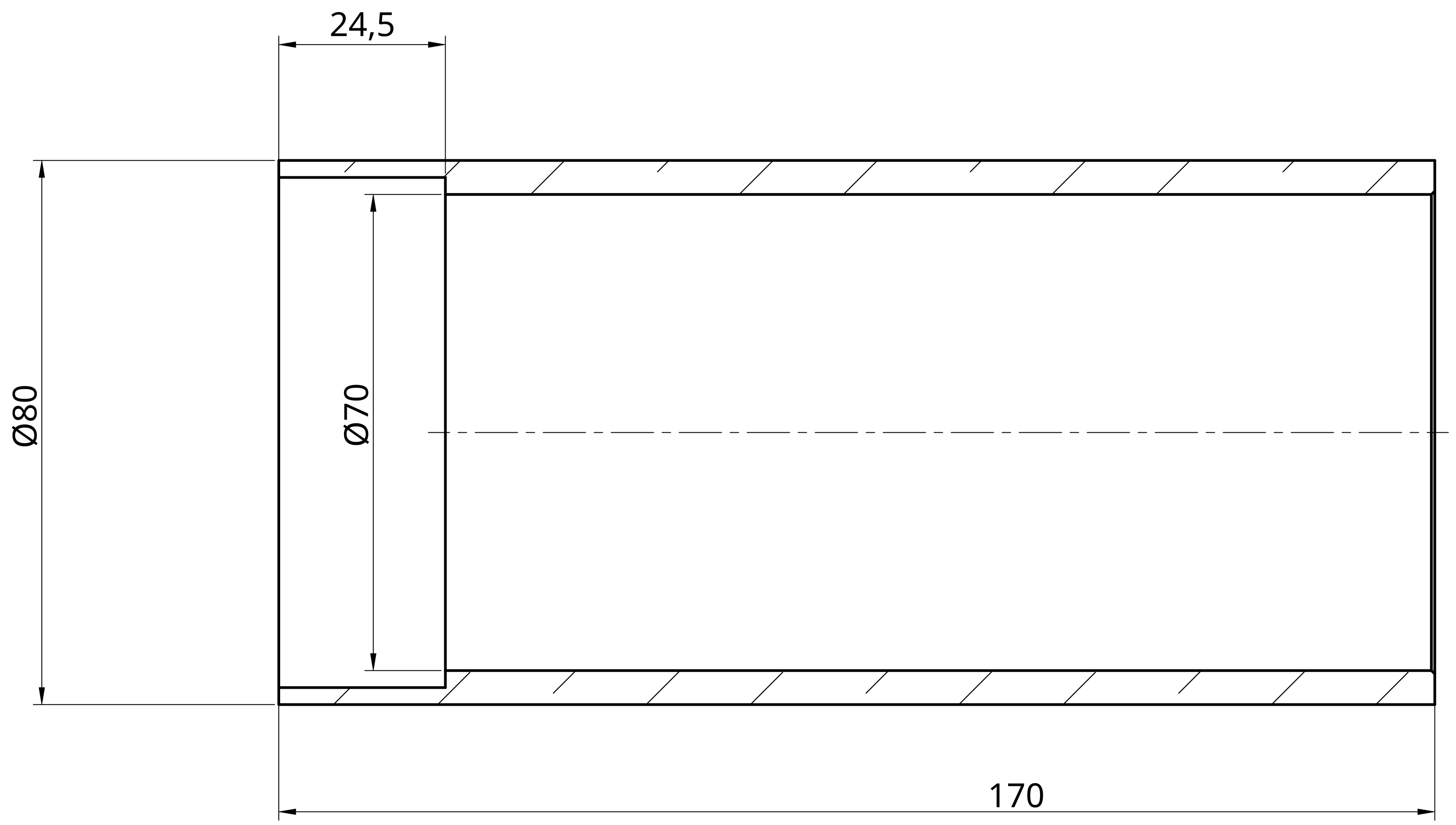
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	FABIO		2024-09-16	
	CHECKED				TITLE Body Fuel Main Valve Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 / DWG NO. / REV.
FIRST ANGLE PROJECTION	MATERIAL EN AW-6061		FINISH		SCALE 1:1 / WEIGHT / SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS
ANGULAR = ± °
SURFACE FINISH
DO NOT SCALE DRAWING
BREAK ALL SHARP EDGES AND REMOVE BURRS
FIRST ANGLE PROJECTION

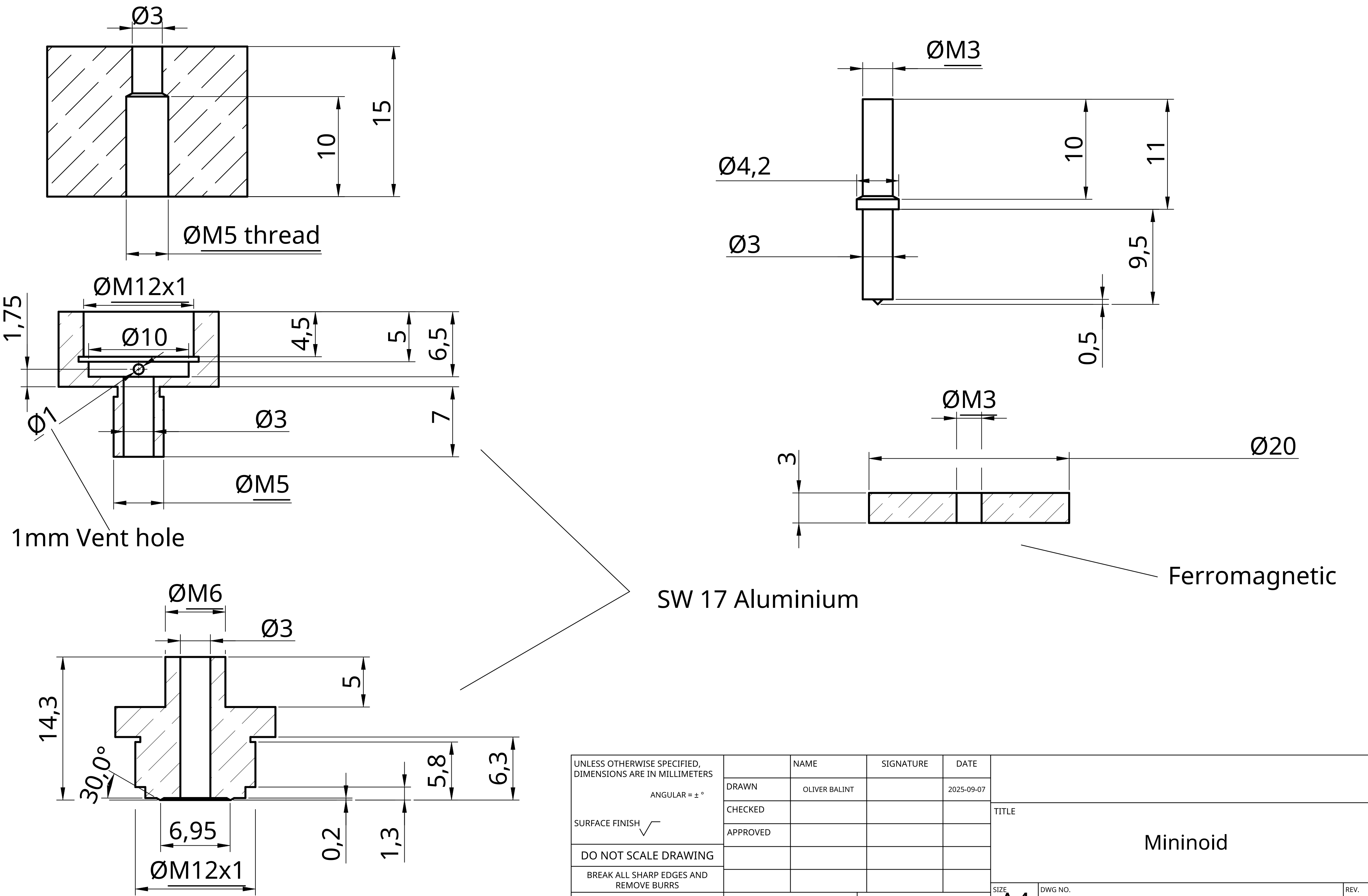
	NAME	SIGNATURE	DATE
DRAWN	MATTHIAS RIER		2025-08-23
CHECKED			
APPROVED			

MATERIAL
FINISH
TITLE
SIZE A4
DWG NO.
REV.
SCALE 1:1
WEIGHT
SHEET 1 of 1

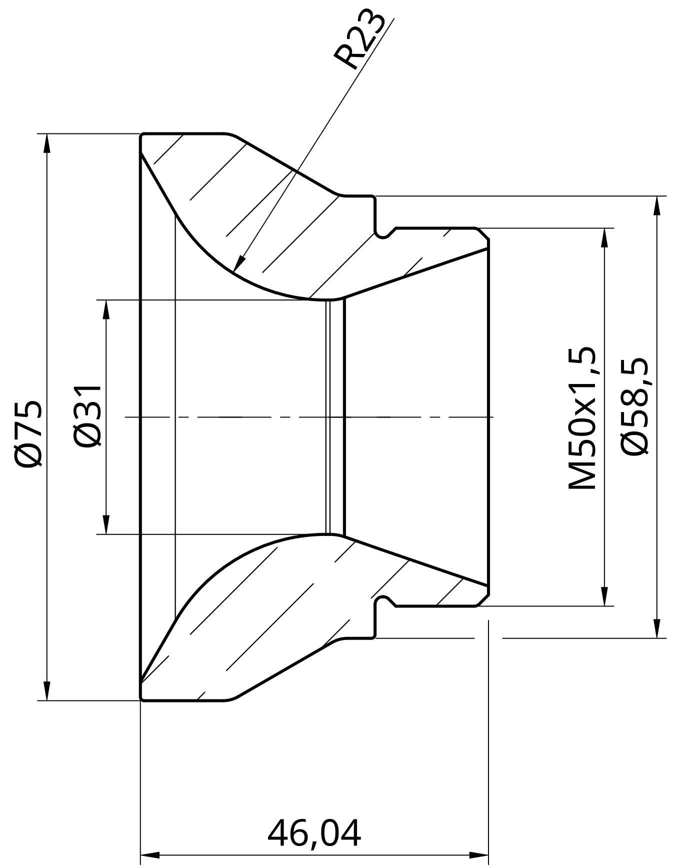


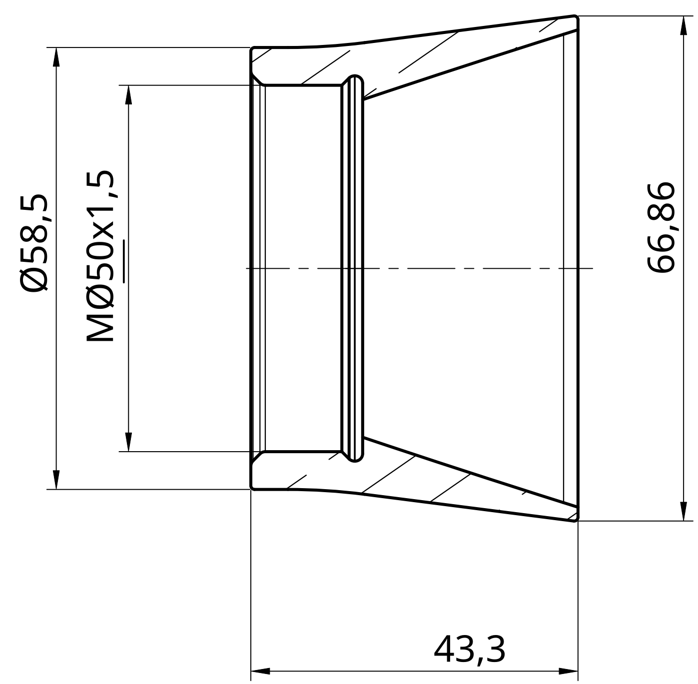
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE
ANGULAR = ± °	DRAWN	FABIO		2024-05-24
SURFACE FINISH	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL: Phenolic Resin Cotton	FINISH		

TITLE	Chamber Liner Thrust Chamber Propulsion		
SIZE: A4	DWG NO.		REV.
SCALE: 1:1	WEIGHT	SHEET: 1 of 1	



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± °		NAME	SIGNATURE	DATE	
	DRAWN	OLIVER BALINT		2025-09-07	
SURFACE FINISH	CHECKED				TITLE Mininoid
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 / DWG NO. / REV.
FIRST ANGLE PROJECTION	MATERIAL 6061 SW17, low carbon steel, stainless steel	FINISH			SCALE 2:1 / WEIGHT / SHEET 1 of 1

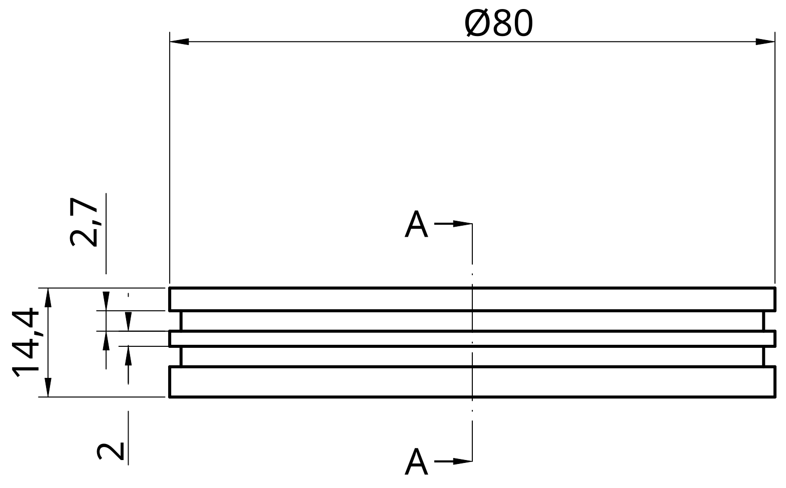


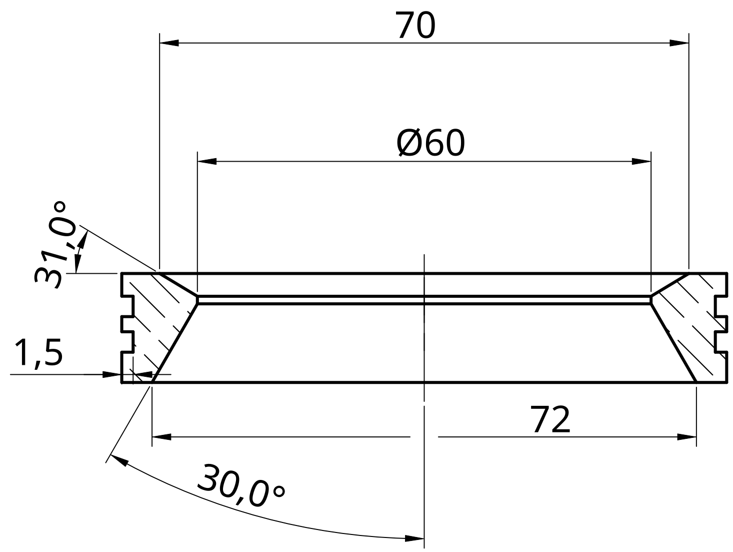


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE
	DRAWN	MATTHIAS RIER		2025-07-02
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL		FINISH	

TITLE

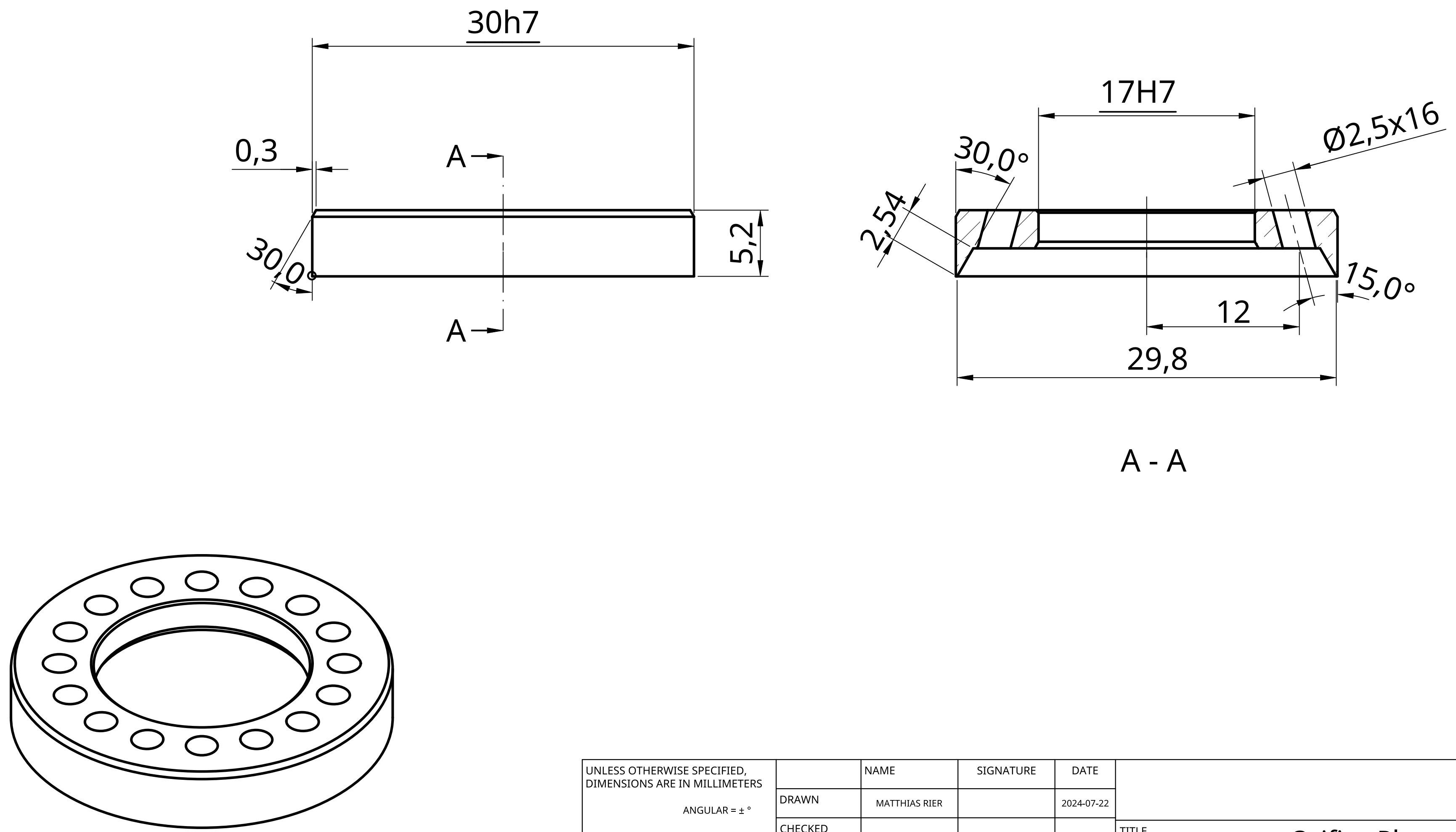
SIZE A4	DWG NO.	REV.
SCALE 1:2	WEIGHT	SHEET 1 of 1



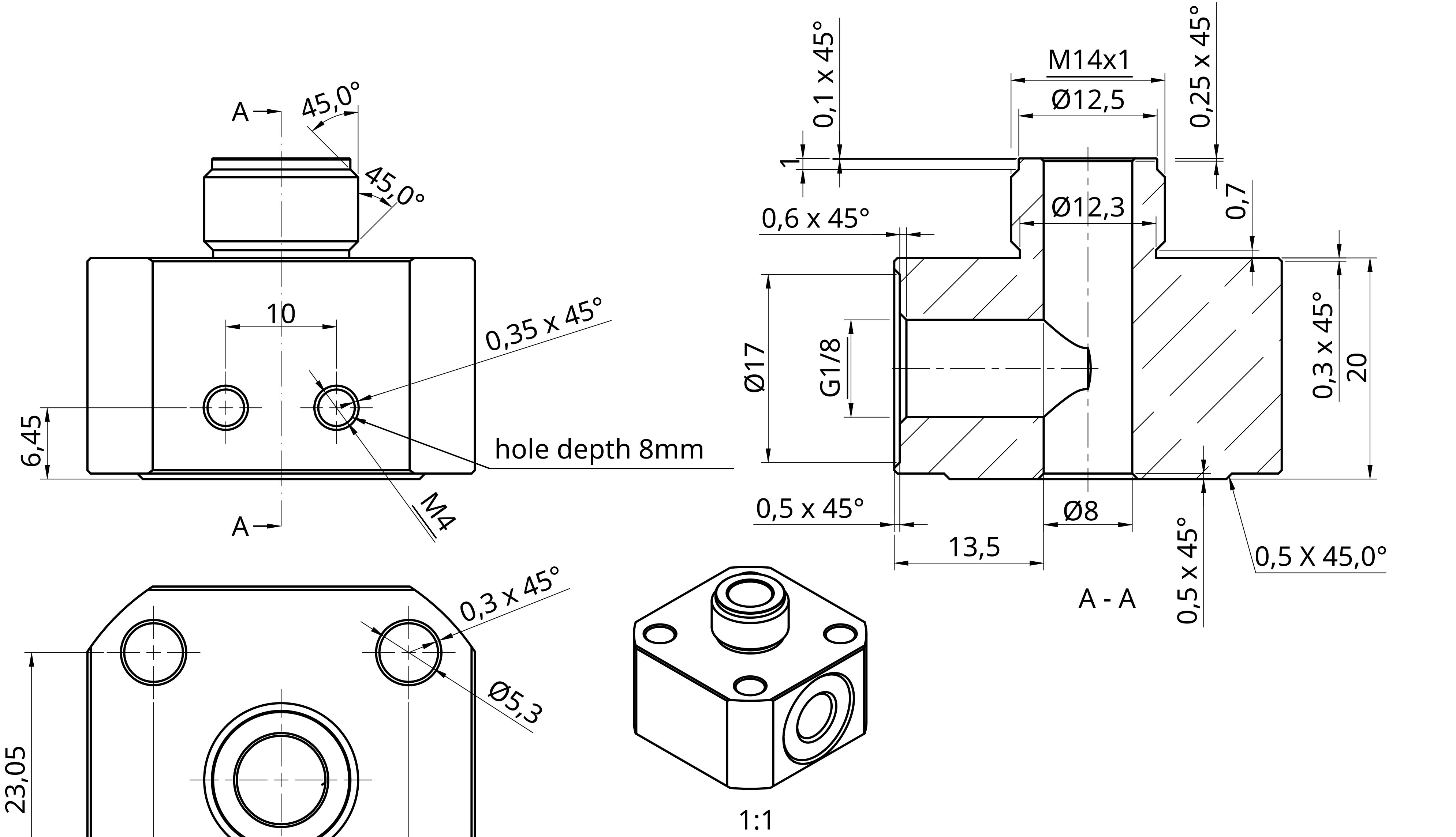


A - A

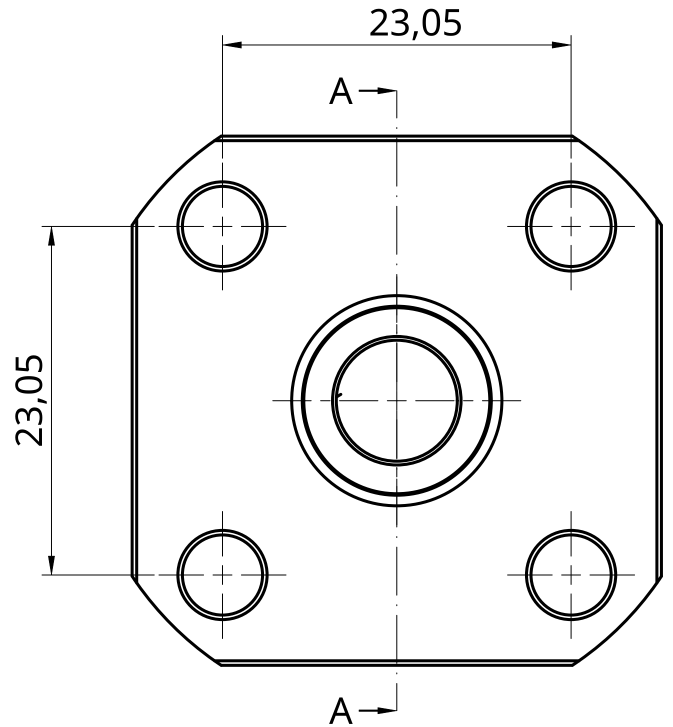
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE		
	DRAWN	MATTHIAS RIER		2025-08-24		
	CHECKED				TITLE	
	APPROVED					
DO NOT SCALE DRAWING						
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4	DWG NO.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 1:1	WEIGHT
					SHEET 1 of 1	REV.

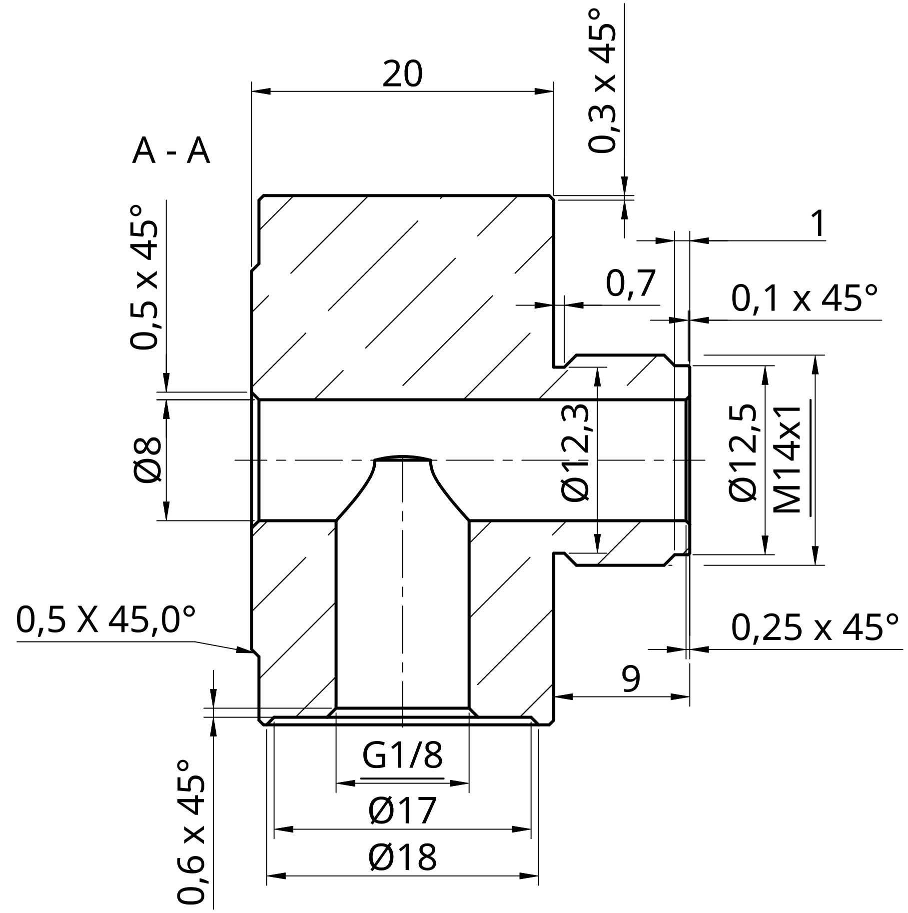


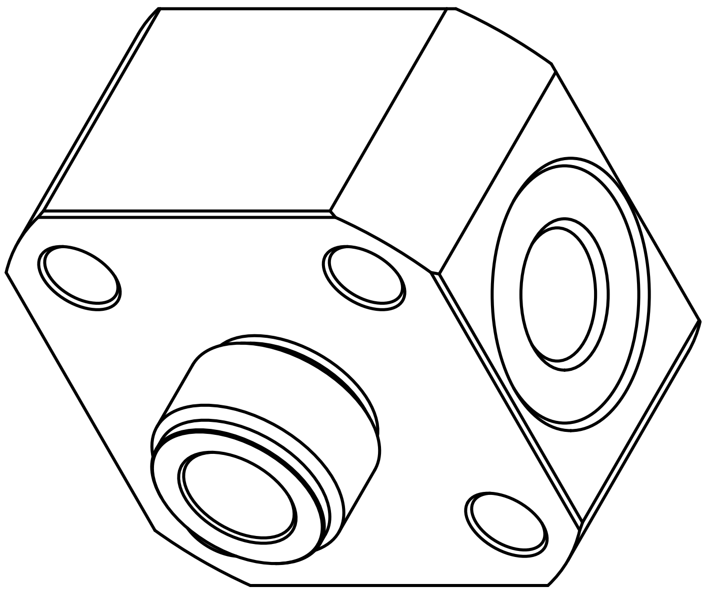
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2024-07-22	
	CHECKED				TITLE Orifice Plate Injector Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 | DWG NO. | REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 2:1 | WEIGHT | SHEET 1 of 1



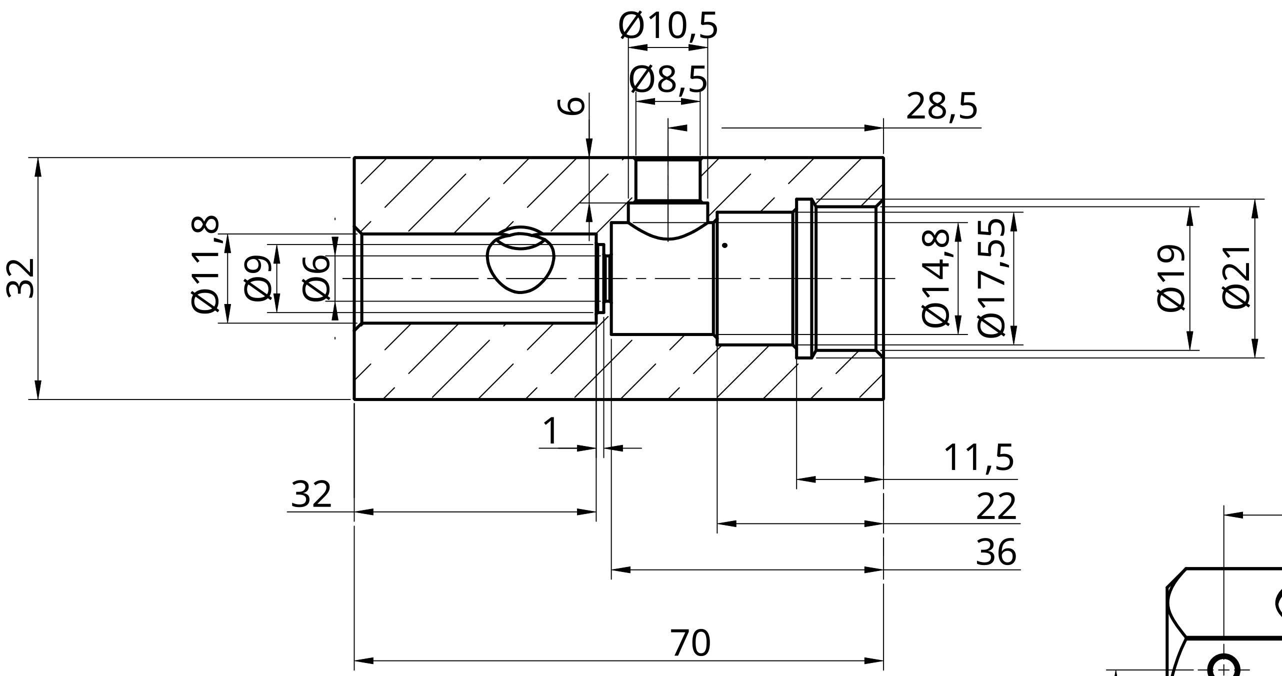
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	FABIO		2024-09-16	
	CHECKED				TITLE Body Downstream Ox Main Valve Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					
FIRST ANGLE PROJECTION	MATERIAL EN AW-6061	FINISH			SIZE A4 · DWG NO. · REV.
					SCALE 2:1 · WEIGHT · SHEET 1 of 1



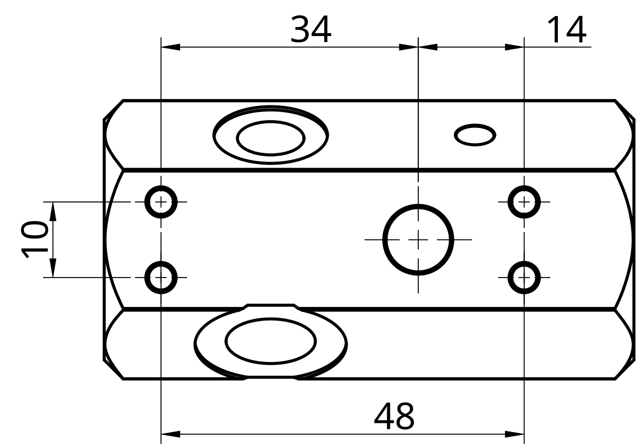




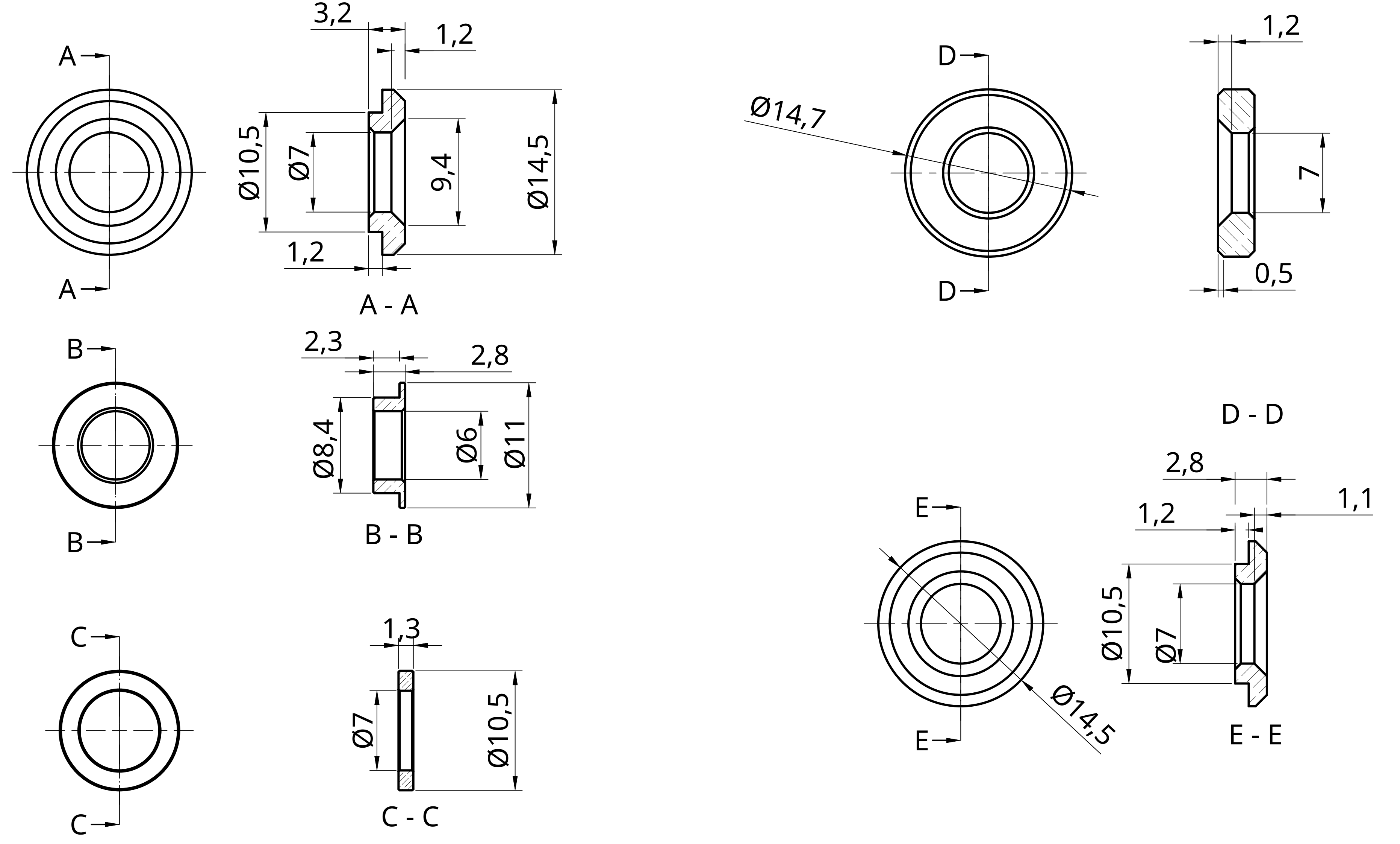
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	FABIO		2024-09-16	
	CHECKED				TITLE Body Upstream Ox Main Valve Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 / DWG NO. / REV.
FIRST ANGLE PROJECTION	MATERIAL EN AW-6061		FINISH		SCALE 2:1 / WEIGHT / SHEET 1 of 1



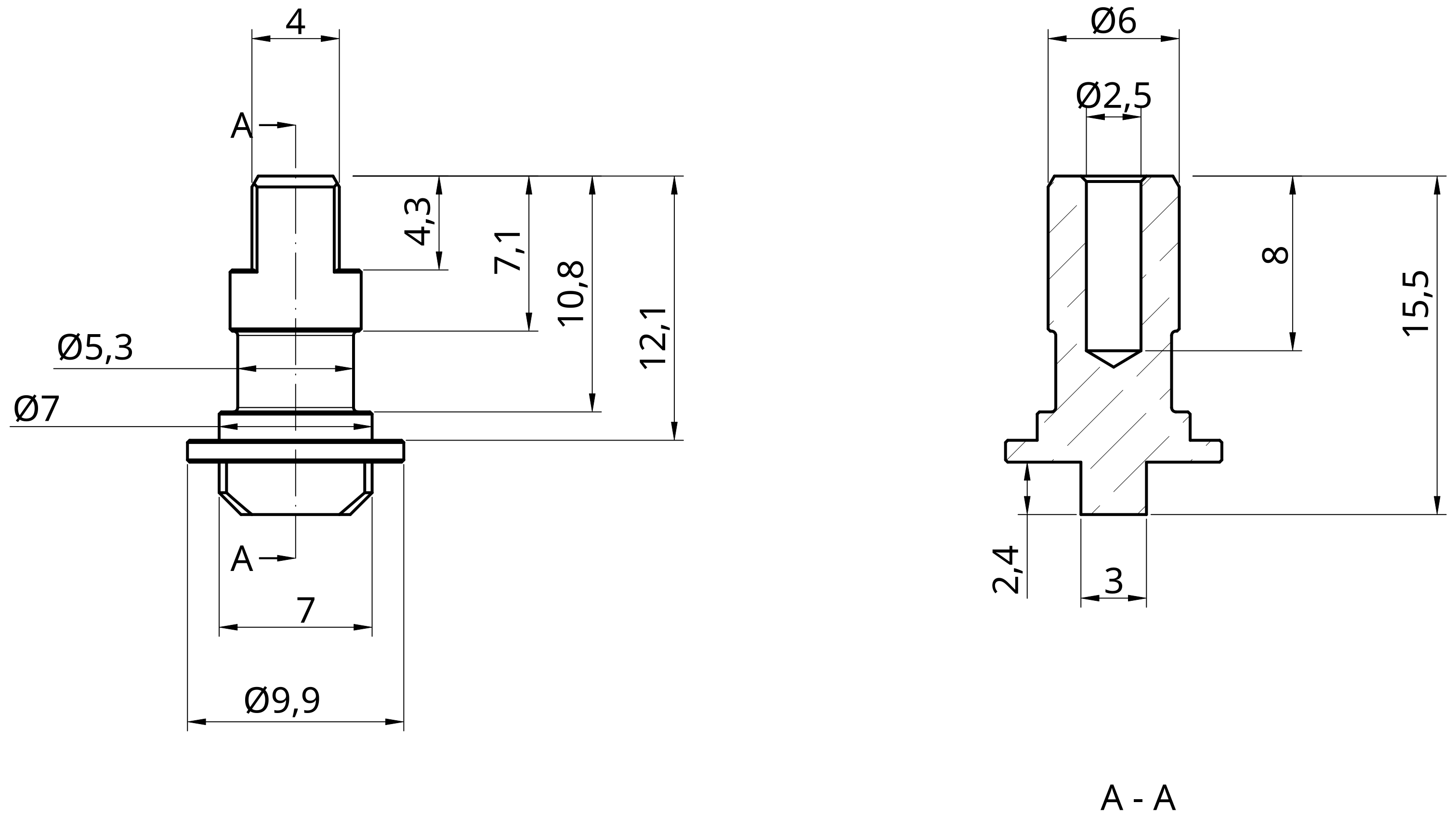
A - A



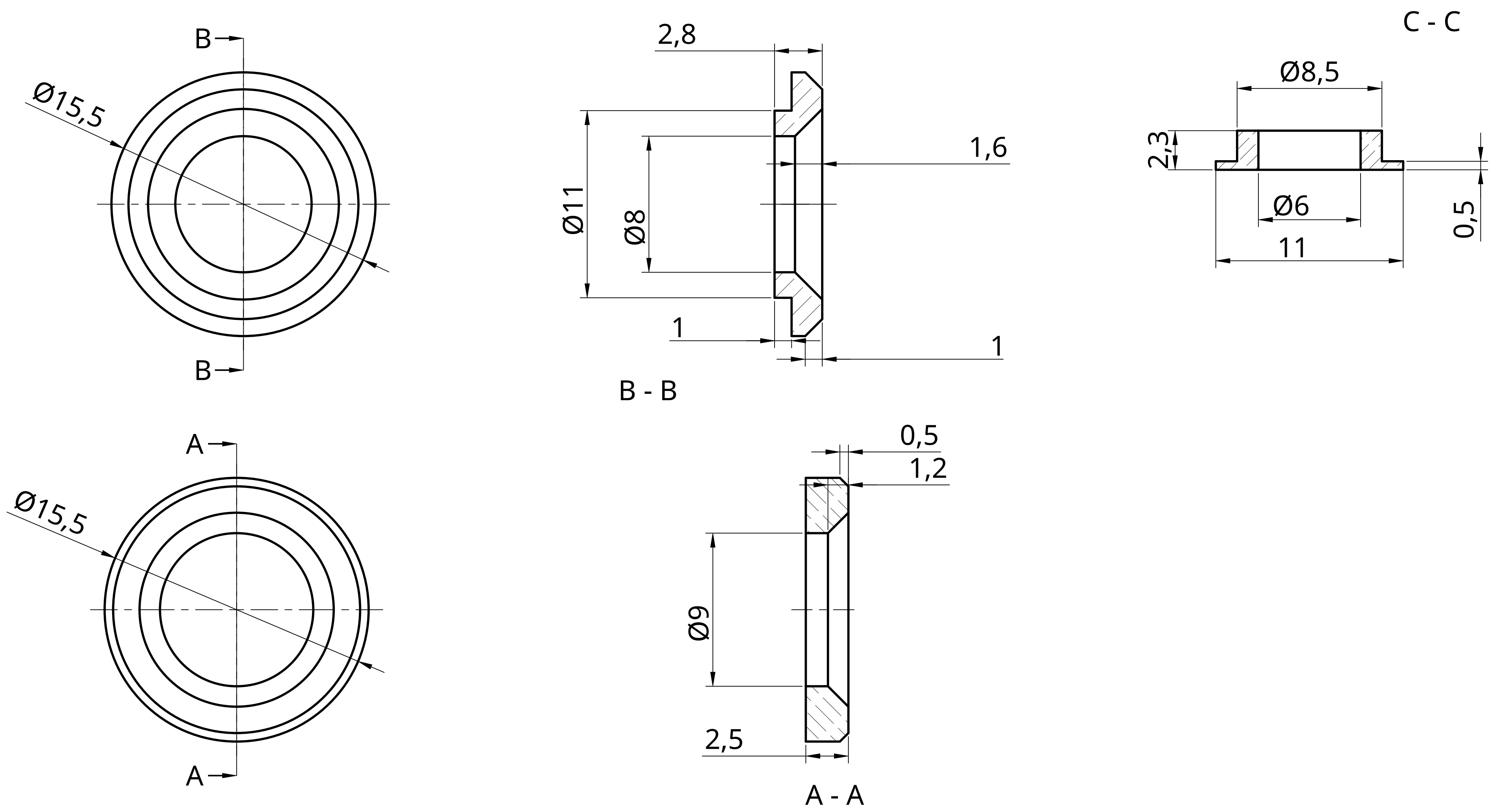
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2025-07-12	
	CHECKED				TITLE
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SIZE A4 · DWG NO. · REV.
					SCALE 1:1 · WEIGHT · SHEET 1 of 1



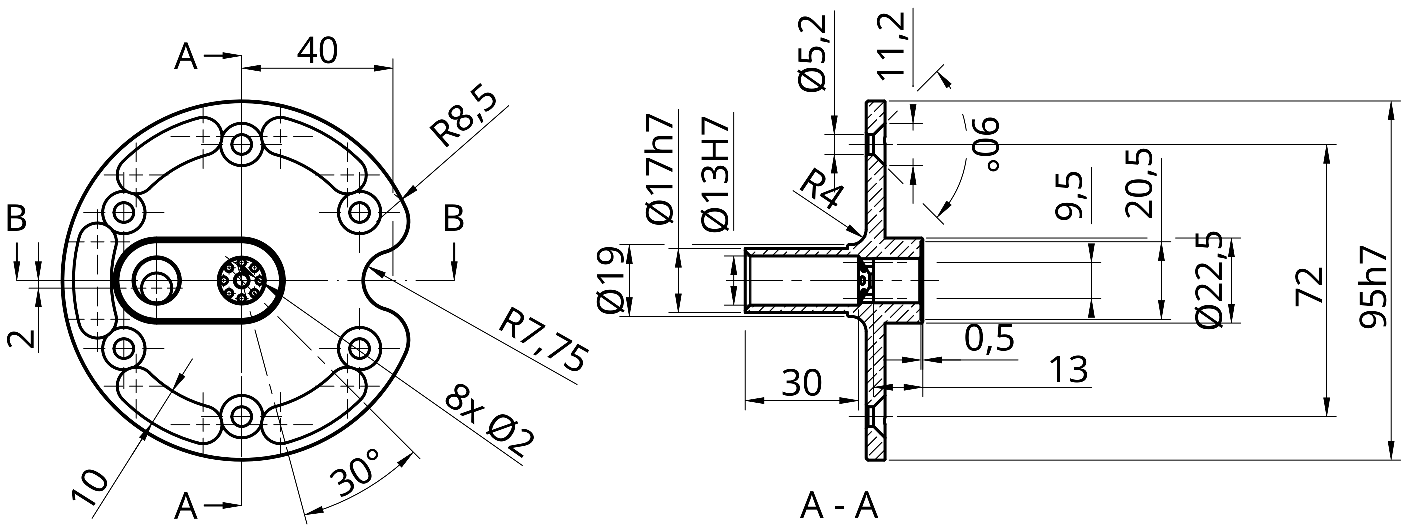
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2025-07-13	
	CHECKED				TITLE
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 2:1 · WEIGHT · SHEET 1 of 1

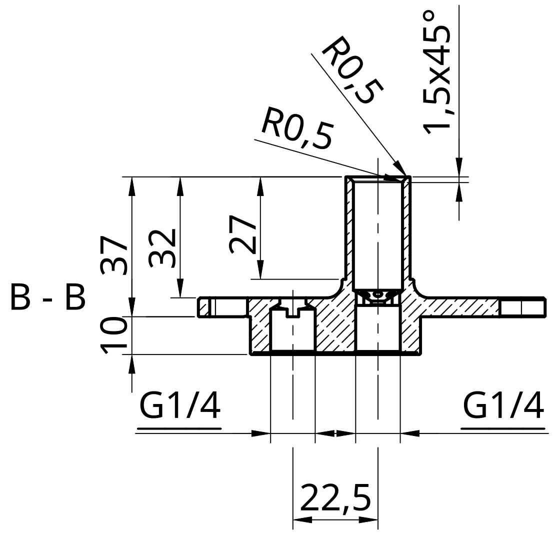


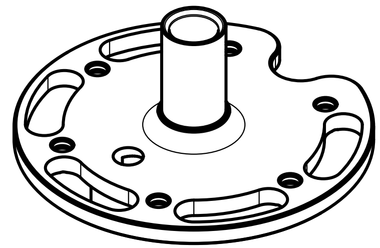
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2025-07-12	
	CHECKED				TITLE
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL	FINISH			SCALE 3:1 · WEIGHT · SHEET 1 of 1



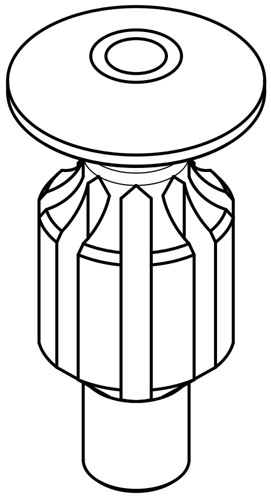
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2025-08-23	TITLE
	CHECKED				
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 3:1 · WEIGHT · SHEET 1 of 1

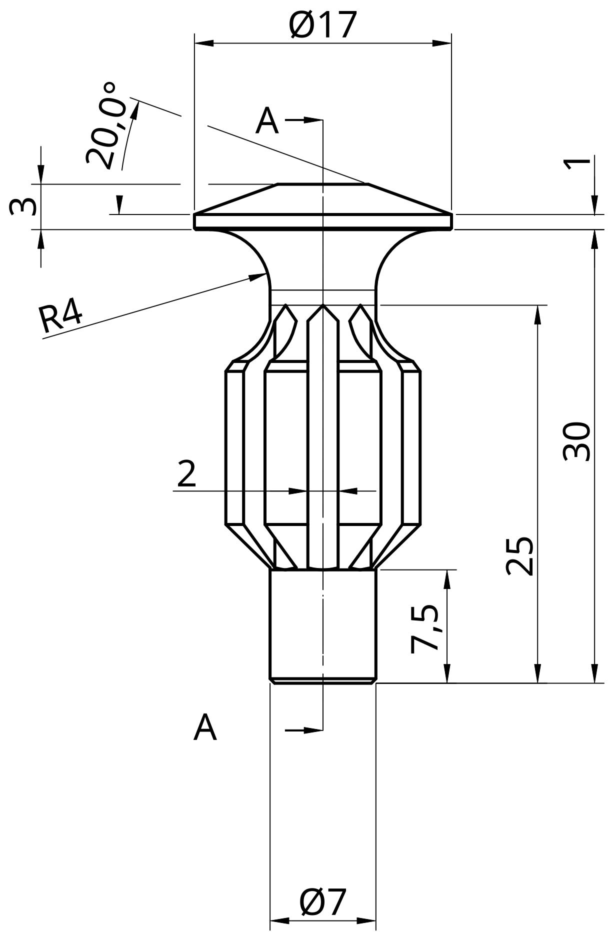


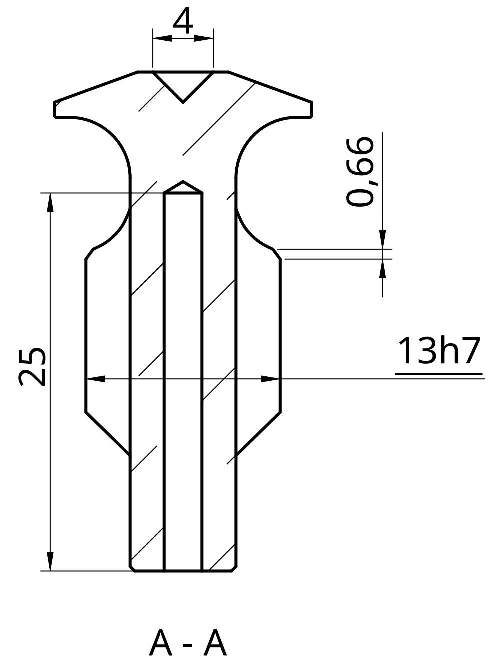




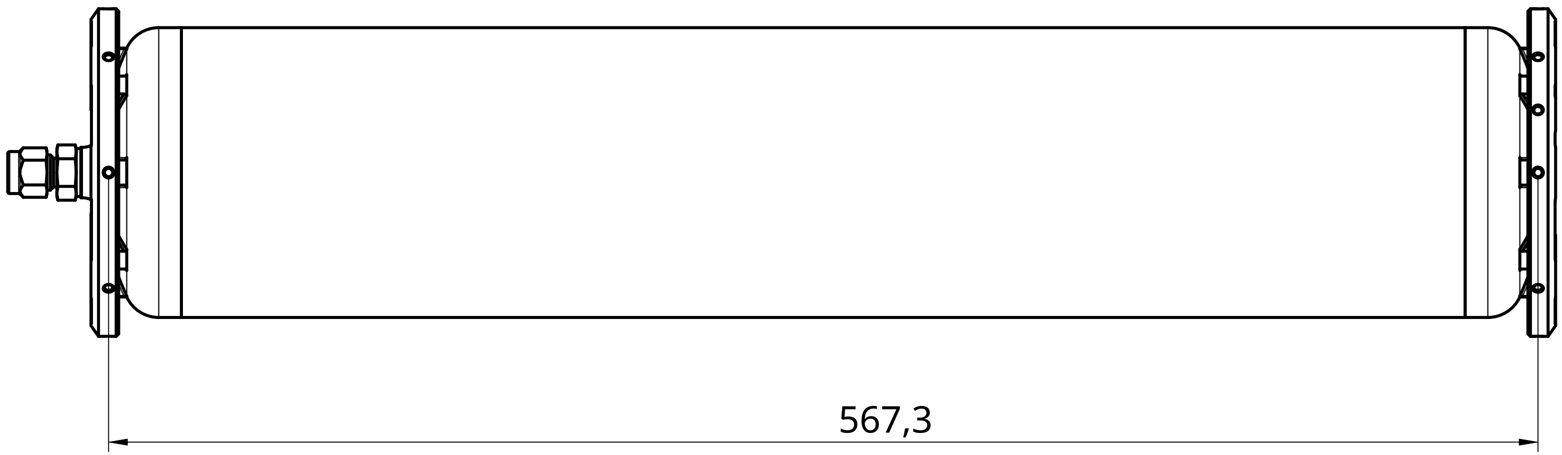
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE	
ANGULAR = ± °	DRAWN	MATTHIAS RIER		2024-09-16	
SURFACE FINISH	CHECKED				TITLE: Pintle Sleeve Injector Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE: A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE: 1:2 · WEIGHT · SHEET: 1 of 1





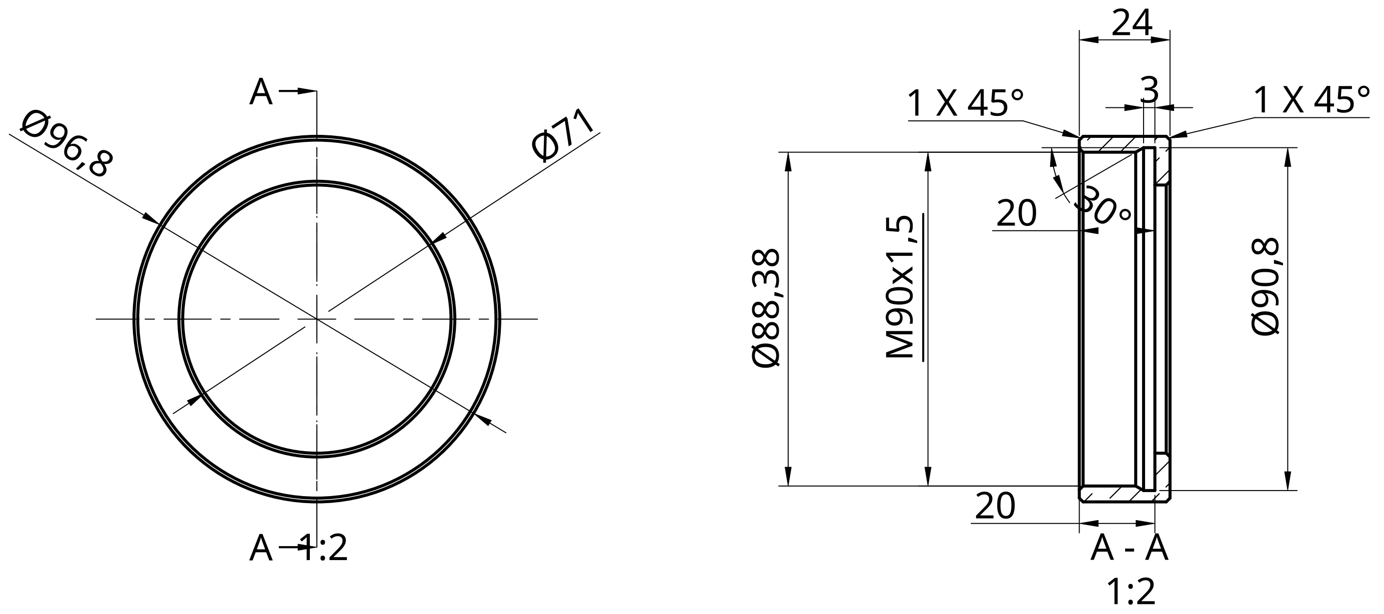


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2024-07-22	
	CHECKED				TITLE Pintle Injector Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 / DWG NO. / REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 2:1 / WEIGHT / SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE
	DRAWN	MATTHIAS RIER		2024-07-01
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL EN AW 6082 Lösungsgeglüht	FINISH		

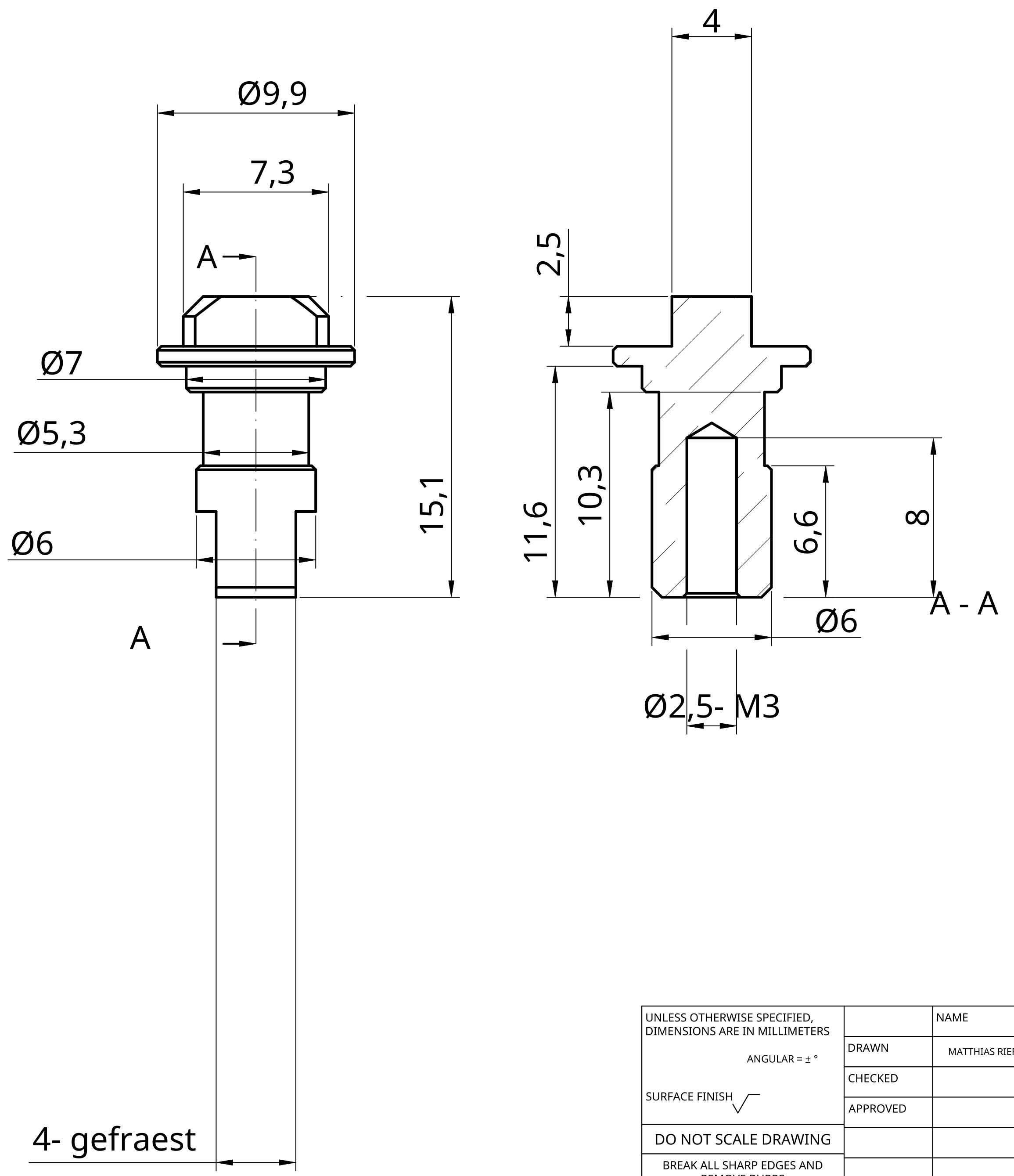
TITLE	Propellant Tank Propellant Tank Propulsion		
SIZE A4	DWG NO.		REV.
SCALE 1:6	WEIGHT	SHEET 1 of 1	



M90x1,5
Thread depth internal thread: 0,81mm

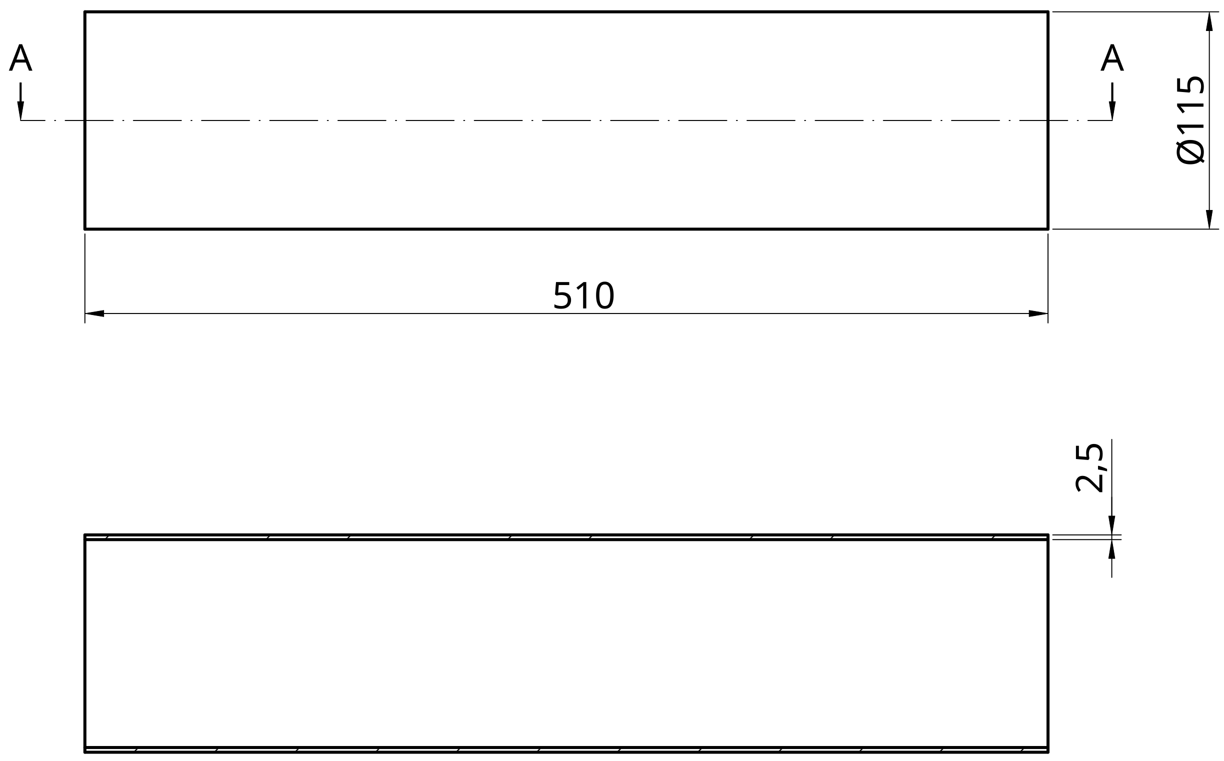
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE
ANGULAR = ± °	DRAWN	MATTHIAS RIER		2024-08-18
SURFACE FINISH	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL	FINISH		

TITLE	Retainer Nut Thrust Chamber Propulsion
SIZE	A4
DWG NO.	
REV.	
SCALE	1:4
WEIGHT	
SHEET	1 of 1



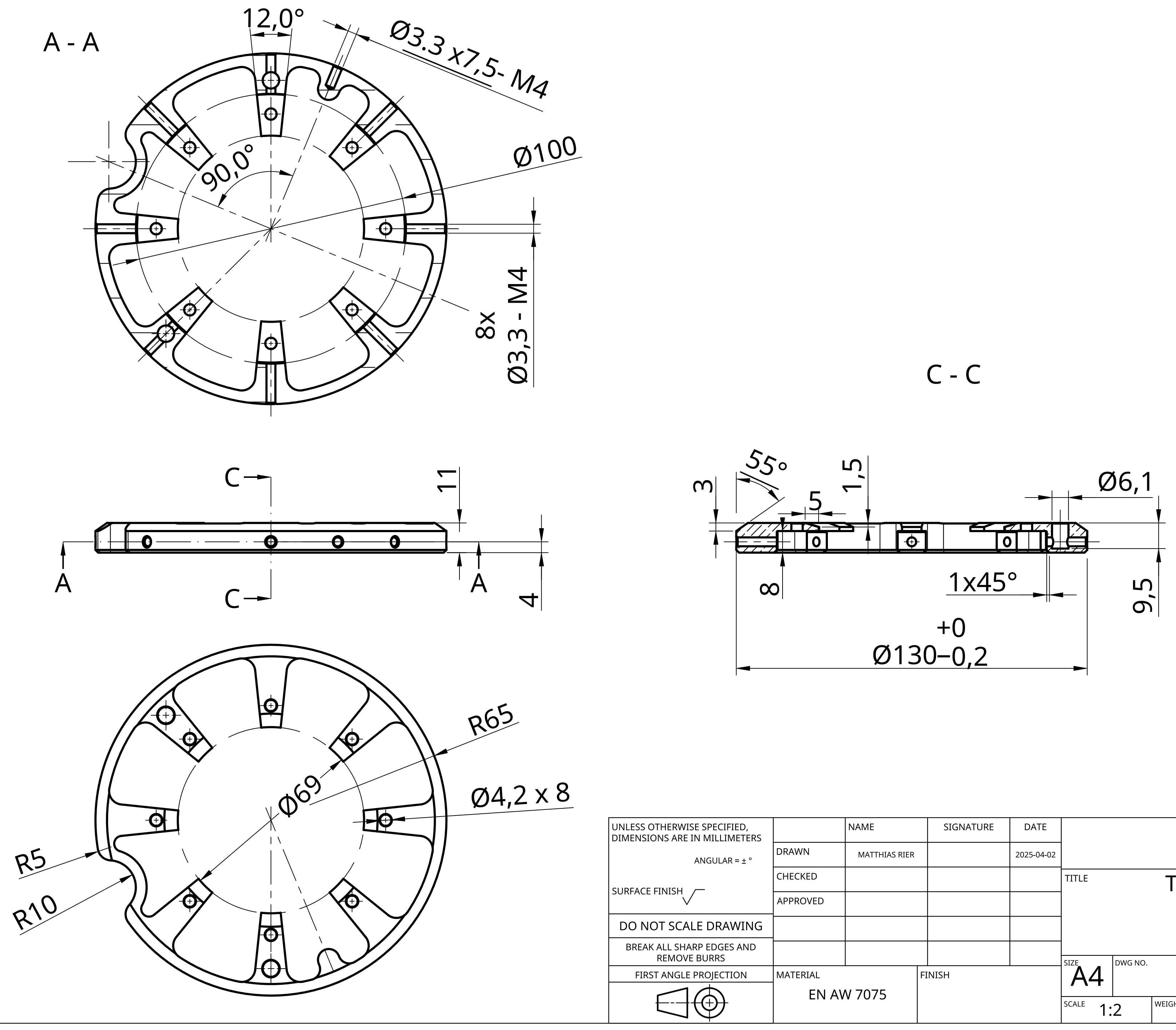
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE	
ANGULAR = ± °	DRAWN	MATTHIAS RIER		2025-08-23	
SURFACE FINISH	CHECKED				TITLE
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL		FINISH		SCALE 3:1 · WEIGHT · SHEET 1 of 1

1:4



A - A
1:4

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	SIGNATURE	DATE	
	DRAWN	MATTHIAS RIER		2024-07-01	
	CHECKED				TITLE Tank cylinder Propellant Tank Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					
FIRST ANGLE PROJECTION	MATERIAL AW EN 6082 Lösungsgeglüht	FINISH			SIZE A4 / DWG NO. / REV.
					SCALE 1:10 / WEIGHT / SHEET 1 of 1

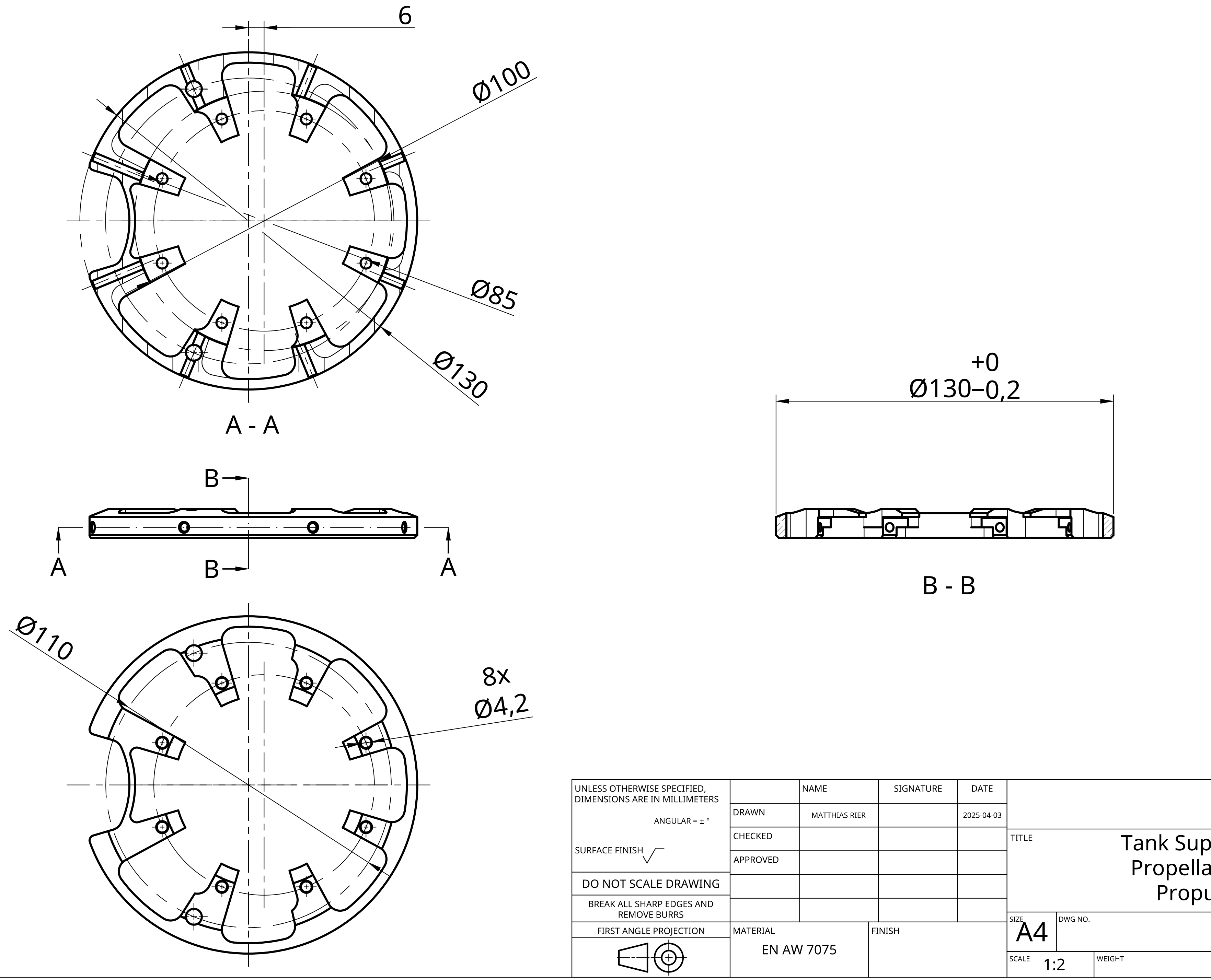


UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± °		NAME	SIGNATURE	DATE
SURFACE FINISH	DRAWN	MATTHIAS RIER		2025-04-02
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				
FIRST ANGLE PROJECTION	MATERIAL: EN AW 7075	FINISH		

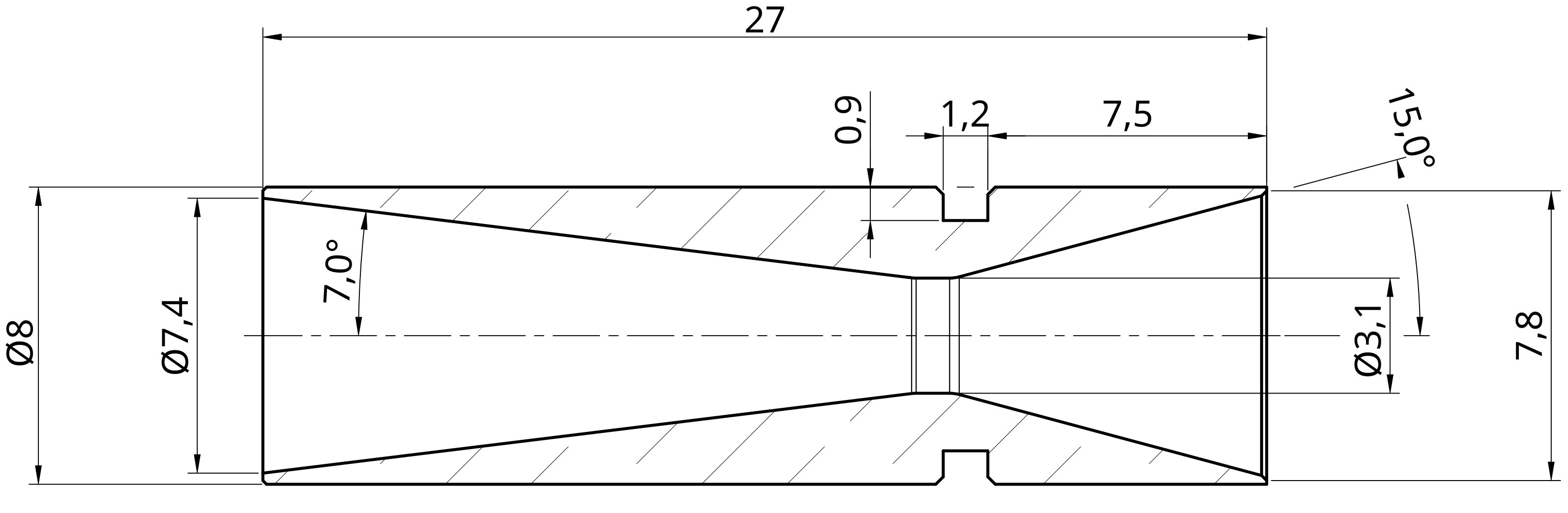
TITLE: Tank Suppor Ethanol Propellant Tank Propulsion

SIZE	DWG NO.	REV.
A4		

SCALE	WEIGHT	SHEET
1:2		1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE	
ANGULAR = ± °	DRAWN	MATTHIAS RIER		2025-04-03	
SURFACE FINISH	CHECKED				TITLE Tank Support LOx Propellant Tank Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL EN AW 7075		FINISH		SCALE 1:2 · WEIGHT · SHEET 1 of 1



A - A

Throatdiameter:
Fuel: 3,1mm
Ox: 3,1mm

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	SIGNATURE	DATE	
ANGULAR = ± °	DRAWN	FABIO		2024-07-09	
SURFACE FINISH	CHECKED				TITLE Ox Venturi Injector Propulsion
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS					SIZE A4 · DWG NO. · REV.
FIRST ANGLE PROJECTION	MATERIAL	FINISH			SCALE 5:1 · WEIGHT · SHEET 1 of 1