

SimLE SimBa R7 Orzeł

Team AH100GUT Project Technical Report for FAR-OUT 2026

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1 Abstract

This technical report presents the design, system architecture, and optimization of the R7 Orzeł sounding rocket, developed by the SimBa program within the student engineering organization SimLE at the Gdańsk University of Technology. Competing in the hybrid-propulsion category of the FAR-OUT 2026 (Friends of Amateur Rocketry - Oxidizers Uninhibited Tournament) competition, the R7 Orzeł is designed to carry a 3U CubeSat form-factor payload to a targeted Contract Apogee of 3642 meters (11949 feet).

The vehicle incorporates several Student Research and Development (SRAD) innovations aimed at maximizing structural reliability and assembly efficiency in harsh desert conditions. The rocket is powered by the newly developed Zygzak hybrid rocket motor, which utilizes a solid fuel grain of paraffin-wax / EVA and a self-pressurizing liquid nitrogen oxide N_2O oxidizer to produce a total impulse of 21 kN over a nominal burn time of 10-seconds. To enhance mass efficiency, the propulsion system utilizes an integrated structural oxidizer tank designed to carry external mechanical flight loads. Aerodynamically, the 4.33-meter vehicle features a fiberglass power series nose cone and a lightweight carbon-fiber boat tail. Airframe segment connections abandon traditional tube-in-tube couplers in favor of custom-machined, self-centering Radial-Axial (RADAX) connectors, mitigating the risk of desert particulate contamination and enhancing overall structural rigidity.

The recovery bay houses a redundant dual-stage deployment system featuring an in-house developed pyrotechnic black powder charge mechanism at apogee for drogue deployment, followed by a custom SRAD resistance-wire line cutter that unreefs the 2.5-meter main parachute at an altitude of 450 meters. The avionics stack architecture consists of a highly reliable, distributed cyber-physical system centered on dual-node BeagleBone Black single-board computers communicating via an Ethernet link utilizing the SOME/IP middleware protocol over an AUTOSAR platform.

Rocket facilitates a dual-payload configuration: an engineering demonstration unit provided by Apator Metrix S.A. to study commercial gas-meter components under extreme launch stress, and a secondary outreach payload (“Jebediah Kerman”) acting as a fixed mass simulator. Ground support infrastructure incorporates a fully remote, distributed cyber-physical fueling pad and telemetry network operating at a safe stand-off distance of 1.5 kilometers. Following a comprehensive institutional phase dedicated to knowledge recovery and the rigorous standardization of technical documentation, the development of the R7 Orzeł fulfills SimLE’s primary goal of preparing university students for high-level professional careers in the aerospace sector.

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2 Nomenclature

The following alphabetical lists define the mathematical symbols, variables, acronyms, and specialized technical terms utilized throughout this report.

Roman Symbols & Variables

A_e	Nozzle exit cross-sectional area, m^2
A_t	Nozzle throat cross-sectional area, m^2
C_D	Aerodynamic drag coefficient, dimensionless
C_L	Aerodynamic lift coefficient, dimensionless
F_A	Axial aerodynamic force vector, N
F_N	Normal aerodynamic force vector, N
F_T	Motor thrust force, N
I_{11}, I_{22}	Transverse moment of inertia elements, $\text{kg} \cdot \text{m}^2$
I_{33}	Axial (longitudinal) moment of inertia element, $\text{kg} \cdot \text{m}^2$
I_{tot}	Total propulsive impulse, N · s or kNs
M	Mach number, dimensionless
P_c	Combustion chamber stagnation pressure, bar or MPa
P_{tk}	Oxidizer tank internal pressure, bar or MPa
t_b	Nominal motor burn time profile, s

Greek Symbols

α	Vehicle instantaneous aerodynamic angle of attack, deg
ρ	Paraffin-wax solid fuel grain density component, kg/m^3

Subscripts & Flight Mechanics Indicators

CG	Center of Gravity absolute coordinate location
CP	Aerodynamic Center of Pressure absolute coordinate location

Acronyms & Abbreviations

ADC	Analog-to-Digital Converter
AGL	Above Ground Level reference altitude
APRS	Automatic Packet Reporting System tracking beacon
ARK	Aufreihbare Reihenklemme (Modular PCB terminal block connection point)
AUTOSAR	Automotive Open System Architecture execution layer
AW	Aluminium Wrought alloy specification prefix
BME	Barometric, Moisture, and Environmental embedded sensor subset
BSPP	British Standard Pipe Parallel thread sealing specification
CAD	Computer-Aided Design model suite
CATS	Commercial Altimeter Telemetry System (e.g., CATS Vega safety module)
CNC	Computer Numerical Control machining interface
COTS	Commercial Off-The-Shelf system componentry
DMLS	Direct Metal Laser Sintering powder-bed additive manufacturing method
EB	Engine Board custom microcontroller section
EC	Engine Computer computational subsystem node
EDM	Electrical Discharge Machining manufacturing method
EEPROM	Electrically Erasable Programmable Read-Only Memory component
ESD	Electrostatic Discharge mitigation componentry
EVA	Ethylene-Vinyl Acetate solid fuel chemical binder constituent

FC	Flight Computer centralized command authority node
FDM	Fused Deposition Modeling rapid-prototyping method
FEA	Finite Element Analysis evaluation methodology
FSM	Finite State Machine algorithmic framework
GNSS	Global Navigation Satellite System tracking configuration
GPIO	General-Purpose Input/Output hardware configuration pin
GSE	Ground Support Equipment physical launchpad stack
GSUART	Ground Segment Universal Asynchronous Receiver-Transmitter physical protocol
GUI	Graphical User Interface localized system overview
HIL	Hardware-In-the-Loop simulation validation platform
IMU	Inertial Measurement Unit multi-axis sensory network
IPC	Inter-Process Communication software layer
ISM	Industrial, Scientific, and Medical radio frequency spectrum bracket
LDPE	Low-Density Polyethylene polymer grain formulation modifier
LDO	Low-Dropout linear voltage regulation component
LoRa	Long Range low-power wide-area radio telemetry protocol
MAVLink	Micro Air Vehicle Link open-source communication bridge protocol
MB	Mainboard custom avionics electronics chassis subset
MCC	Mission Control Center localized monitoring cluster
MEOP	Maximum Expected Operating Pressure vehicle safety limits
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor switching block
MOV	Main Oxidizer Valve main physical feed control actuator
NBR	Nitrile Butadiene Rubber physical elastomer sealing componentry
NMEA	National Marine Electronics Association deterministic geospatial phrase protocol
OLED	Organic Light-Emitting Diode diagnostic display component
P&ID	Piping and Instrumentation Diagram structural overview
PCB	Printed Circuit Board array subset
PET-G	Polyethylene Terephthalate Glycol structural additive fabrication material
PLA	Polylactic Acid rapid-prototyping fabrication material
PMS	Power Management System hardware regulation matrix
PoE	Power over Ethernet communication and electrical power integration protocol
PTFE	Polytetrafluoroethylene thread matrix sealing method
PTZ	Pan-Tilt-Zoom remote camera positional tracking matrix
PWM	Pulse-Width Modulation system drive signaling layer
RADAX	Radial-Axial self-centering conical interface airframe joint system
RF	Radio Frequency telemetry subset
ROS2	Robot Operating System 2 distributed publish-subscribe cyber-physical infrastructure
RTV	Room-Temperature Vulcanizing chemical polymer assembly barrier
RUD	Rapid Unplanned Disassembly critical field failure mode
SD	Secure Digital persistent non-volatile local data logging platform
SOME/IP	Scalable service-Oriented Middleware over IP communication interface
SRAD	Student Research and Development programmatic categorization
SRP	Simple Rocket Platform software application orchestration layer
SVG	Scalable Vector Graphics diagnostic display paradigm
UART	Universal Asynchronous Receiver-Transmitter communications block
UDP	User Datagram Protocol network transmission configuration
VHF	Very High Frequency amateur radio recovery network band
WBS	Work Breakdown Structure strategic framework
WMM	Weight Measurement Module custom load-cell rocket scale infrastructure
XPS	Extruded Polystyrene composite manufacturing core substrate

3 Introduction

3.1 Academic program and stakeholders

SimLE is a student engineering organization established in 2013 at the Gdańsk University of Technology (GUT). The organization primarily comprises undergraduate and master's students from GUT, though it remains open to students from other local universities. The core objective of SimLE is to prepare members for professional engineering careers by fostering both technical proficiency and critical soft skills. The organization oversees six active projects: Stardust, SimBa, Stellar, SeaSentinel, Singo, SeeSky. These projects work on different devices explained in Table 3.1 below.

Project	Field of work
SimBa	Rockets and rocket engines
SeaSentinel	Autonomous Sea Vessels
Stardust	Stratospheric balloons
Singo	Flying quadrocopter drones
Stellar	Autonomous Martian rovers
SeeSky	Sky viewing telescopes

Table 3.1: SimLE Projects

3.2 Program history and mission overview

The SimBa project was established in 2017 to develop amateur launch vehicles, beginning with the R1 rocket, which featured an active flight trajectory control system utilizing actuated fins. By 2018, the team completed the R2 prototype and conducted its first static engine tests. During this period, the organization significantly expanded, integrating new members who brought critical expertise in composite materials and electronics manufacturing.

In 2019, the team developed the R3 launch vehicle, featuring an upgraded avionics architecture. The R3 completed a successful test flight to an apogee of 2.5 kilometers, marking SimBa's inaugural participation in an international rocketry competition. Despite pandemic-related constraints in 2020, the team successfully transitioned to remote development to design the R4 rocket, which introduced a more advanced propulsion system.

In the 2022 SimBa team built an R5 rocket. It was presented during Spaceport America Cup 2022 and secured 4rd place in the 10 k feet hybrids category.

The development of the R6 launch vehicle in 2023 was highly driven by the R5 rocket architecture. It was a successor that used the same R5 platform but facilitated newer more complicated electronics and software systems. The R6 was presented at the Spaceport America Cup securing a 3rd place in the 10k feet hybrids category even though it did not managed to launch.

Following the R6 campaign, the SimBa project experienced a significant attrition of senior personnel. Because rigorous documentation standards had not yet been fully institutionalized, the departure of these experienced members resulted in a severe loss of corporate knowledge. Between 2023 and 2026, the team was forced to undergo a comprehensive knowledge recovery phase, dedicating significant time to reverse-engineering previous subsystems and rebuilding the organization's technical foundation from the ground up.

Having successfully overcome these institutional setbacks with a renewed, strict mandate on technical documentation and knowledge transfer, the current SimBa team has developed the R7 Orzeł launch vehicle to meet the rigorous mission requirements of the FAR-OUT 2026 competition.

3.3 Team structure and management strategies

To optimize engineering workflows and maintain clear lines of accountability, the SimBa division is organized into a structured hierarchy consisting of executive management and technical divisions. This organizational framework is designed to manage the interdependencies of a complex aerospace project.

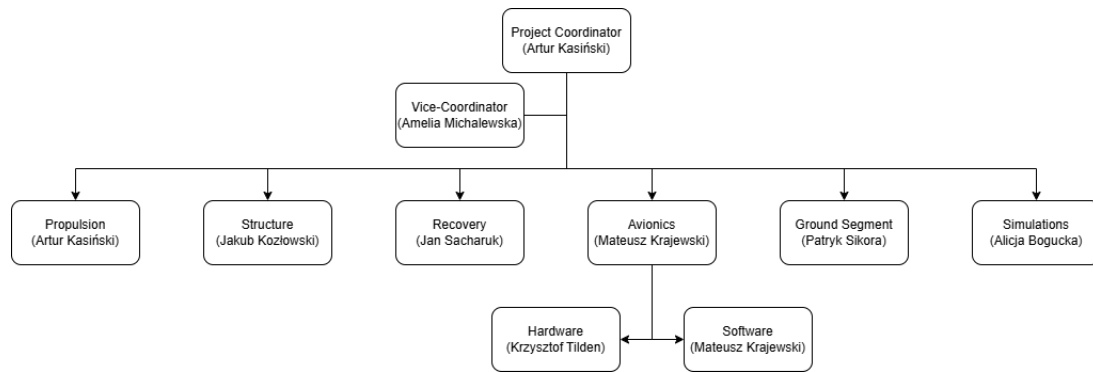


Figure 3.1: SimBa WBS

The program management team enforces operational discipline, schedule tracking, and strategic oversight across all technical disciplines:

- **Project Coordinator:** Functions as the ultimate authority for program management and engineering operations. The Project Coordinator is responsible for technical oversight, systems integration validation, and final safety sign-offs across all sub-teams.
- **Vice-Coordinator:** Manages all non-technical operations, including corporate sponsorship acquisition, university relations, public relations campaigns, and budget allocation. Additionally, this role oversees logistical planning for testing campaigns and competition deployment.

Engineering workloads are distributed across specialized technical divisions, each led by a designated Team Lead responsible for component-level delivery and verification. Personnel assignments and leadership roles as of 2026 are detailed in Figure 3.1.

- **Avionics (Electronics and Software):** To maximize interdisciplinary cohesion, the Electronics and Software teams are consolidated under a single Avionics Supervisor. This structural choice is dictated by the tight coupling of custom Student Research and Development (SRAD) hardware execution and the underlying Simple Rocket Platform (SRP) software architecture. The Supervisor facilitates seamless hardware-in-the-loop (HIL) testing and ensures robust systems integration.
- **Propulsion:** Responsible for hybrid motor design, fuel grain manufacturing optimizations, and fluid circuitry layout.
- **Structures:** Governs airframe design, composite lamination processes, and structural coupling mechanics.
- **Recovery:** Designs and validates the dual-stage parachute deployment mechanisms and pyrotechnic line-cutter hardware.
- **Ground Support Equipment (GSE):** Engineers the physical launchpad interfaces, remote fluid loading setups, and long-range communication infrastructure.
- **Simulation:** Conducts iterative flight profile optimization, static margin analysis, and aerodynamic verification using OpenRocket and numerical simulation environments.

4 System architecture

4.1 Overview

The system architecture for the R7 Orzeł mission is divided into two heavily interdependent operational segments: the Launch Vehicle and the Ground Support Equipment (GSE). The primary design driver for the R7 platform was balancing high aerodynamic and propulsive performance with rapid, reliable field assembly and maximum operator safety.

Configured specifically for the FAR-OUT 2026 competition profile, the R7 Orzeł is a hybrid-propulsion sounding rocket. To facilitate rapid assembly in harsh desert environments and mitigate the risk of particulate contamination in structural joints, the vehicle abandons traditional tube-in-tube couplers in favor of custom-machined Radial-Axial (RADAX) connectors.

Following a top-down architecture (Fig. 4.1), the vehicle consists of five major integrated subsystems:

1. **Recovery module** - Houses the dual-deployment parachute system, custom SRAD line-cutters, and redundant deployment mechanisms (CO₂ and pyrotechnic).
2. **Service Bay (Payload & Avionics)** - A modular aluminum frame structure housing the primary flight computers, telecommunications, electronics, the Apator Metrix scientific payload, and the "Jebediah Kerman" outreach payload. ;
3. **Feed subsystem** - Contains the oxidizer plumbing, main oxidizer valve (MOV), and remote actuation mechanisms.
4. **Tank** - A high-pressure vessel designed to safely store and distribute liquid nitrous oxide (N_2O)
5. **Engine** - A hybrid rocket motor utilizing a paraffin-wax/EVA fuel grain, interfacing directly with the feed system .
6. **Aerostructure** - everything is packed in the body made out of carbon and glass fibre composite tubes joint together with RADAX couplers.

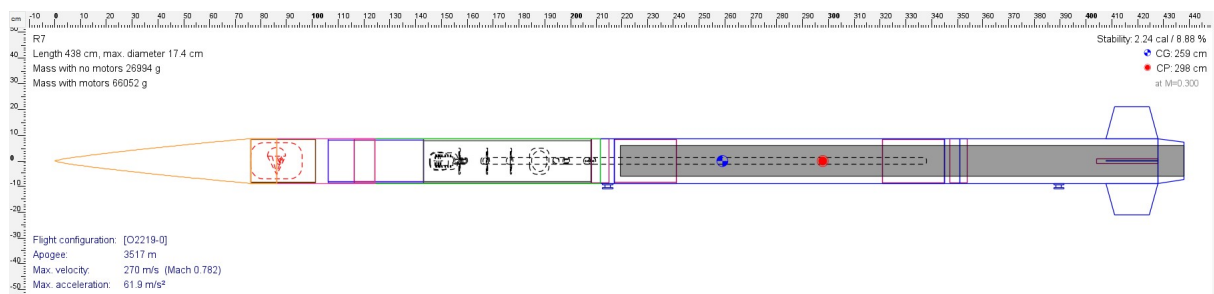


Figure 4.1: Subsystems arrangement

Due to the hazards associated with hybrid rocket nitrous oxide operations, the GSE is engineered to act as a fully remote, distributed cyber-physical system. It ensures operator safety by keeping all personnel at a minimum distance of 1.5 km during active fueling and pressurization. As outlined in Figure 4.87, the GSE architecture consists of three primary nodes:

- **Launch Pad Infrastructure:** Features the automated fueling system, remotely actuated servo valves, a physical decoupler mechanism, and an active weight measurement module to calculate real-time oxidizer mass.
- **Mission Control Center (MCC):** The central command hub, featuring a hardware-in-the-loop control panel and a custom web application for telemetry visualization and critical command execution (e.g., launch authorization, emergency abort).
- **Communications Network:** A multi-layered RF architecture utilizing a 5 GHz Wi-Fi bridge for high-bandwidth pad infrastructure data, a 433 MHz radio link for active flight telemetry, and an independent 915 MHz LoRa beacon for post-flight recovery tracking.

4.2 Propulsion

4.2.1 Overview

The engine developed for the R7 Orzeł rocket is a completely new hybrid rocket motor named Zygzak. It was designed as the main propulsion unit for the new vehicle and represents a major design step in comparison with

previous propulsion systems developed by the team. The target total impulse of the engine is 21 kNs, with a nominal burn time of 10 s. Based on these values, the average thrust of the motor is approximately 3.8 kN.

The most important parameters of the Zygzak engine are summarized in Table 4.1.

Table 4.1: Summary of Zygzak hybrid rocket motor parameters

Engine name	Zygzak
Rocket	R7 Orzeł
Total impulse	21 kNs
Burn time	10 s
Average thrust	3.8 kN
Engine type	Hybrid rocket motor

The Zygzak engine introduces several major improvements to the propulsion subsystem. One of the most important changes is the use of a structural oxidizer tank, which is integrated with the rocket structure and is designed to carry mechanical loads during flight. This solution reduces the number of additional structural elements and allows for a more mass-efficient layout of the vehicle.

Another significant development is the new fuel grain. For the first time, the team fully designed, manufactured, and tested a new grain configuration dedicated specifically to this engine. This required extensive work on the internal geometry, manufacturing process, and fuel composition in order to ensure stable combustion and repeatable performance.

The main challenge during the development of the Zygzak engine was to reduce flow choking and combustion-related restrictions occurring during motor operation. A significant part of the development process was therefore focused on improving the fuel mixture and optimizing the internal flow conditions inside the combustion chamber. These changes were introduced to increase combustion stability, improve regression behavior, and provide more predictable engine performance.

The propulsion subsystem is divided into three main sections:

- combustion chamber,
- oxidizer tank,
- feed system.

The general layout of the propulsion subsystem is shown in Figure 4.2. The figure presents the relative placement of the main engine sections and their integration with the rocket structure.

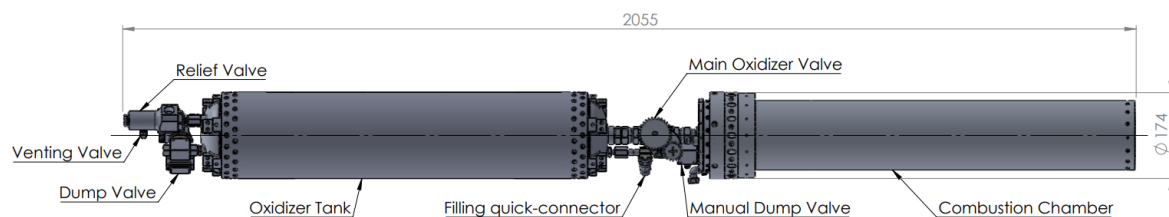


Figure 4.2: Propulsion overview.

A detailed P&ID diagram of the propulsion subsystem is presented in Figure 4.3. The diagram includes all valves, feed lines, filling lines, venting lines, sensors, and other components required for safe operation of the engine. It also shows the interfaces between the oxidizer tank, feed system, combustion chamber, and ground support equipment used during filling and testing procedures.

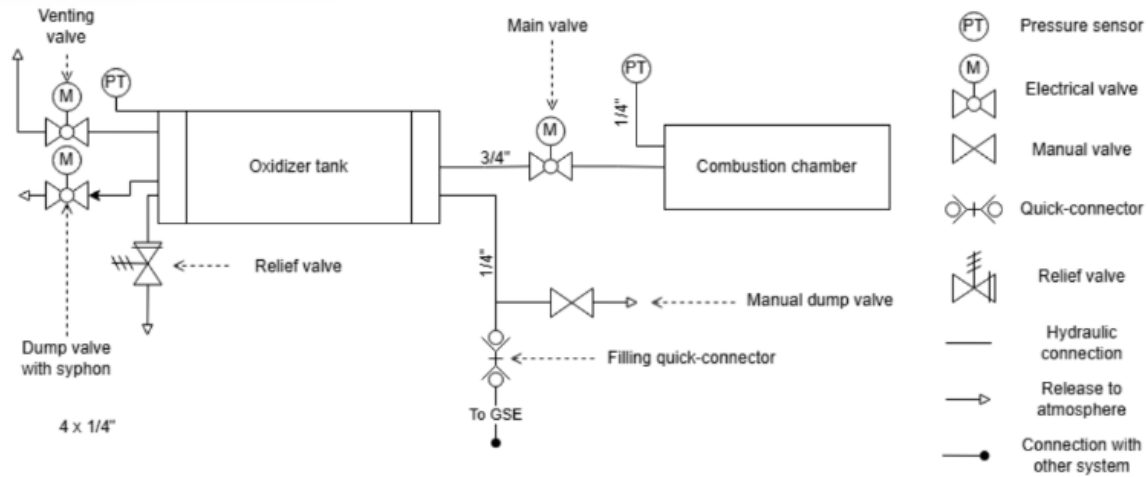


Figure 4.3: Engine P&ID diagram.

The feed system is responsible for delivering oxidizer from the structural tank to the combustion chamber in a controlled and repeatable way. It includes all necessary valves and fluidic elements required for filling, venting, isolation, and engine operation. The combustion chamber contains the newly developed fuel grain and is designed to withstand thermal and mechanical loads generated during the burn. The oxidizer tank serves both as a pressure vessel and as a structural part of the rocket, making it one of the key elements of the new propulsion architecture.



Figure 4.4: Assembled engine.

Further details concerning the design, manufacturing, and testing of individual propulsion subsystem components are provided in the following sections.

4.2.2 Combustion chamber

The combustion chamber is one of the key components of the Zygzak hybrid rocket motor, developed for the R7 Orzeł rocket. Its main function is to provide a controlled environment for the combustion of nitrous oxide and the solid paraffin-wax based fuel grain. The motor is designed for a total impulse of 21 kNs and a nominal burn time of 10 s, which gives an average thrust of approximately 3.8 kN. Achieving this performance required reducing flow choking and combustion instabilities observed during the development phase, as well as improving the fuel composition and internal grain geometry.

The chamber assembly consists of the following main elements:

- injector,
- combustion chamber walls,
- thermal insulation liners,
- paraffin-wax fuel grain,
- nozzle.

A cross-section of the combustion chamber is presented in Figure 4.5. The figure shows the relative position of the injector, fuel grain, thermal liner, chamber casing, and nozzle section.



Figure 4.5: Combustion chamber cross-section.

The main materials used in the combustion chamber assembly are listed in Table 4.2.

Table 4.2: Materials used in the combustion chamber assembly

Component	Material
Combustion chamber walls	AW6060
Holder	AW2007
Retainer	AW2007
Thermal insulation liners	Cotton phenolic liner
Washers	Cotton phenolic liner
Mixer	Cotton phenolic liner
Nozzle	Fine-grained graphite
Fuel grain	84% paraffin wax, 1% carbon, 15% EVA
Bolts	M4x6, class 12.9, DIN 912

The combustion chamber walls are manufactured from AW6060 aluminium alloy. The chamber walls were machined in-house by the team. The turning operations were performed on a lathe, whereas the holes in the chamber walls were drilled using an indexing head and a bench drill to ensure proper angular positioning. The manufactured chamber walls are shown in Figure 4.6.



Figure 4.6: Manufactured combustion chamber walls.

The injector section is responsible for delivering oxidizer into the chamber and strongly influences the stability of the combustion process. The injector plate is manufactured from AW-7075 aluminium alloy. Its initial shape is

produced using wire EDM to ensure accurate geometry and reliable reference surfaces, and the final geometry is machined using CNC technology. The manufactured injector is presented in Figure 4.7.

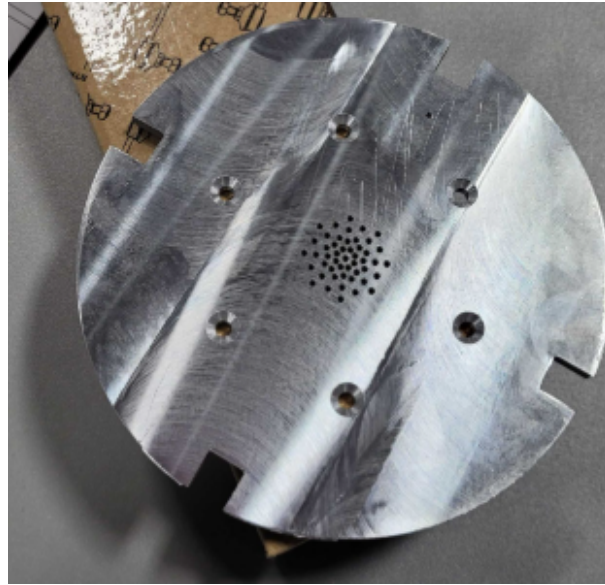


Figure 4.7: Manufactured injector.

The fuel grain is manufactured from a paraffin-wax based mixture with additives. For the first time in the development of the R7 propulsion system, the team fully designed, manufactured, and tested a new grain configuration dedicated specifically to this motor. Details about the fuel grain manufacturing process will be provided in Section 4.2.3.

The ignition system of the combustion chamber is based on primers and flares placed in the pre-combustion chamber. They are bonded directly inside this section to ensure reliable ignition of the fuel grain and to provide a stable ignition source before the main oxidizer flow reaches nominal operating conditions.

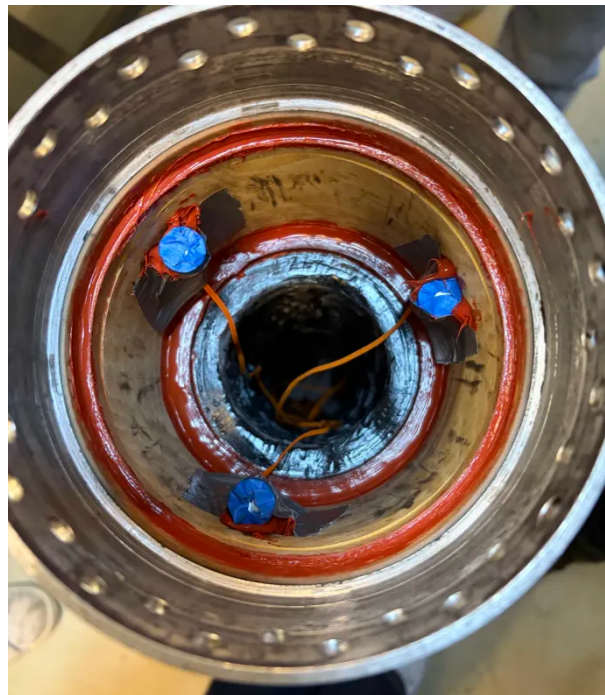


Figure 4.8: Igniters and flares glued to pre-combustion chamber.

The thermal protection of the chamber wall is provided by a cotton phenolic liner. This material was selected due to its low thermal conductivity, dimensional stability, good machinability, and ability to maintain the grain

geometry during operation. It also limits heat transfer from the combustion zone to the combustion chamber walls and holder, reducing the risk of thermal damage to the casing.

All insulation components used in the combustion chamber were manufactured in-house by the team. The pre-combustion chamber, post-combustion chamber, and grain insulation were produced by turning. The washers and mixers were first milled using a CNC milling machine and then finished on a lathe to obtain the required final geometry and fit inside the chamber assembly.



Figure 4.9: Manufactured insulation elements.

Additional cotton phenolic washers are placed at both ends of the fuel grain. Their purpose is not only to protect the axial surfaces of the grain, but also to create sharp geometric edges at the inlet and outlet of the grain port. These sharp edges promote local flow separation and recirculation zones, which improve flame holding and support more stable combustion inside the chamber.

During the first static firing test, post-test inspection showed that the fuel grain burned more intensively close to the chamber walls, especially near the grain insulation interface. This observation indicated that the local heat feedback and flow structure near the liner have a significant influence on the regression pattern of the paraffin-wax fuel. For this reason, the liner, washers, and grain-end geometry were treated as important design features affecting combustion stability and repeatability.

A mixer is also installed in the post-combustion chamber. In hybrid rocket motors, the oxidizer-rich core flow and fuel-rich gases generated near the grain surface may not mix completely inside the grain port, which can reduce combustion efficiency. The mixer increases turbulence and recirculation in the aft part of the chamber, improving the mixing of remaining reactants before the flow enters the nozzle.

The nozzle is manufactured from fine-grained graphite. This material was selected due to its high temperature resistance and good behavior under exposure to hot combustion products. The nozzle is responsible for accelerating the exhaust gases and converting the thermal energy of combustion products into thrust. The manufactured nozzle is shown in Figure 4.10.



Figure 4.10: Manufactured nozzle.

To ensure proper sealing of the combustion chamber assembly, NBR O-rings are used in several critical interfaces. They are installed on the nozzle, on the chamber holder, and between the nozzle and the injector plate. This sealing solution prevents gas leakage during engine operation and helps maintain the designed chamber pressure throughout the burn. The use of O-rings also simplifies assembly and disassembly of the chamber, which is important for inspection, maintenance, and post-test analysis.

During assembly, selected combustion chamber components are additionally bonded and sealed using high-temperature red silicone. This silicone is applied at the interfaces where additional sealing and thermal resistance are required. It helps prevent leakage of hot gases, improves the integrity of the assembled chamber, and protects selected joints from direct exposure to elevated temperatures during engine operation.



Figure 4.11: Assembled parts with room temperature vulcanizing (RTV) silicone.

A pressure sensor is installed in the combustion chamber holder to measure chamber pressure during engine operation. The pressure data are used to evaluate ignition transients, steady-state combustion stability, pressure oscillations, and possible choking effects. This measurement is also one of the main diagnostic parameters during

static firing tests, as it allows the chamber behavior to be compared with thrust and oxidizer feed data.



Figure 4.12: pressure sensor IFM PT5402.

4.2.3 Fuel grain

The grain is cast from paraffin wax with additives directly inside a dedicated mold assembly. Because of this, a new manufacturing process and a dedicated production setup are used.

The fuel is based on paraffin wax with several additives. Pure paraffin has very low mechanical strength, so polymer additives such as EVA or LDPE are added to improve its structural and operational properties. In this case, an EVA-based hot-melt adhesive is used because it is easy to obtain, simple to process, and provides sufficient mechanical strength for this application.

Carbon black is also added to the mixture. It helps increase the regression rate by improving heat absorption at the grain surface.

The final fuel composition is 84% paraffin, 15% EVA-based hot-melt adhesive, and 1% carbon black. For a grain mass without insulation of 116.4 oz, this corresponds to 97.8 oz of paraffin, 17.5 oz of hot-melt adhesive, and 1.16 oz of carbon black. The grain is tested in three static fire tests, both of which confirm satisfactory performance of the propulsion system.

Initially, we planned to perform centrifugal casting using a lathe as the spinning platform, with a custom-built aluminum cylindrical mold. We validated this approach through several casting sessions, which confirmed the feasibility of the centrifugal method. However, the process proved to be both labor-intensive and excessively noisy during extended spinning sessions, which led us to transition to gravity casting as the primary production method.



Figure 4.13: Centrifugal casting stand mounted on a lathe.

Although gravity casting is known to introduce challenges such as elevated grain porosity and internal cracking due to uneven solidification, we successfully mitigated all of these issues through iterative refinement of the casting procedure, vacuum degassing, and fuel mixture optimization.

The gravity casting mold assembly, consists of a cylindrical mold body we produced using 3D printing, subsequently coated with epoxy resin on all internal surfaces to prevent leakage of liquid paraffin through the porous print structure. We closed the mold at both ends with custom-designed plugs, also manufactured in-house via 3D printing and similarly coated with resin to ensure a leak-tight fit. All joints between the mold body and the plugs are additionally sealed prior to each casting session. Inside the mold, we place an aluminum rod with a diameter of 70mm, coaxially along the mold axis. This rod serves as a mandrel, defining the geometry of the oxidizer port — the central channel through which the oxidizer flows during engine operation. Following careful selection of the fuel mixture composition, we found that the mandrel did not require the use of a release agent prior to insertion, and once set, it could be withdrawn without significant resistance, leaving a clean and well-defined port surface.

The paraffin fuel mixture is prepared and heated according to a defined thermal procedure. After melting and thorough mixing, we allow the mixture to cool to the target casting temperature before transferring it to a vacuum chamber. The vacuum degassing step is critical to grain quality — by removing dissolved air and entrained bubbles from the liquid mixture, we significantly reduce porosity in the solidified grain and eliminate the internal cracking observed in early casting attempts made without this step. Following degassing, we pour the mixture from above into the vertically positioned, fully assembled gravity casting mold and allow it to solidify at ambient conditions.



Figure 4.14: Fuel grain manufactured using the vacuum-assisted casting method

After complete solidification, we remove the plugs and withdraw the aluminum mandrel, yielding a finished grain with a well-defined central port. We then visually inspect each grain for surface defects and dimensional accuracy. Minor cracks appearing in the vicinity of the port, resulting from thermal contraction of the paraffin around the mandrel during cooling, are addressed by filling them with a small quantity of the remaining heated mixture and re-profiling the port surface using a heated aluminum rod of matching diameter. We apply this repair procedure exclusively to defects of negligible size, where filling is judged to have no meaningful effect on the local regression rate during combustion. Grains exhibiting larger cracks or significant porosity were rejected.

The geometry of the final grain assembly, with all key dimensions, is included in the technical drawing at the end of this document.

4.2.4 Oxidizer Tank

The oxidizer tank is responsible for storing nitrous oxide used by the hybrid propulsion system. Nitrous oxide was selected as the oxidizer due to several properties beneficial for hybrid rocket propulsion. It is relatively safe, commercially available, and remains in liquid phase at room temperature under pressure. Additionally, its high vapor pressure enables the propulsion system to operate in a self-pressurizing configuration, eliminating the need for a separate pressurization system.

The oxidizer tank assembly consists of three structural parts: cylindrical tank walls and two end caps, one on each side (Figs. 4.16, 4.17). One end cap accommodates the fill line, manual dump valve and the Main Oxidizer Valve (MOV), while the opposite end cap integrates the burst disc, remote venting valve, remote dump valve, and the pressure sensor. Both end caps were manufactured using Direct Metal Laser Sintering (DMLS) technology.

The oxidizer tank and all associated plumbing components are designed to withstand elevated operating pressures and oxidizing environment of nitrous oxide. Structural integrity of the assembly was verified using Finite Element Analysis simulations (Fig. 4.15) and hydrostatic pressure testing of the fully assembled tank and plumbing system. Requirements for the pressure vessel are based on FAR-OUT regulations, which specify a minimum proof pressure factor for pressure vessels used in the competition.

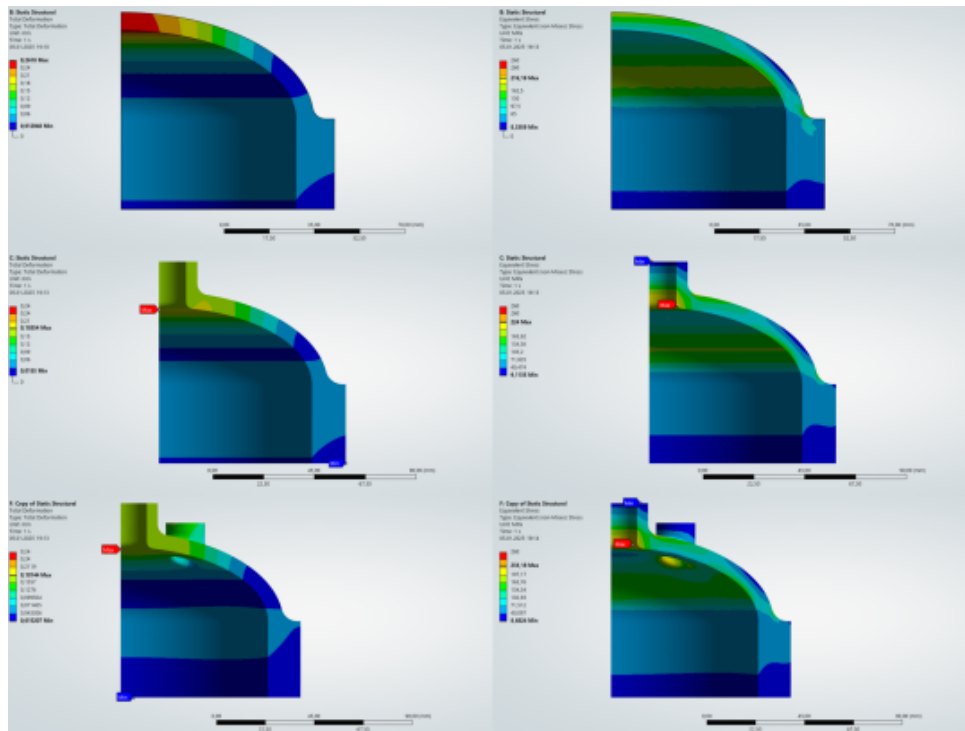


Figure 4.15: FEA simulations of endcaps

The propulsion subsystem incorporates a set of sensors dedicated to monitoring the oxidizer state during filling and operation. The measured parameters include oxidizer pressure, oxidizer temperature, tank external temperature, and oxidizer fill level. Oxidizer fill level is estimated using mass measurements obtained from a load cell. Monitoring of pressure and temperature is critical for safe operation of the propulsion system and estimation of oxidizer properties during operation.

The tank walls are made from AW-6082-T6 aluminum alloy, selected for its favorable strength-to-weight ratio, corrosion resistance in contact with nitrous oxide, and good manufacturability. The DMLS end caps are also produced from AW-6082-T6 powder intended for additive manufacturing processes. The structural connection between the end caps and the tank walls is achieved using DIN7984 M5×8 stainless steel bolts.

Sealing between mating surfaces is provided by two O-ring seals with dimensions of 152×5 mm. The seals are manufactured from NBR rubber and hardness of 70, selected for compatibility with nitrous oxide applications. Hydraulic interfaces are implemented using a G1/4 hydraulic plug and IN-OUT G1/4 – G1/8 straight fittings.

Table 4.3: Materials used in the oxidizer tank assembly

Component	Material	Specification / Notes
Tank walls	AW-6082-T6	Aluminum alloy, P64.4 temper
Upper end cap	AW-6082-T6	DMLS manufactured
Lower end cap	AW-6082-T6	DMLS manufactured
Bolts	DIN7984 M5×8	Stainless steel, A2-70
O-rings	NBR	152×5 mm
Pressure sensor	-	Pressure transmitter IFM PT5402

(Fig. 4.16)(Fig. 4.17).

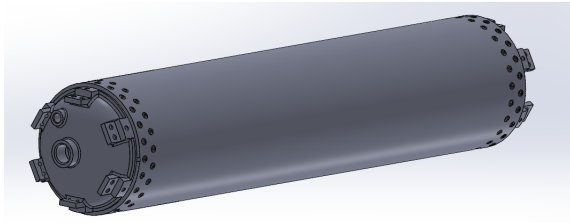


Figure 4.16: Oxidizer tank view 1

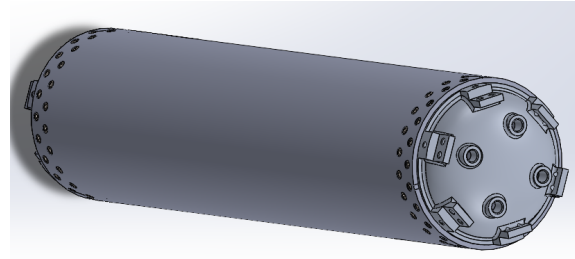


Figure 4.17: Oxidizer tank view 2

Previous generations of tanks developed within the project provided valuable operational experience. Lessons learned from earlier designs resulted in improvements in manufacturing simplicity, sealing reliability, and durability of tank connections.

4.2.5 Feed

The feed subsystem is responsible for managing and distributing the oxidizer, nitrous oxide (N_2O). It is connected to the outlets located in the oxidizer tank endcaps.

The lower part of the tank includes:

- **Main Line** - delivers the oxidizer to the combustion chamber,
- **Fill Line** - connects the tank to the ground segment,
- **Emergency Manual Dump Valve** - allows manual emergency dumping of the oxidizer.

The upper part of the tank includes:

- **Remote Dump Valve** - enables remote oxidizer dumping,
- **Venting Valve** - allows tank venting,
- **Burst Disc** - provides overpressure protection.

The feed subsystem uses mainly BSPP-standard fittings. Depending on the connection type, sealing is achieved by one of the following methods:

- **metal-to-metal sealing** – used in rotary fittings, where two matching conical surfaces are pressed together during tightening; this type of fitting also allows adjustment of the relative orientation of connected components,
- **metal-rubber washers** – used when the fitting provides flat sealing surfaces at the end of the thread,
- **PTFE tape** – applied to male threads only when no suitable sealing surface for a washer is available.

PTFE tape is avoided wherever possible due to poor repeatability of assembly and increased risk of leakage at higher pressures.

The Main Line delivers oxidizer from the tank to the combustion chamber through the Main Oxidizer Valve. The valve is a COTS 3/4 in BSPP valve with a custom actuator consisting of a 7 Nm servomechanism and a two-gear transmission connected to the valve shaft. The actuator is mounted on a custom laser-cut aluminium plate. The valve is connected to the tank with BSPP fittings. On the combustion chamber side, a custom threaded 3/4 in aluminium pipe is used to adjust the line length to the tank-chamber structural brackets by changing its thread engagement depth in the combustion chamber holder.

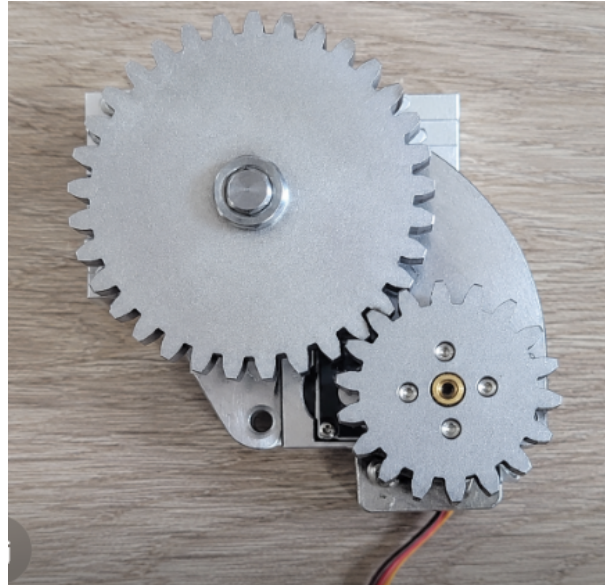


Figure 4.18: Main Oxidizer Valve servomechanism.

The Fill Line connects the oxidizer tank to the ground segment and includes an integrated manual dump path. It is connected to the bottom of the tank through a three-way fitting.

The current Fill Line mainly consists of:

- a quick connector facing outwards from the airframe, used for filling the tank from the ground segment,
- a 1/4 in manual dump valve mounted below the three-way fitting,
- three connected 1/4" in 90-degree elbows at the outlet of the valve, in order to direct its exhaust out of the airframe.

Venting valve is designed to let out a small portion of the gaseous phase from the top of the tank, in order to lower the pressure within it. This is necessary for filling procedures, as they require a pressure difference between the ground segment's plumbing and the oxidizer's tank on the rocket, and also for managing oxidizer's boil-off and pressure rise due to heating while the vehicle is loaded and waiting for the launch. The design was adapted from the previous SimBa rocket, the R6 Chrzyszcz. It consists of a COTS 3/8" valve actuated by a servomechanism with two custom made "arms" cut out of aluminium. At the top, the valve is connected to a 90-degree elbow fitting to direct gas out of the airframe.

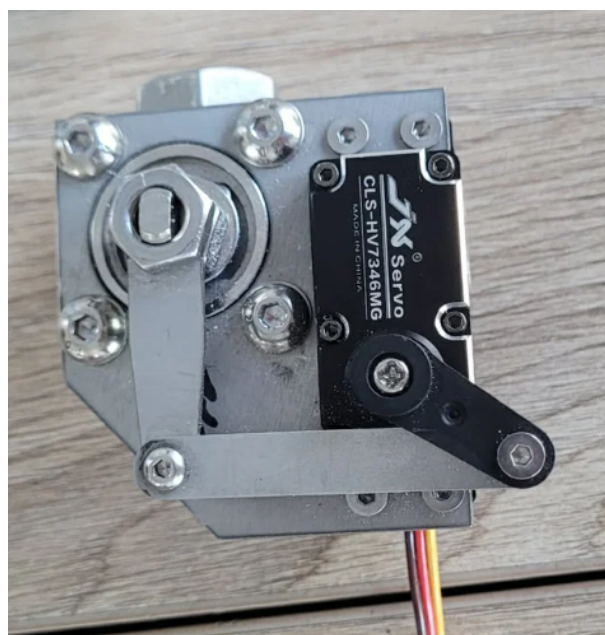


Figure 4.19: Venting Valve servomechanism.

Dump valves serve the purpose of emptying the oxidizer's tank as fast as possible, so they should be mounted such that they are fed the liquid phase from the bottom of the tank. It was first decided to place both valves at the fill line, but it turned out to be impossible due to space constraints, so the remote dump valve was located at the upper tank's cap, with a siphon dip tube reaching to the bottom of it.

Remote dump valve is made out of COTS 1/4" BSPP valve, actuated by a 46kg (4.6Nm) servomechanism and two custom made gears. The mounting plate for the servomechanism and the gears are 3D-printed from nylon PA12.

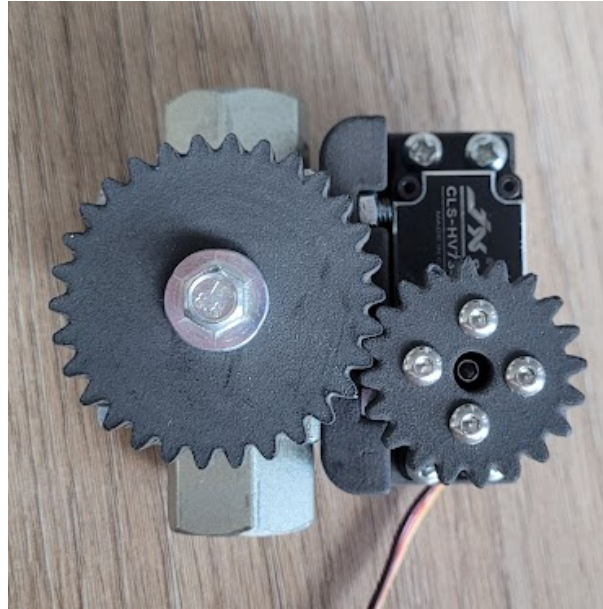


Figure 4.20: Remote Dump Valve servomechanism.

Manual dump valve is made out of the same COTS valve as the remote one. It is placed at the bottom of the fill line. It is actuated by mounting a custom made hand with a rope, then retreating to a safe distance and pulling. The hand is 3D-printed from ABS and attached to the rope using a carabiner. The manual dump valve is a last-resort safety device, activated only if the ground segment hose is disconnected, and none of the remotely-actuated valves on the rocket (Main valve, Venting valve and the Remote dump valve) are able to relieve the pressure.

For safety reasons, a passive pressure relief device is added to the tank. It's a COTS 3/8" burst disc, rated at 70 ± 5 bars, and it prevents the tank from overpressurizing by bursting at the set pressure.

4.2.6 Tests

Pressure tests were conducted on 12 December 2025 to confirm the structural integrity and leak-tightness of the main pressurized propulsion system components before integrated testing. The tests were performed using a modified pressure washer system with a high-pressure hose, control valve, and pressure gauge. Water was used as the test medium to reduce stored energy and improve safety compared with pneumatic testing. The oxidizer tank was filled with water and gradually pressurized to 105 bar, corresponding to 1.5 times the maximum expected operating pressure, which gives an MEOP of 70 bar. The pressure was held for one hour while the tank was monitored for leakage, pressure loss and visible damage.



Figure 4.21: Oxidizer tank during hydro-test.

The combustion chamber was pressurized to 60 bar and held for 5 minutes. No abnormalities were observed. After depressurization, the tank walls, fittings, and welded joints were visually inspected. No cracks or deformation were found. The combustion chamber was pressurized to 60 bar and held for 5 minutes.



Figure 4.22: Combustion chamber during hydro-test.

The first static fire test was performed on 22 February 2026. The main objective of the test was to validate the overall engine and feed system design without operating the propulsion system at its full performance limit.



Figure 4.23: 1st static fire testing

For this test, the oxidizer tank was loaded with approximately 5.1 kg of nitrous oxide. The system operating pressure before firing was approximately 50 bar, and the ambient temperature during the test was 7°C. The ignition sequence had 1.5 s delay between the ignition charge activation and the main valve opening command.

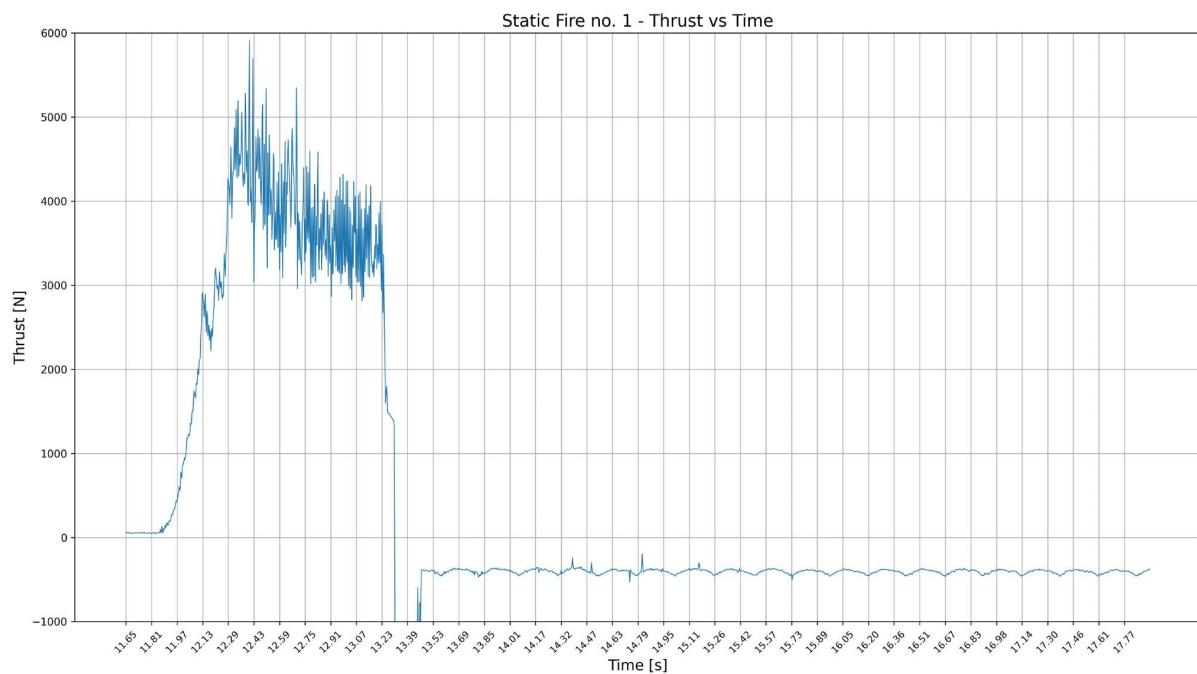


Figure 4.24: 1st static fire thrust-time diagram.

The second static fire test was performed on 21 March 2026. The main objective of the test was to evaluate the updated engine configuration and verify the influence of newly implemented components, including the mixer and washer elements. The oxidizer tank was loaded with approximately 9.7 kg of nitrous oxide. The initial tank

pressure was approximately 55 bar, and the ambient temperature during the test was 12°C. The total impulse was calculated as 22,629.98 Ns, and the burn time was approximately 8 seconds.



Figure 4.25: 2nd static fire testing

Although the engine produced the expected thrust level, a structural failure occurred during the test. The failure was caused by an insufficient preliminary design of the mechanical interface between the mixer and the combustion chamber insulation. As a result, the thermal liner and combustion chamber assembly were damaged. The test confirmed that the engine was capable of reaching the target thrust level, but also showed that the mixer-insulation interface required redesign before further hot-fire testing.

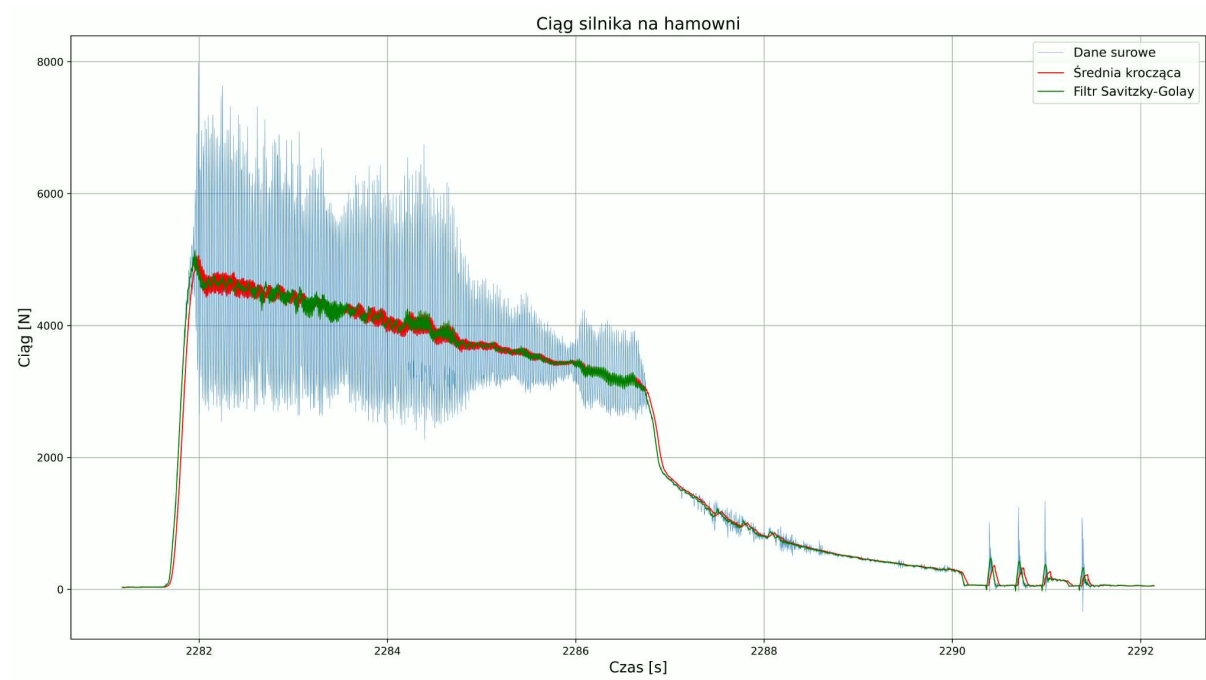


Figure 4.26: 2nd static fire thrust-time diagram.

The third static fire test was performed on 10 April 2026. The main objective of the test was to verify the updated engine configuration after the previous failure and to evaluate the ignition sequence under representative operating conditions. The oxidizer tank was loaded with approximately 8.0 kg of nitrous oxide. The initial tank pressure was approximately 52 bar, and the ambient temperature during the test was 10°C. During the firing, the engine reached a maximum thrust of approximately 4750.7 N. The total impulse was calculated as 20,634.6 Ns, and the burn time was approximately 10 seconds.



Figure 4.27: 3rd static fire testing

The test confirmed stable engine operation and showed that the applied ignition sequence was suitable for this configuration. In particular, the 1 second delay between ignition activation and main valve opening was found to be sufficient to achieve reliable ignition before oxidizer flow reached the combustion chamber. Overall, the third static fire test was considered successful. The engine operated for the intended duration, produced thrust close to the target level, and validated the revised configuration for further testing.

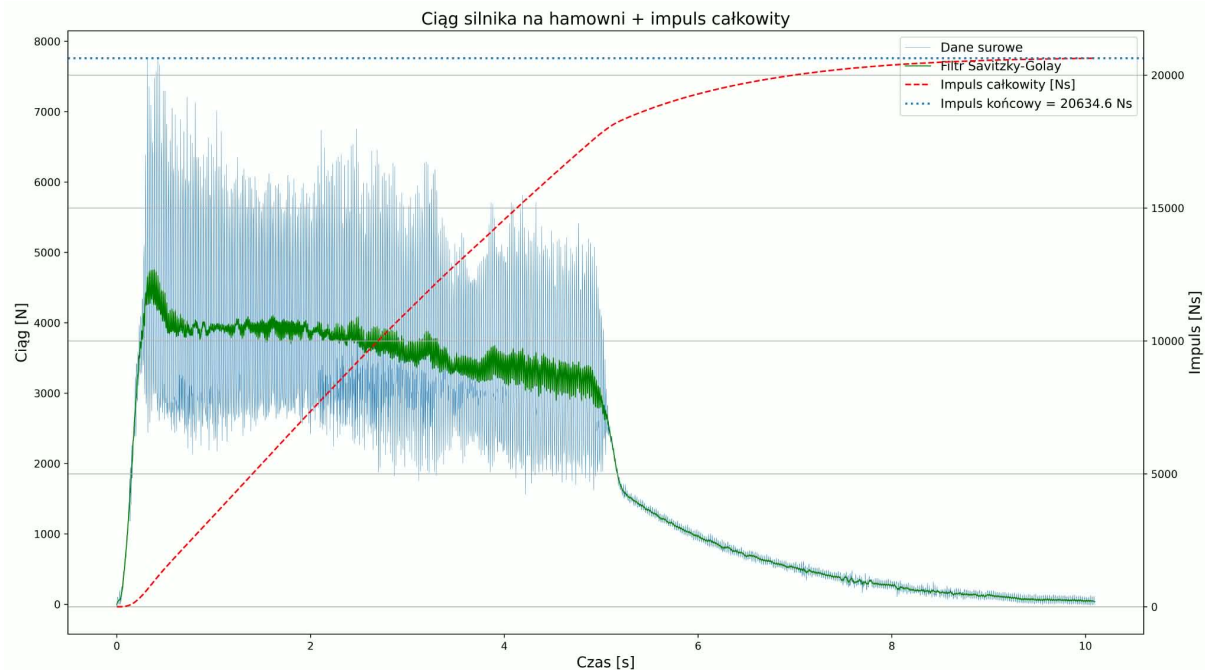


Figure 4.28: 3rd static fire thrust-time diagram

4.3 Aero-structure

4.3.1 Overview

Our main goal was to design a rocket that combines outstanding performance with the highest safety standards. The most valuable aspect of this project was the experience gained through the mistakes and challenges encountered during the development process. Each setback revealed weaknesses in our design and forced us to analyze, adapt, and improve our solutions. These lessons played a crucial role in the final outcome of the project, as many of the improvements and design decisions were direct results of earlier failures and testing. The iterative process of identifying problems and refining our approach significantly increased both the reliability and overall quality of the rocket.

Throughout the entire manufacturing and assembly process, appropriate safety procedures and personal protective equipment were consistently used. Protective glasses were worn while operating machinery, gloves during work with epoxy resins, and respiratory masks during sanding and finishing operations to ensure safe working conditions.

Most of the rocket was built using self-made components (Fig. 4.29), which provided us with a deeper understanding of the structure and the engineering decisions behind it. Overcoming technical challenges throughout the project made this work not only rewarding but also an important step in developing our engineering skills and experience.

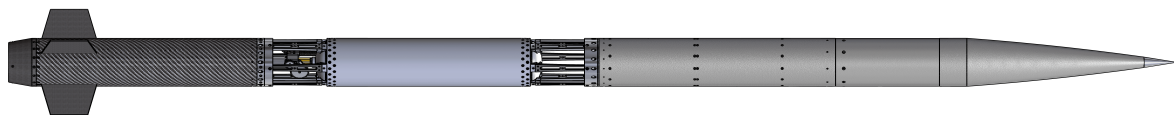


Figure 4.29: Main Assembly

4.3.2 Nose Cone

The nose cone is the first part of the rocket to interact with the airflow during flight and therefore has a significant influence on the aerodynamic characteristics of the vehicle. Its geometry affects both aerodynamic drag and the overall stability of the rocket. Multiple nosecone profiles, including elliptical, parabolic, power series, Haack, and Von Kármán shapes, were analyzed using simulations performed in OpenRocket. Based on the obtained results, a power series profile with an exponent of $n = 0.8$ was selected as the optimal solution. At the velocities that were planned to be achieved, this geometry provided the best compromise between aerodynamic performance, flight

stability, and the predicted apogee of the rocket. The final nose cone length was selected according to a fineness ratio of approximately 1:5, resulting in a total length of 763 mm for a rocket with an overall length of 4328 mm. The internal volume of the nose cone is additionally used to house the parachute recovery system.

The nose cone (Fig. 4.32) was manufactured from a fiberglass composite to ensure low mass, sufficient structural strength, and transparency for radio communication between the onboard systems and the ground segment antennas. The manufacturing process began with the creation of a 3D CAD model in SolidWorks, which was subsequently sliced and 3D printed from PET-G filament to form the mandrel (Figs. 4.30 and 4.31) used for lamination. Additional internal supports were introduced to increase stiffness during manufacturing. Fiberglass fabric templates were generated based on the developed geometry and cut using paper templates assembled from A4 sheets. Five double-layer fiberglass sheets, resulting in a total of ten layers, were laminated using epoxy resin. After applying the composite layers, peel-ply and breather material were added to ensure uniform resin distribution and removal of excess resin during curing. The entire structure was then tightly wrapped and left to cure.

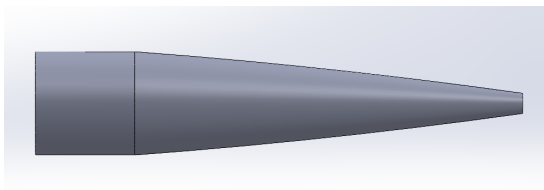


Figure 4.30: 3D printed nose cone mandrel (Side View)

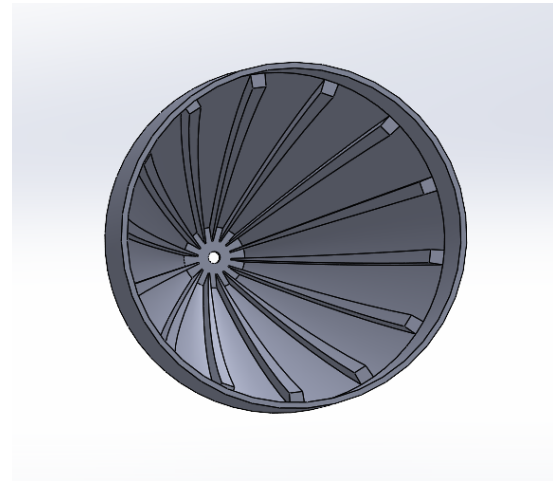


Figure 4.31: 3D printed nose cone mandrel (Bottom View)

After curing, the auxiliary layers were removed and the nose cone surface was machined on a lathe using a dedicated 3D-printed mounting element attached to the internal ribs of the structure. Since machining alone did not provide the required surface quality, fiberglass filler was applied and the surface was sanded again to achieve the desired smoothness. The tip of the nose cone (Fig. 4.33) consists of a separate aluminum component manufactured on a lathe from an aluminum rod. This element improves structural durability while also providing a sharper aerodynamic profile. The lower section of the nosecone was manufactured separately as a fiberglass body tube fitted to the internal dimensions of the structure and bonded using the same epoxy resin applied during lamination. Its primary purpose is to serve as a coupler between the nose cone and the main body tube containing the recovery system. Particular attention was given to the dimensional tolerances and interface fit to ensure reliable separation at apogee, allowing the nose cone to detach smoothly and enabling the parachute to deploy safely and without obstruction.

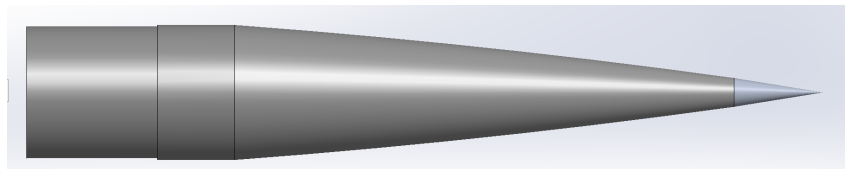


Figure 4.32: Nose cone

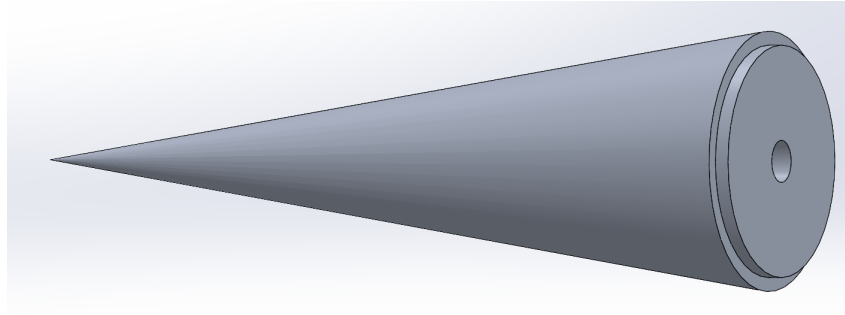


Figure 4.33: Nose cone tip

4.3.3 Service bay

Our service bay (Fig. 4.34) was designed with three main factors in mind, the first being creating a structure that could be as light as possible while still possessing high strength. The second one being a modular design that could be easily adapted to the current, as well as the potential future needs of the Avionics and Payload teams. The third one was the ability to insert the whole structure of the service bay in one motion into the body. High torsion and bending resistance was not considered, as most of the load was planned to be carried out by the outer body.

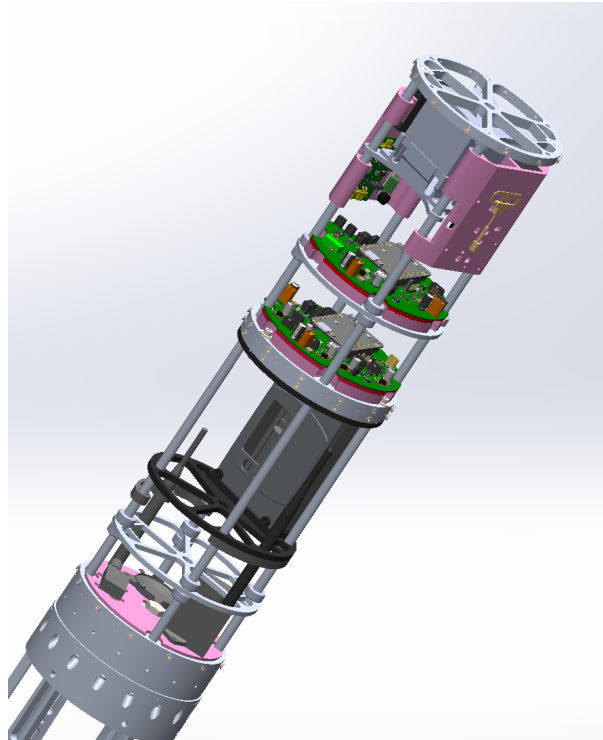


Figure 4.34: Full 3D assembly of the Service Bay with all internal components and mounts

The service bay is divided into two base frames (Fig. 4.35) with identical dimensions that are joined together with bolts. These frames slide connected together into the body. Each frame is made up of two 10 mm thick aluminium rounds (Fig. 4.36) that create the ends of the frame and possess threaded fastening points to the body of the rocket. Between them from 1 to 2, 5mm thick aluminium rounds can be inserted (Fig. 4.37). They allow for the mounting of electronics in the construction.

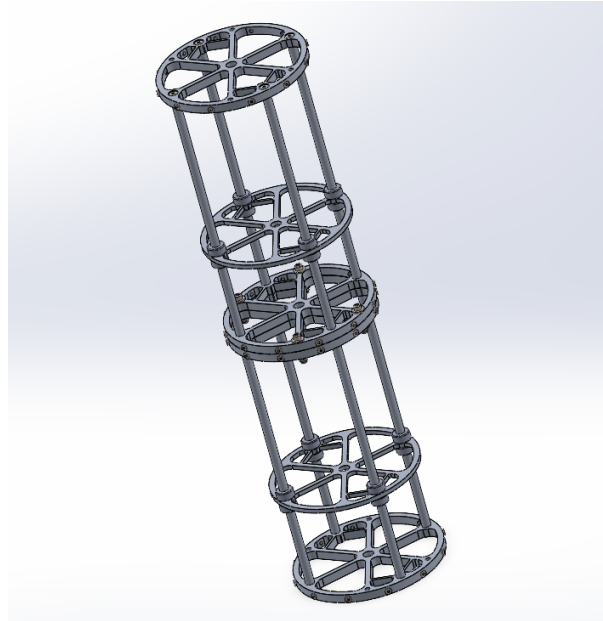


Figure 4.35: Aluminium frame of the Service Bay

The geometry of the ORANGES (Figs. 4.36 and 4.37) was iterated multiple times to reduce weight while keeping the construction stiffness at a satisfactory level. These adaptations were also made in order to eliminate weak points created by stress concentration. Further into the design process additional gibs for cables were added. There are 4 gibs, symmetrically positioned in order not to influence the moment of inertia. The rounds were laser-cut on a CNC plotter. This approach was chosen as it allowed for good precision and easy manufacturing of the 2 dimensional, but complex geometry of the ORANGES. The countersunk and counterbored indentations that house the bolts and rods in the thicker rounds were added separately on a bench drill.

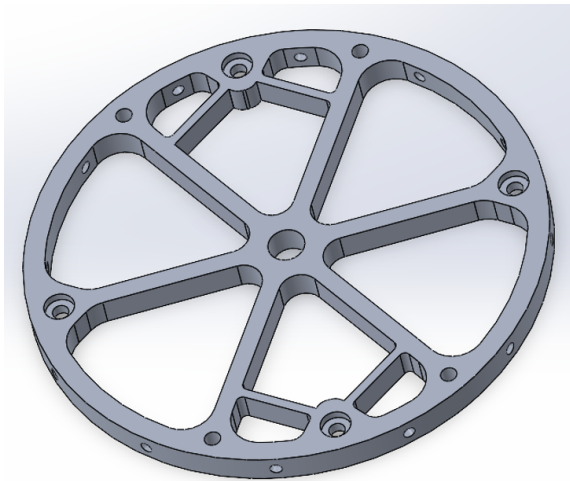


Figure 4.36: ORANGE-OUT

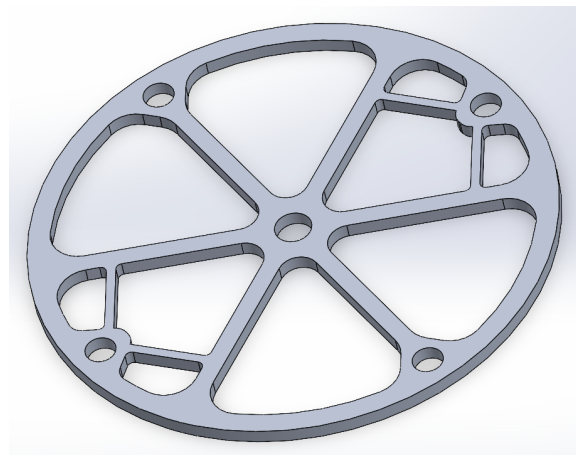


Figure 4.37: ORANGE-IN

All ORANGES are connected together by 4 aluminium rods. All rods were turned, drilled on a lathe and tapped using a manual tap. The strength of the entire aluminium frame was simulated in SolidWorks. Aluminium was chosen as the working material for the rounds and rods as it is easy to machine and possesses a satisfying strength to weight ratio as well as an appropriate stiffness. More 3D-Printed mounts were added to safely house all components that did not require high horizontal stability. The 3D-printed mounts were manufactured out of PET-G, as it prints reliably and possesses a higher plasticity temperature than the equally easy to print PLA. Small threaded inserts were added after printing. They provide a strong attachment point for the electronics to connect to. Each part was custom made to fit a designated component (that includes all circuit boards, radios, antennas, and battery packs). Leveling friction rings are fastened to the rods in order to position all mounts and ORANGE-INS at the correct height and distance. Thanks to this solution the service bay construction allows for even more adaptability and

customisation. Mounts can be added vertically or horizontally, they can even be adjusted during assembly in order to make more space and ease the integration process. Special openings were added to the component that houses the CATS in order to allow the antenna to be placed outside the main assembly. This way the aluminium in the construction wouldn't create any problems related to communication with the rocket.

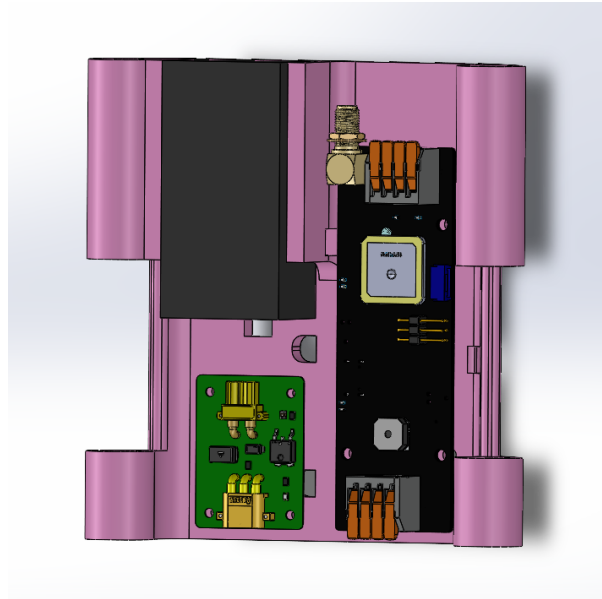


Figure 4.38: CATS mounting component

All threads in the aluminium parts were enhanced with helicoil inserts. This decision was prompted by the experiences related to the previous rocket (R6), in which even slight over-tightening caused the aluminium threads to become unusable. The constant fastening and de-fastening also quickly wore-down the threads. Adding inserts in Helicoil technology now shifted the action of steel on aluminium to steel on steel, which proved to help with the longevity and strength of the threads. All Helicoil inserts required for the manual tapping and inserting of helicoils into the threaded holes.

4.3.4 Body

The main body of the rocket was manufactured using laminated composite structures (Fig. 4.39). Depending on the functional requirements of a given section, either fiberglass or carbon fiber fabric was used. Excluding the nose cone, the rocket body consists of three separate laminated sections (Figs. 4.40, 4.41 and 4.42). The manufacturing procedure remained identical for both composite materials. The wall thickness of the structures was designed to reach approximately 2 mm, providing sufficient stiffness and structural strength while maintaining low mass.

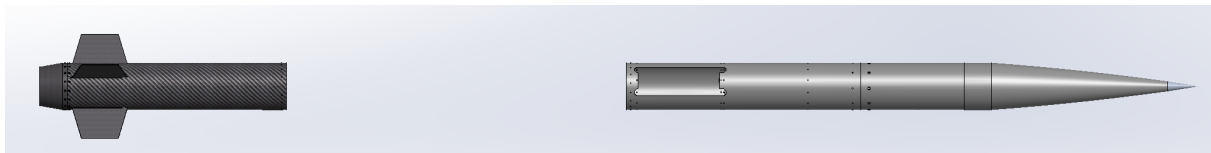


Figure 4.39: All laminated body parts

The manufacturing process began with cutting a single continuous sheet of fabric to the calculated length required to achieve the desired wall thickness after lamination. The fabric was then weighed in order to determine the appropriate amount of epoxy resin and hardener needed for the process. The resin mixture was distributed uniformly across the entire surface of the fabric before winding. A single continuous sheet was used instead of multiple separate layers to minimize fabric displacement, reduce the risk of air bubble formation, and ensure a more uniform structure. An aluminum pipe with a final outer diameter of 169.3 mm was used as the lamination mandrel. This non-standard dimension was intentionally selected to account for the thickness of the applied Mylar layer used during the manufacturing process. After inclusion of the Mylar layer, the final outer diameter of the manufactured component reached the target value of 170 mm. In order to achieve the required dimensional accuracy

and surface quality, the pipe was machined on a lathe from its initial diameter of 180 mm. Prior to lamination, the mandrel was covered with a layer of Mylar foil secured using thermal tape, allowing the cured composite tube to be removed easily after the process. During lamination, two team members rotated the mandrel while the impregnated composite fabric was wound around its surface. At the same time, a third person carefully worked the composite material by hand, ensuring proper resin penetration, eliminating trapped air bubbles, and maintaining the correct alignment and structure of the fabric throughout the lamination process.

After applying the composite layers, peel ply and breather material were added to ensure even resin distribution and removal of excess resin during curing. The entire structure was then tightly wrapped and placed inside a custom-built heating chamber constructed by the team. The chamber, built from plywood and insulated using mineral wool, utilized a fan heater as the heat source and was capable of maintaining temperatures of up to 80°C. This allowed safe and accelerated curing of the laminated structures.

After the curing process was completed and the mandrel had cooled down, the composite body tubes were removed from the aluminum pipe. The tubes were subsequently cut to their final dimensions using a rotary cutting tool, while particular attention was given to maintaining parallel and precise edges. Openings, maintenance hatches, and mounting holes required for integration with other rocket components were then machined by hand and adjusted to ensure an accurate fit.



Figure 4.40: Recovery Body

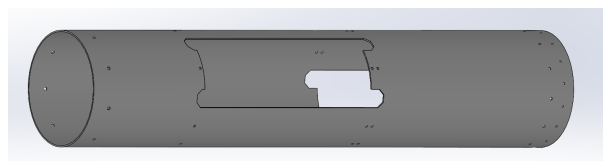


Figure 4.41: Service Bay Body

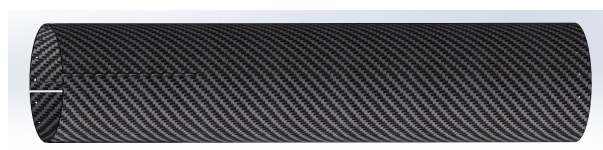


Figure 4.42: Engine Body

The manufactured body sections were later finished using fiberglass filler and sanded in order to obtain a smooth and uniform surface. The prepared elements were coated using an airbrush. Multiple layers of primer were applied and sanded between coatings until the desired surface finish was achieved. Afterwards, acrylic paint and a final clear coat layer were applied to protect the surface and improve the visual appearance of the rocket. Decorative patterns were created by masking selected areas with paint tape and applying additional colour layers before the final clear coating process. The colours used were selected with the working conditions in mind (desert), we wanted to ensure that as much light is reflected off the body as possible. Throughout the manufacturing and finishing stages, isopropyl alcohol cleaner was used to clean the surfaces without damaging the paint or composite materials.

4.3.5 Launch Lugs

Launch lugs constitute an essential component of the rocket launch system, as they are the only structural elements responsible for guiding and constraining the rocket along the launch rail during tank filling and the initial phase of liftoff. The rocket is equipped with two launch lugs: an upper lug attached to the upper RADAX connector

and a lower lug integrated with the boat tail and fin can section of the airframe. Their placement was selected to ensure adequate load distribution and stable guidance during launch.

As the team does not possess a dedicated launch rail system, the rocket was designed to be compatible with two different launch rails provided by the competition organizers. This approach increases operational flexibility and eliminates dependence on a single launch infrastructure. However, the selected launch rails differ in their geometric profiles, which required the development of two separate sets of launch lug sets (Figs. 4.44 and 4.43), each corresponding to a specific rail standard; the Baxter T-Rail and Microcosm T-Rail. Although the overall construction principle remains identical, the lug dimensions and hole distribution differ depending on the rail type as well as the mounting location on the rocket.

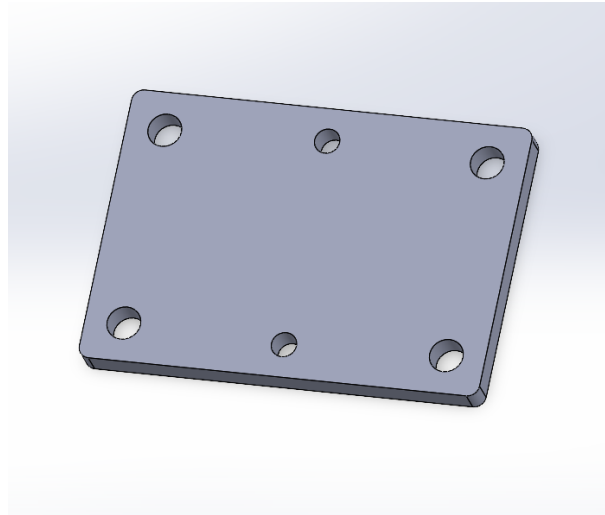


Figure 4.43: Launch Lug Baseplate for the Baxter T-Rail

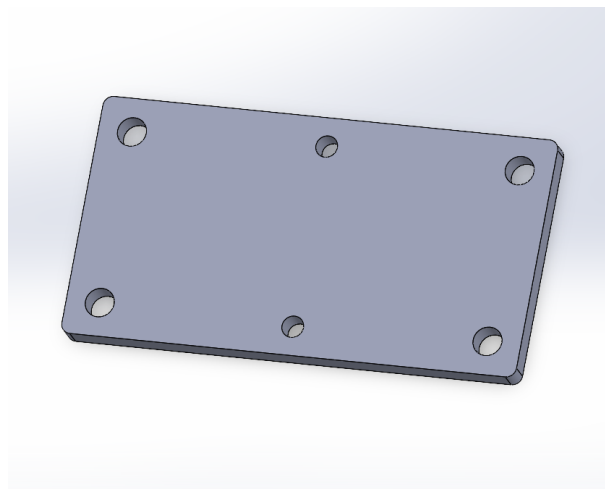


Figure 4.44: Launch Lug Baseplate for the Microcosm T-Rail

The launch lugs were manufactured from 5 mm thick aluminum plates machined out of an aluminium sheet using CNC milling technology. The main structural element contains four corner holes used for assembly with bolts and nuts, which function as spacers. Two smaller plates are mounted on opposite sides of the main plate, forming a sandwich-like structure that creates a T-shaped channel matching the geometry of the launch rail. This design provides sufficient structural rigidity while remaining simple to manufacture using inexpensive and readily available materials. Numerical analyses and structural simulations were performed to verify that the launch lug assemblies are capable of withstanding the loads associated with the fully fueled rocket mass as well as the dynamic forces occurring during the launch phase. The obtained results confirmed that the designed structure provides adequate strength and stiffness for safe launch operations.

4.3.6 Couplers

An important structural element of the rocket is the coupling system used to connect individual airframe sections. Instead of employing a conventional “tube-in-tube” coupling solution, the rocket utilizes custom-designed Radial-Axial Connectors (RADAX). This connector type is based on a conical geometry, which provides significant advantages over traditional fitted-pipe approaches. In particular, the RADAX system does not require extremely tight manufacturing tolerances to ensure proper alignment and structural integrity. As a result, the assembly process is considerably simpler and more reliable in demanding field conditions, especially in desert environments where the presence of sand and dust can interfere with conventional coupler systems. Similar connector solutions have previously been implemented in rockets of comparable and larger scale, confirming the practicality and reliability of this design approach. (Fig. 4.45)

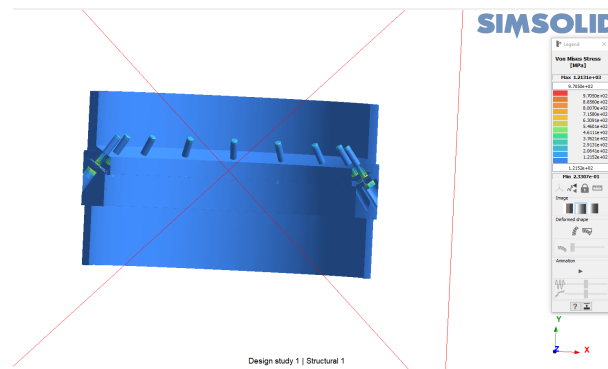


Figure 4.45: RADAX bolt simulation

Each RADAX connector consists of two mating halves that form the complete coupling interface between adjacent rocket sections. The primary disadvantage of the RADAX system is the manufacturing complexity associated with its geometry, as the components require machining using a 5-axis CNC machine. For this reason, the manufacturing process was carried out with the support of one of the project sponsors based on technical documentation prepared by our team. The connectors were machined from solid aluminum stock in order to achieve the required structural strength and dimensional precision.

A major advantage of the RADAX design is the simplified assembly procedure. Due to the self-centering conical interface, only a single screw is required to achieve proper alignment between adjacent rocket sections, while the remaining fasteners serve primarily to maintain preload and structural rigidity of the joint. Two RADAX connectors are incorporated into the rocket structure: an Engine-Feed (Fig. 4.46) and Service-Tank connector (Fig. 4.47). Although both share the same fundamental operating principle, they differ slightly in geometry and functionality. The Engine-Feed includes additional mounting features used for integration with the propulsion system, whereas the Service-Tank contains attachment points for the upper launch lug assembly.

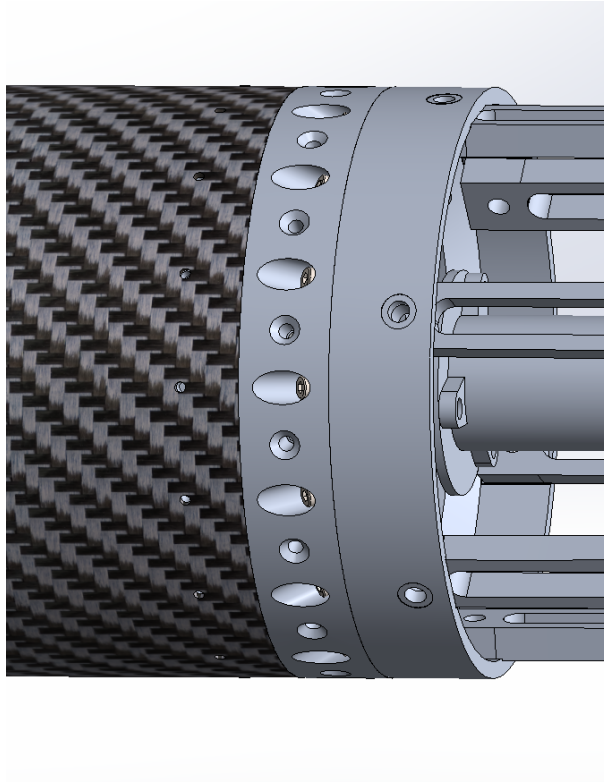


Figure 4.46: Engine-Feed RADAX composition

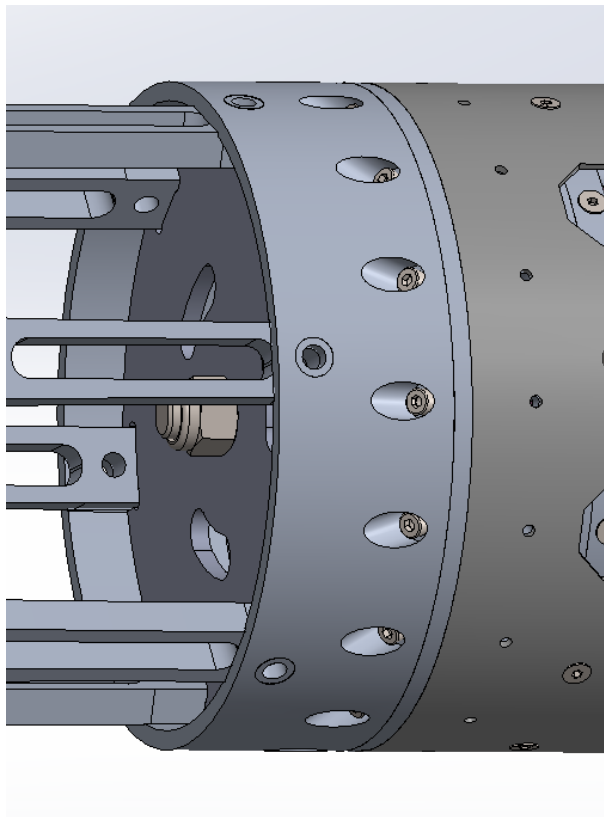


Figure 4.47: Service-Tank RADAX composition

Each connector (Figs. 4.48, 4.49 and 4.50) is permanently bonded and riveted to one side of the body tube, while the opposite side interfaces with dedicated brackets integrated into the liquid oxidizer feed systems. The

implementation of RADAX connectors constitutes a significant improvement in the structural design of the rocket, as the system not only simplifies the assembly and disassembly procedures, but also increases the overall rigidity, repeatability, and reliability of the airframe connections.

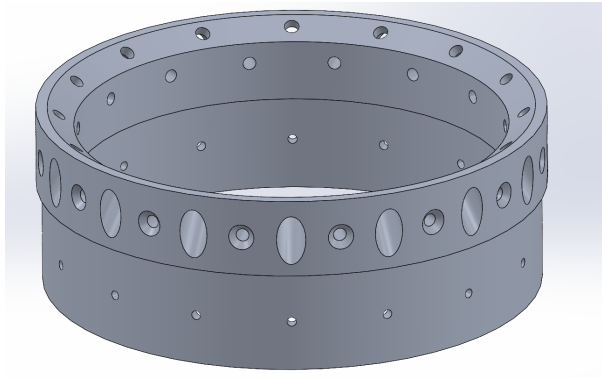


Figure 4.48: RADAX Engine

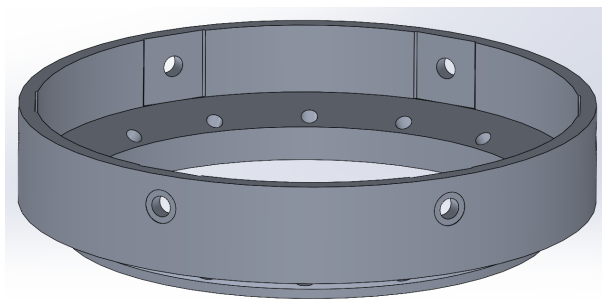


Figure 4.49: RADAX Feed



Figure 4.50: RADAX Tank

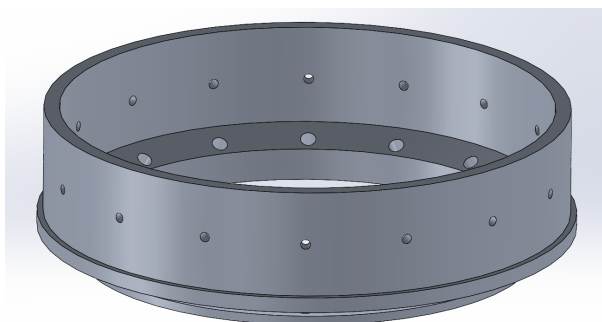


Figure 4.51: RADAX Service

4.3.7 Brackets and covers

Brackets connect both of the structural oxidizer's tank's endcaps to the RADAX couplers. They are each attached by two M6 screws to the endcap, and by a one M6 with a nut to the couplers. They also have a one M6 threaded hole to mount their covers, described below. Their simple architecture and ease of mounting and removal allows for easy access to oxidizer's plumbing connected to the tank's endcaps by simply removing one or two of them.

To shield section's with brackets against airflow during flight, there are two, two-part, 3D-printed non-structural covers. They have holes for attaching filling quick-connection and charging cable, safety pins, outlets for the Venting and Dump valves, mount for engine igniters' connectors and mounts for wires running on the side of the oxidizer's tank. They are mounted by six M6 screws (each of four parts) to the brackets and the tank's caps.

4.3.8 Boat tail

The boat tail is the aft-most aerodynamic component of the rocket, positioned between the main body tube and the engine nozzle section. Its purpose is to provide a smooth reduction in diameter, improving airflow around the rear section of the rocket and reducing base drag during flight. Based on aerodynamic calculations and simulations, the selected boat tail geometry with an angle of 10 degrees provided an estimated improvement of approximately 10 % in drag reduction during flight. Due to its complex geometry and tapered structure, the boat tail was one of the most challenging composite elements to manufacture. The manufacturing process began with cutting multiple circular sections with a diameter of 190 mm from Polystyren XPS sheets foam using a CNC plotter. The individual sections were then bonded together using polystyrene adhesive, forming a single cylindrical structure. An M12 bolt was inserted through the center axis of the cylinder, while steel plates mounted on both sides were tightened using nuts in order to prevent the Polistyren structure from moving or rotating during machining. The resulting cylinder was intentionally made longer than the final boat tail component to provide additional space required during the lamination process. (Fig. 4.52)

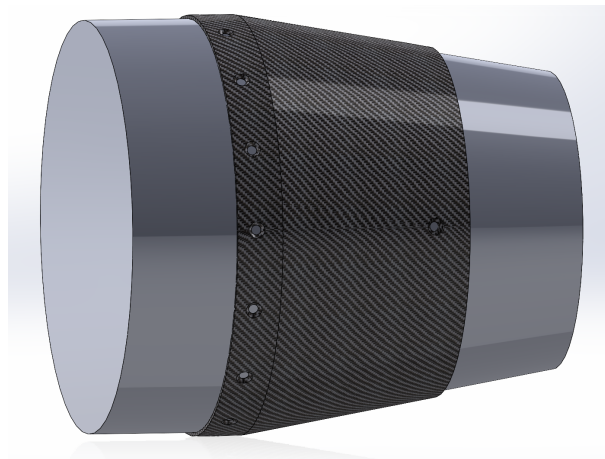


Figure 4.52: Boattail on Styrodur form

After the adhesive had cured, the Polystyren cylinder was mounted on a lathe and machined into the final geometry based on a previously prepared CAD model. Due to the delicate nature of the foam mandrel, particular care was required throughout the machining process to avoid damaging the structure. Once the desired shape had been obtained, carbon fiber fabric was cut into sections matching the geometry of the mandrel. The composite layup process was then carried out using epoxy resin in the same manner as for the previously described structures. After lamination, peel ply and breather material were applied, and the entire structure was tightly wrapped in stretch film and left to cure.

Following the curing process, the M12 bolt was removed and the entire assembly was placed inside a sealed container filled with acetone. The acetone dissolved the Polystyren mandrel, leaving behind only the cured carbon fiber composite structure (Fig. 4.53). The resulting component then underwent trimming, grinding, and edge finishing operations to achieve the required dimensions and ensure proper alignment with the remaining rocket structures. An additional outer layer of epoxy resin was later applied to improve the surface finish and visual appearance of the component, followed by final sanding and polishing operations to obtain a smooth aerodynamic surface.

Structurally, the boat tail is a relatively simple component (Fig. 4.54) consisting of a lightweight carbon fiber shell. The completed part slides onto the combustion chamber section and is mechanically fastened to the fin

mounting ring structure, which is described in the following section.

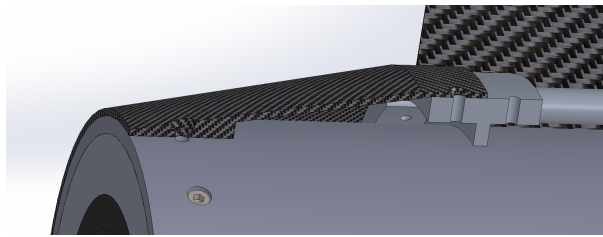


Figure 4.53: Cross-section of Boattail

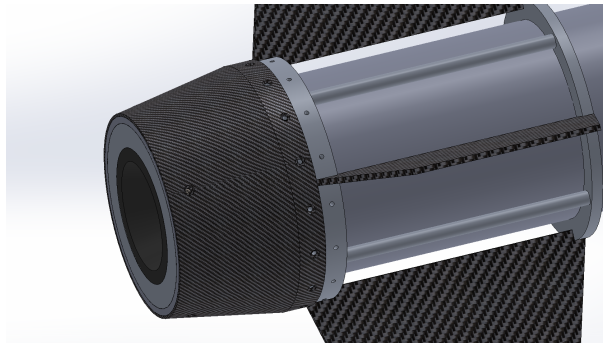


Figure 4.54: Boattail Final Model

4.3.9 Fins

The fins constitute one of the most important aerodynamic components of the rocket, as their geometry, alignment, and structural integrity directly influence the stability of the vehicle during flight. The rocket is equipped with four fins manufactured from custom-made carbon fiber composite panels. The composite panels were fabricated in-house by stacking multiple layers of carbon fiber fabric soaked in resin on a glass plate until the desired thickness of 5 mm was achieved. The composite was subsequently covered with an additional glass layer and processed using the vacuum bagging method in order to remove trapped air and excess resin, thereby improving the mechanical properties and overall quality of the composite structure. After the curing process, the fin geometry (Fig. 4.55) was machined using a CNC milling machine to ensure high dimensional accuracy and repeatability.

The fins are mounted using a custom-designed internal support structure referred to as a fin basket (Fig. 4.56). The basket consists of two aluminum rings connected by four aluminum rods. Its primary purpose is to ensure precise centering and alignment of the fins with respect to the rocket body. Each ring contains dedicated grooves that geometrically constrain the fins and maintain their position during assembly. Additional stabilization is provided by grooves machined directly into the body tube, allowing the fins to pass through the airframe and integrate with the internal support structure. This solution significantly increases mounting rigidity and minimizes the possibility of fin misalignment.

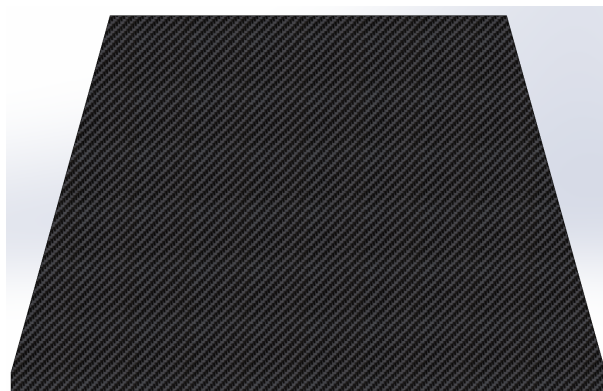


Figure 4.55: A singular fin

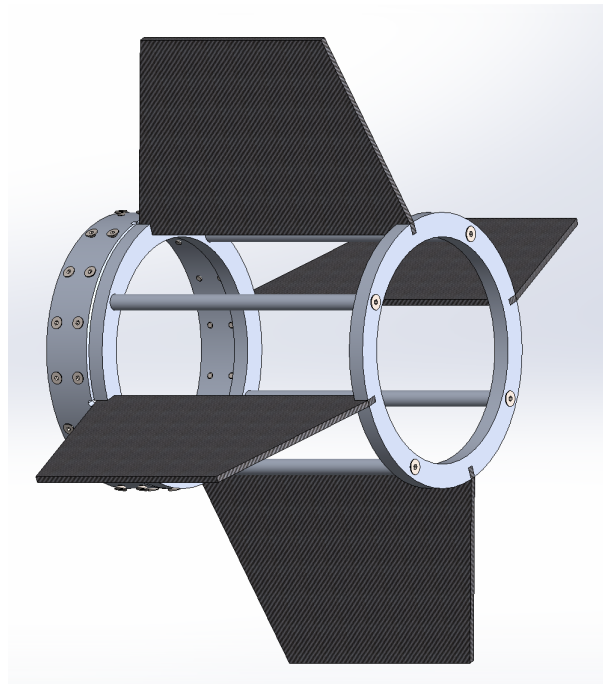


Figure 4.56: Fin assembly

During assembly, the fins were temporarily fixed to the basket using hot glue. Subsequently, structural fillets were applied along the fin-body joints using elastic adhesive in order to distribute stresses more uniformly and improve the durability of the connection. To maintain precise alignment during the curing process, four additional centering fixtures manufactured from plywood and machined using CNC technology were installed externally to hold the fins in their intended positions until the adhesive fully cured.

Following the initial assembly stage (Fig. 4.57), additional carbon fiber reinforcement layers were applied manually. The layup process began with narrow strips placed directly along the fin-body interface, followed by progressively larger layers extending beyond the fin surfaces in order to create a continuous and highly rigid composite joint between the fins and the airframe. The outermost layer was covered with peel ply to obtain a uniform surface finish and improve the quality of subsequent processing steps. Due to geometric constraints and the required manufacturing precision, each side of every fin had to be laminated separately. After each layup stage, the rocket body was placed in a heating chamber to accelerate the curing process under controlled conditions. Once cured and cooled, excess composite material was trimmed and the next side could be processed.

After completing the reinforcement of all fin surfaces, the entire assembly underwent additional grinding and surface finishing operations to ensure smooth transitions and aerodynamic consistency along all edges. Final surface preparation, including filler application, sanding, and painting, was performed as described in the body tube manufacturing section. The completed fin structure exhibits high rigidity and dimensional stability, which, according to performed simulations, ensures adequate rocket stability throughout the flight envelope. Special attention was devoted to the precision of the bonding and lamination processes in order to eliminate even minor fin misalignments, as such imperfections could induce unwanted rocket autorotation during flight.

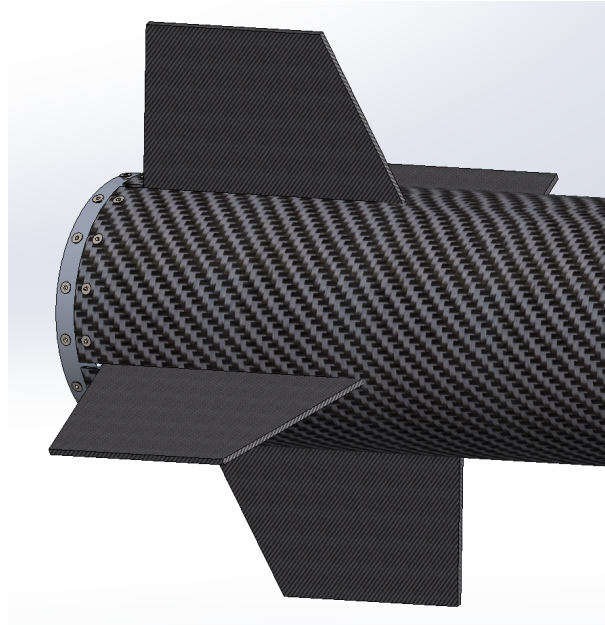


Figure 4.57: Fins before tip-to-tip layup

4.4 Recovery

4.4.1 Introduction

The recovery subsystem for the R7 rocket has been developed over the last three years as an evolution of the systems used in previous rocket generations. Its primary purpose is to ensure a safe and stable return of the rocket after flight, which is why the recovery process is divided into two distinct stages. The most important components of the recovery subsystem are presented in Figure 4.58.

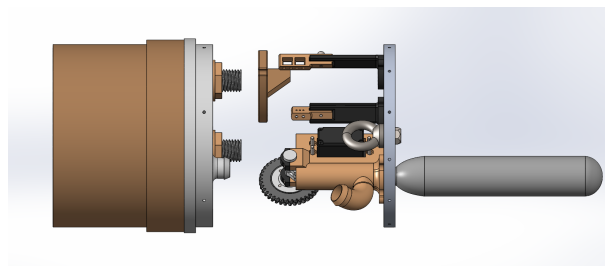


Figure 4.58: Recovery subsystem assembly

When the rocket reaches apogee, the parachute deployment sequence is initiated. A servo rotates a crankshaft connected to a piston equipped with a needle. The piston moves forward and pierces a CO_2 cartridge. The released gas then pressurizes the ejection piston, causing it to move and separate the nose cone from the rocket body. This action ejects and partially inflates the parachute, which is connected to both the nose cone and the rocket body using a shock cord, allowing the whole rocket assembly to return under one parachute.

The second stage of recovery begins after the parachute has been deployed and the rocket descends to an altitude of 450 m. At this point, the parachute is unreefed using a SRAD line-cutting device. During this process, a resistance wire cuts a length of Dyneema line, releasing the main reefing line and allowing the parachute to fully expand. The increased parachute area significantly increases aerodynamic drag and further reduces descent velocity. A skirt reefing system was selected to improve descent control and to implement and test a less commonly used recovery system.

The recovery subsystem is located in the topmost section of the rocket. The parachute is packed inside the nose cone and recovery body joint section, ensuring ease of release. Separation occurs at the interface between these two

sections. Both the nose cone and the recovery body are connected to the parachute using a shock cord of sufficient length to prevent collisions between separated components during deployment.

Several measures were introduced to improve the reliability of the recovery system. Detailed pre-launch checklists are used to verify all critical procedures and components. Spare parts are available for all deployment mechanism elements. Additionally, system redundancy is achieved by implementing three independent deployment mechanisms, each powered by a separate flight controller assembly.

To improve manufacturing times and allow for cost reduction during development, many of the recovery components are 3D printed using the FDM method. None of the 3D-printed elements are subjected to parachute loads. Load-bearing connections are handled by commercially available hardware with issued load ratings. The structural components have been manufactured from PETG filament, which is less brittle than other available options while offering a higher glass transition temperature. The seals have been printed using FiberFlex 30D. We have made sure to print using light colored filaments to further mitigate the problem of components heating to plasticity.

The following subsections describe the main elements of the recovery subsystem in greater detail, including the deployment systems, reefing system, line cutter, and coupler. Structural analysis and weight optimization of the coupler are also discussed.

4.4.2 Deployment

The purpose of the deployment system is to eject both the nose cone and the parachute. Deployment is achieved by either piercing a CO_2 cartridge or lighting a black powder charge. Unlike the previous rockets' deployment, which was solely based on puncturing a CO_2 cartridge using a spring-loaded mechanism, the R7 deployment system allows for control of the puncturing using a gear mechanism, with future iterations adding limit switches to check the piston's position, as well as additional deployment measures in the form of black powder or pyrodex charge wells. The flight configuration can be chosen as either $2 \times CO_2$ deployment mechanisms, $2 \times$ black powder mechanisms, or $2 \times$ black powder mechanisms with a single CO_2 system, depending on the desired application and flight requirements. During FAROUT 2026, the $2 \times$ black powder mechanism configuration will be used.

Blue Jay

Since the primary flight computer used at FAROUT 2026 will be the FeatherWeight Blue Jay, the primary deployment mechanism is a black powder charge well shown in Figure 4.59. Although commercial options are available in the United States, we chose to design and manufacture the system ourselves. All components are 3D printed and have proved to be sufficiently strong to handle ejection forces. The wells can fit an igniter and up to 4 g of FFFF black powder. The top cap is designed to rip and release the expanding charge onto the ejection piston. This solution is also commonly found in commercially available charge wells, using water bottle caps.

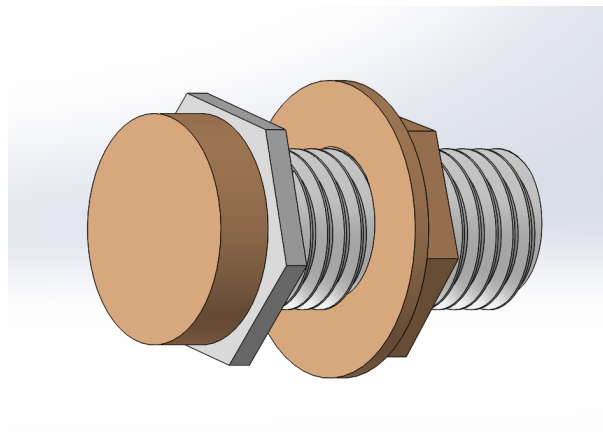


Figure 4.59: Charge Well assembly

SRAD

Although it serves as a tertiary, non-actuating system during FAROUT 2026, the CO_2 ejection system (Fig. 4.60) is designed as the primary, or as both the primary and secondary deployment system in the rocket, depending on the chosen configuration.

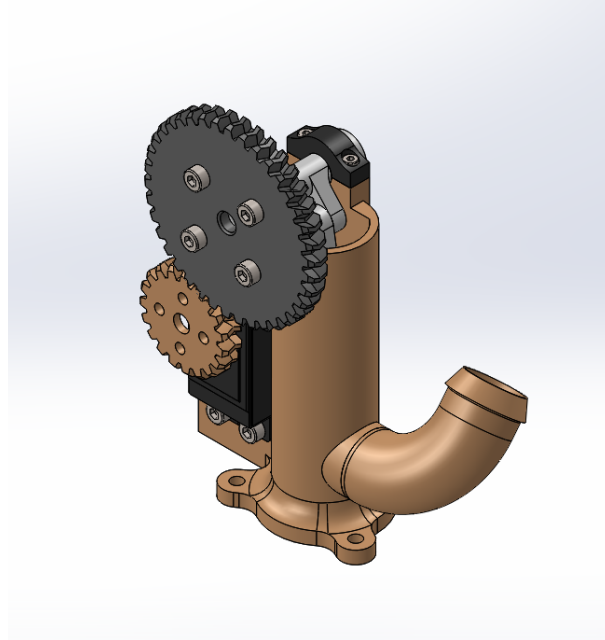


Figure 4.60: Cartridge piercing assembly

The puncturing force of a CO_2 cartridge is said to be 400N. The puncturing system is powered by a standard servo, allowing for force variability. The primary system uses a $25kg \times cm$ servo, while the backup is equipped with at least a $46kg \times cm$ servo. The piercer uses a 1:2 herringbone gear drive, with a 1cm crank (Fig. 4.61), giving us a piercing force that significantly exceeds the required 400N, and ground tests have proven the system works nominally.

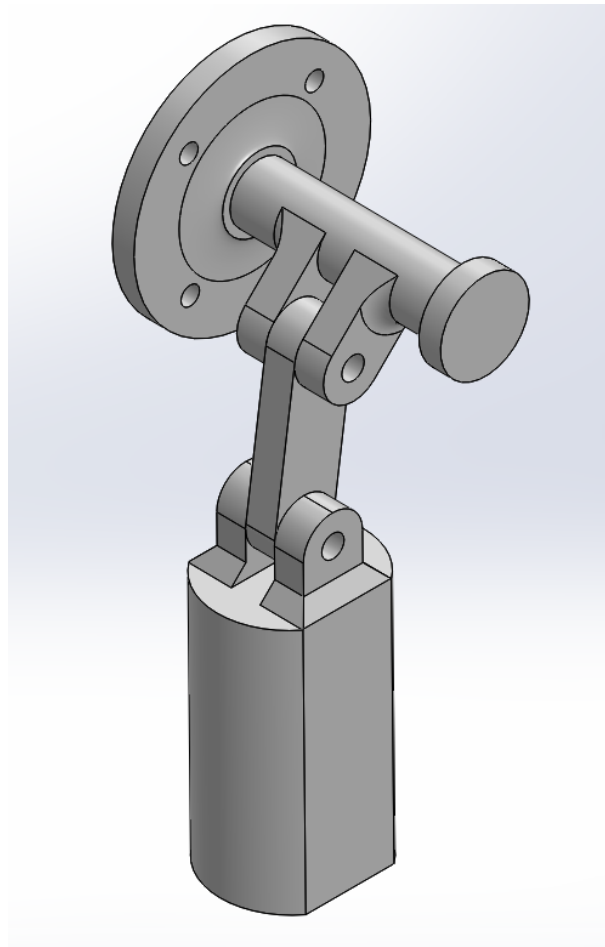


Figure 4.61: Piston subassembly

Initial calculations and testing proved that smaller, 33g cartridges are capable of ejecting the nose cone and parachute, but their significantly higher cost, lower availability, and limited piercing reliability greatly outweighed the benefits. For this reason, 88g cartridges are chosen.

The deployment mechanism consists of a servo, herringbone gears, the crankshaft, a piston with a needle, plastic tubes, and the ejection piston. When the servo rotates the gear, the crankshaft lowers the piston and needle (Fig. 4.62), which pierces the cartridge.

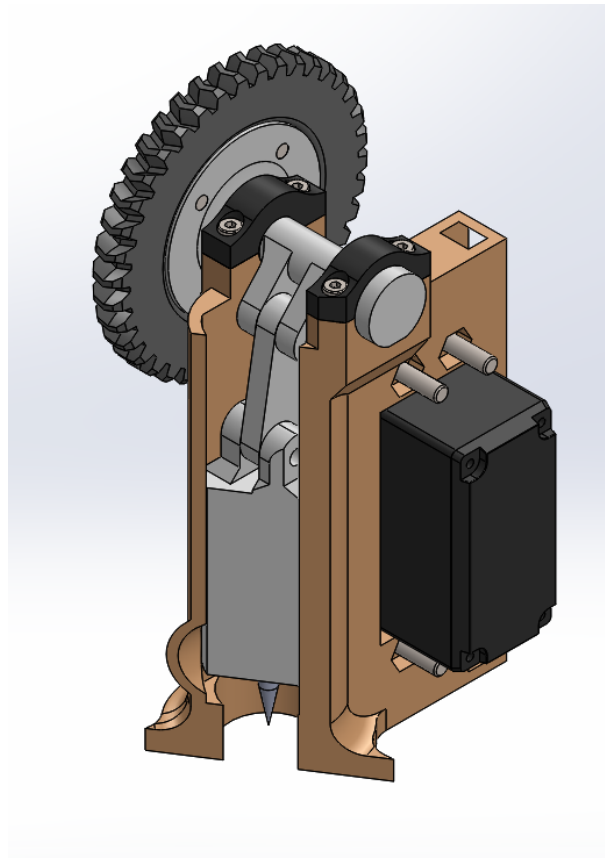


Figure 4.62: Bottom position

The puncturing moment is set to when the crank is perpendicular to the piston and fully extended (Fig. 4.63), allowing for the maximum puncturing force.

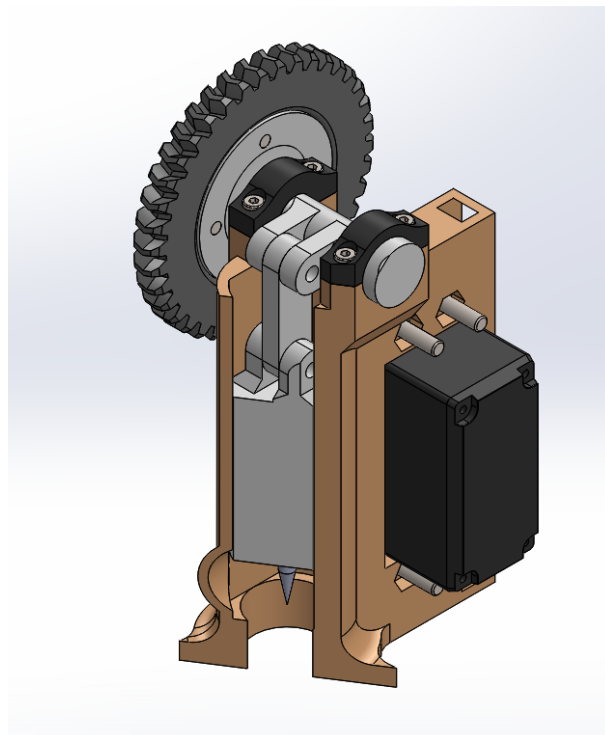


Figure 4.63: Piercing position

The released gas flows through a plastic tube into the chamber above the main piston. The generated pressure rapidly moves the piston and ejects the parachute. CFD simulations were performed to choose the optimum size of tubing. The components of the deployment mechanism are either 3D-printed or commercially available hardware.

CATS Vega

The secondary flight computer is the CATS Vega; it has the option to actuate both servo and pyrotechnic ports, but will be operating an additional charge well with a slightly larger amount of black powder than the Blue Jay, acting as both a redundant and stronger deployment mechanism.

4.4.3 Parachute, Reefing, Rigging, and Harness

The second stage of the dual deployment system is implemented using the reefing system. Its main component is the parachute shown in Figure 4.64. The parachute has a diameter of 2.5 m and was manufactured by a local supplier. It is made from nylon and polyester. Sixteen suspension lines are grouped into two bundles connected to the bridle.



Figure 4.64: Fully inflated parachute

Sixteen welded steel rings with an internal diameter of 20 mm and a thickness of 3 mm are mounted along the canopy edge. The rings are attached to reinforced tape and secured using locking seams positioned 1 cm below the canopy edge. This arrangement (Fig. 4.65) is used for skirt reefing.



Figure 4.65: Reefing line passing through rings

The parachute is connected to a 10 m shock cord made from nylon tubular webbing with a tensile strength of 9 kN. The shock cord is attached through a 25 kN swivel link quick link to the main line, which is a 5ft, 5300lbf Kevlar line. The main line is connected to the rocket body using an M8 reinforced eyebolt with a permissible

working load of 800 kg and a safety factor of 4:1. The nose cone is connected to the parachute using a 1 m nylon tape rated for 1.3 kN and a quick link.

The reefing system uses skirt reefing, as shown in Figure 4.66. At apogee, the parachute is deployed in a reefed configuration corresponding to an effective diameter similar to a 4 ft pilot parachute. Two reefing lines pass through the rings around the skirt, each covering approximately half the circumference and crossing at two points. The lines are sewn together below the parachute skirt and routed along the shock cord through dedicated loops. This assembly forms the main reefing line, which is connected to the Dyneema line inside the rocket body. After receiving a signal from the flight computer, the line cutter burns through the Dyneema line, releasing the main reefing line and allowing the parachute to fully inflate.

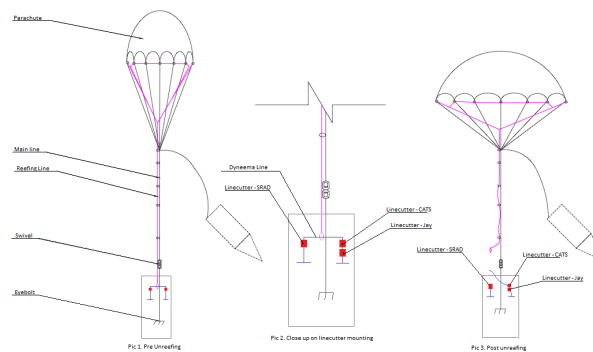


Figure 4.66: Reefing diagram

Before the main reefing line is released, the swivel link cannot operate correctly because the line is routed along the shock cord. However, this does not create a risk of unscrewing the main eyebolt because separate attachment points are used. To minimize line tangling, a dedicated parachute packing procedure and deployment bag are used.

All reefing lines, the shock cord, and the deployment bag are manufactured in-house using sewing machines or hand sewing. The shock cord was previously tested during flights of earlier rockets and carefully inspected afterward to verify that no strength-reducing damage had occurred.

4.4.4 Line Cutter

To cut the Dyneema reefing line, a dedicated line-cutting device was developed. The Line Cutter (Fig. 4.67) in the R7 rocket is an improvement over the previous version found in R6; it allows for modularity and does not require the PCB assembly, as all electronics required are found natively in the flight computers used. The 28AWG Kanthal A1 wire is cut to an appropriate length that allows 12V to pass at 4A and heat it up to working temperatures, without melting the wire itself.

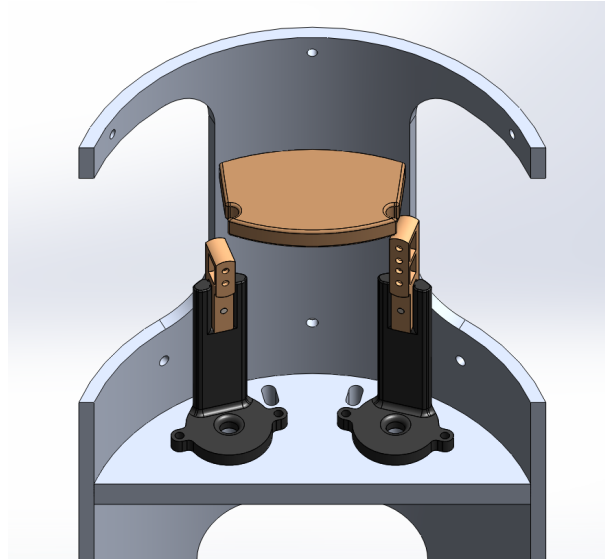


Figure 4.67: Line cutter assembly

For redundancy, each computer operates its own line cutter, allowing the rope to be burned through at multiple independent points. One of the modules is equipped with a double line cutter set. This does not affect the working procedure or cause jamming, even though the line cutters are positioned above each other.

M6 eyebolts mounted to the main bulkhead serve as attachment points for the Dyneema line. Both the linecutter stand and module are 3D-printed. Since the Kanthal resistance wire operates at high temperatures, the ends are placed into crimp sleeves and screwed into 2.54mm ARK terminals

Above the Line Cutter, a tension plate (Fig. 4.68) maintains tension in the Dyneema line at all times. This prevents uncontrolled movement of the line and ensures stability of the resistance wires.

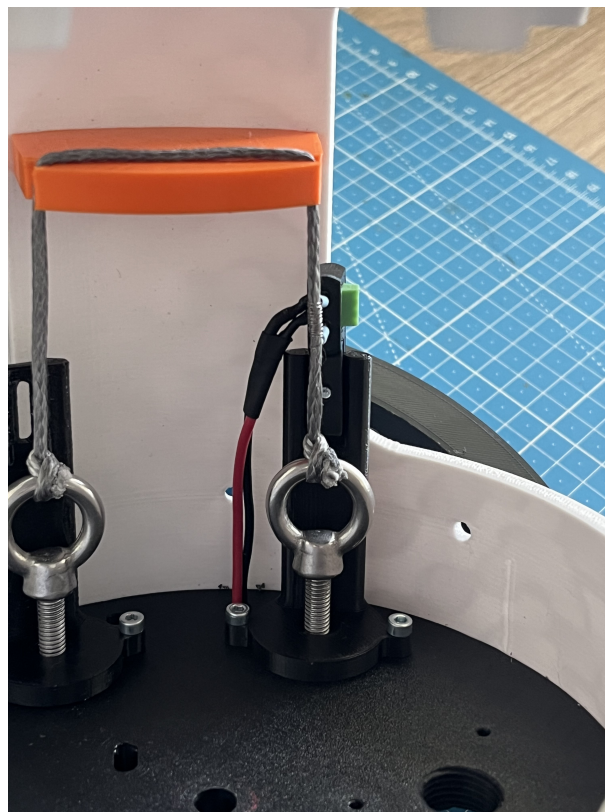


Figure 4.68: Tension Plate holding Dyneema line

4.4.5 Coupler

Most recovery system components are housed inside the coupler (Fig. 4.69). This design simplifies assembly and provides secure mounting points for critical elements. The coupler used in the R7 rocket is based on an optimized version of the design previously developed for the R6 and R4 rockets. An aluminum pipe with a wall thickness of 5 mm was selected due to material availability. To reduce mass and simplify integration, six large cutouts were introduced into the structure.

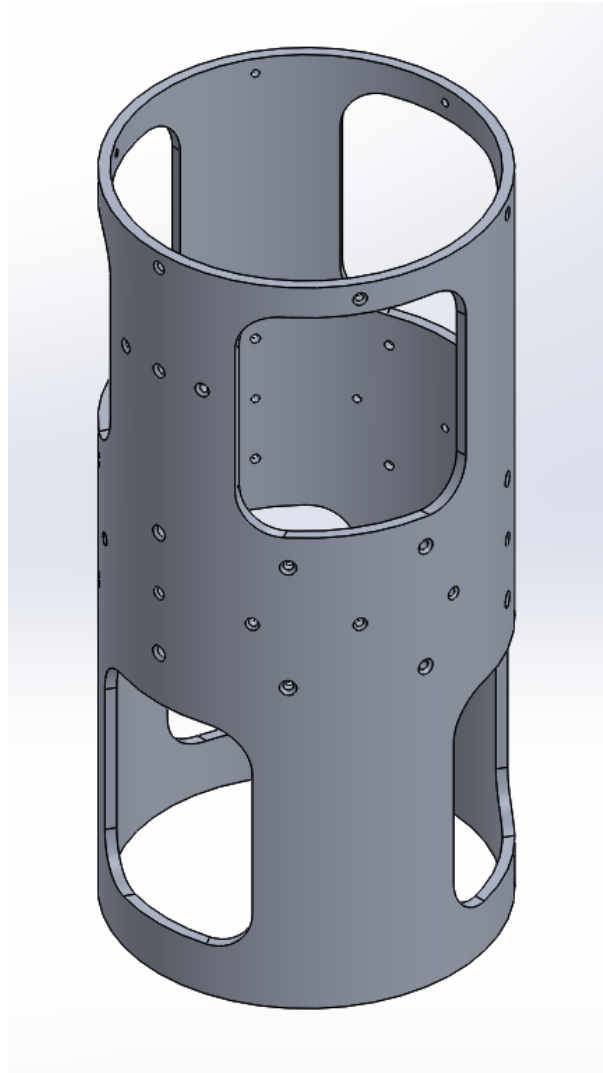


Figure 4.69: Coupler

The coupler is bolted to both rocket body sections using 9x M5x8 mm bolts. The thickness of the coupler is intentionally thicker than structurally required in order to secure the hardware properly. The baseplate is secured to the coupler using 12x M3x16 bolts. The top 3 access windows are larger than the bottom row, since adjustments to the recovery systems may be made once mounted, and on the bottom side, we will only insert the CO_2 cartridges and connect the wires.

The following components are installed inside the coupler:

- Baseplate,
- Top plate with charge wells,
- Piercer deployment mechanisms,
- CO_2 cartridges.

To verify the structural rigidity of the coupler, a finite element analysis was performed in SolidWorks. The lower section of the rocket was fixed to a rigid support, while a lateral force representing aerodynamic loading from the

nose cone was applied to the upper section. The force was calculated using the lift force equation.

Assuming a lift coefficient of 0.3 for the nose cone resulted in a calculated force of 230 N. Due to the simplified assumptions used in the analysis, a safety factor of approximately 2.5 was applied, and a load of 600 N was used in the simulation. These results were also compared with OpenRocket simulations, which indicated that the applied load significantly exceeded expected flight conditions. The simulation results are shown in Figures 4.70 and 4.71.

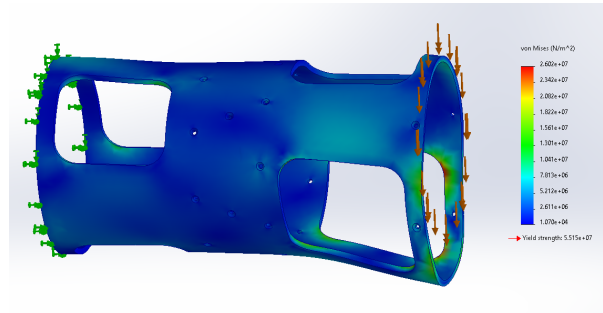


Figure 4.70: Stress distribution in the coupler

The maximum stress remained significantly below the allowable limit.

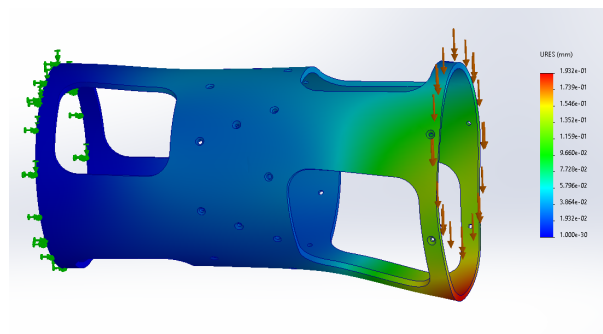


Figure 4.71: Displacement of the coupler

Under the applied loading conditions and assumptions, the predicted displacement was below 0.5 mm, indicating that the coupler provides sufficient rigidity and is not expected to undergo significant bending during flight.

4.5 Avionics

4.5.1 Overview

The rocket's avionics architecture is designed as a highly reliable, distributed cyber-physical system, divided into two primary categories: SRAD (Student Research and Development) custom systems and COTS (Commercial Off-the-Shelf) safety modules. The core of the system is built around a dual-node computing architecture utilizing two identical BeagleBone Black single-board computers that operate within a hardwired ecosystem.

The primary architecture utilizes a dedicated Ethernet link running the AUTOSAR (Automotive Open System Architecture) and SOME/IP (Adaptive-compliant Scalable service-Oriented MiddlewarE over IP) protocol for high-bandwidth, deterministic inter-process communication. The system software is built on the custom SRP (Simple Rocket Platform) in C++20, orchestrating modular services managed by a thread-safe global state machine.

To maximize mission success and ensure safety, the avionics stack decouples critical flight phases into localized tasks: the EC (Engine Computer) governs propulsion-side data acquisition and actuation, while the FC (Flight Computer) serves as the main authority for state machine transitions, navigation, ground telemetry, and recovery. This custom architecture is complemented by fully independent COTS telemetry and tracking units that guarantee complete redundancy in emergency situations.

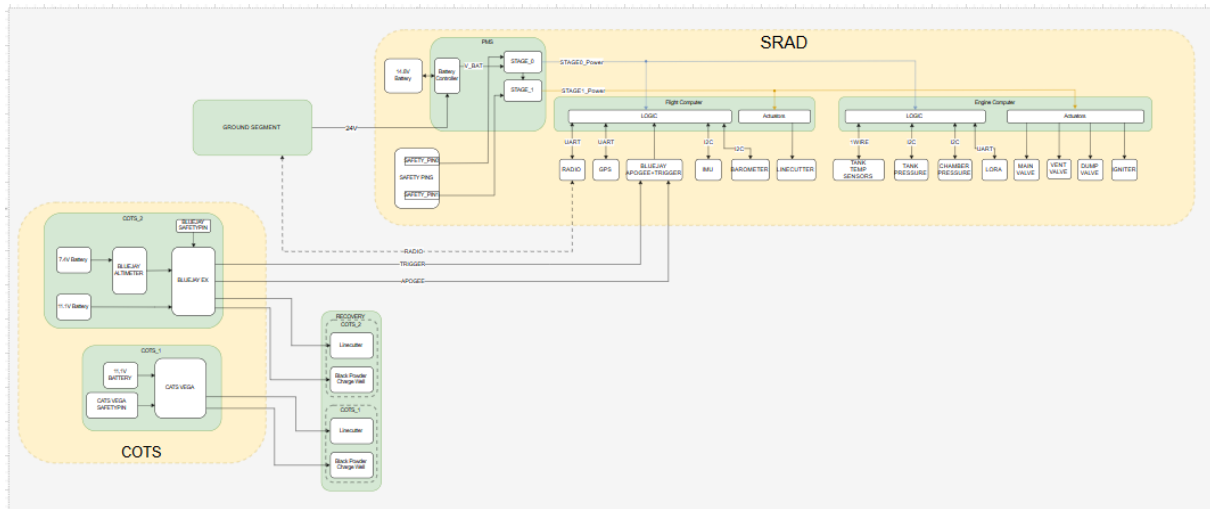


Figure 4.72: Avionics system overview

SRAD

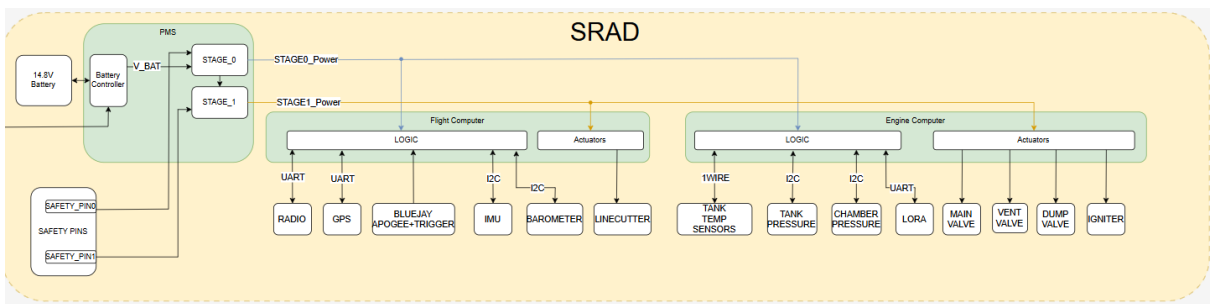


Figure 4.73: SRAD avionics overview

The SRAD electronics encompass all custom-designed hardware and software tailored specifically for this launch vehicle. Structurally, the system is split across two nodes on a private network.

The SRAD ecosystem relies on structural, software, and hardware interdependencies:

- **Propulsion & Actuation (EC Node):** The EC manages real-time tasks using an array of I²C peripherals. It samples high-frequency pressure data from the tank and combustion chamber using the 12-bit ADS7828 ADC, monitors bus vitals via an INA219 sensor, and drives the main oxidizer, vent, and dump valves through a 16-channel PCA9685 PWM expander. Pyrotechnic ignition is managed by a hardware-monitored, GPIO-controlled MOSFET circuit with automatic pre-arm continuity sensing.
- **Navigation & Recovery (FC Node):** The FC acts as the centralized master of the flight state machine (MainService). It interfaces with a BME280 barometric sensor over I²C for real-time altitude estimation and reads NMEA-0183 sentences via a dedicated GNSS UART link. It controls a two-stage recovery subsystem via a dual mechanism: releasing a drogue parachute through a PCA9685 servo channel at apogee, and activating a secondary, GPIO-driven pyrotechnic linecutter to deploy the main parachute at a configurable altitude.
- **Telemetry & Communication:** Ground control links are maintained by the SRAD RadioService on the FC, which packages state vectors, sensor packets, and diagnostics into a custom *SIMBA* MAVLink dialect transmitted over a primary radio module. A secondary, independent LoRa beacon functions in the 915 MHz ISM band to stream backup GPS coordinates and peak altitude data.
- **Multi-Layered Power Safety:** The SRAD power distribution is governed by a custom Power Management System (PMS) board providing regulated power sequencing. Unintended hardware actuation is strictly prevented by physical, manual safety pins, backed up at the software level by strict GPIO arm-enable interlocks which instantly force pins low during a connection_lost or abort event.

All SRAD components continuously log telemetry locally to post-flight flash arrays and share high-integrity variables utilizing the thread-safe `RocketStateController` abstraction layer.

COTS

Commercial off-the-Shelf (COTS) technology gives the Recovery system independence, allowing us to deploy the parachute in the case of a malfunction without worrying about collateral damage. The recovery system can achieve higher levels of resilience, independence and fault tolerance by utilizing COTS components and dual CAN bus redundancy (fig. 4.74). This reduces the possibility of damage and guarantees proper opening of the parachute, especially in difficult conditions. We use Altus Metrum Telemetry v3.0 in our solution.

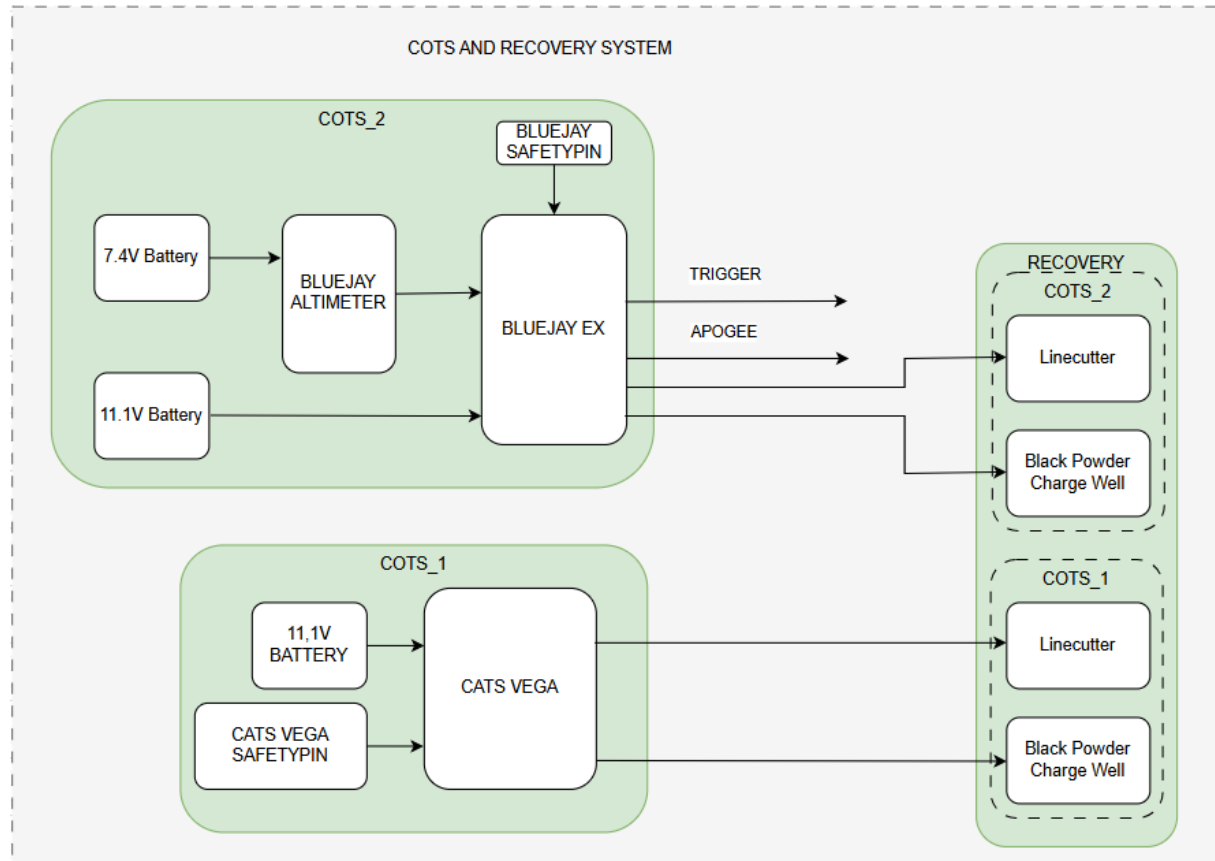


Figure 4.74: COTS avionics overview

4.5.2 Rocket modules

The avionics stack of the rocket consists of two onboard computing units communicating over a dedicated Ethernet link using the SOME/IP protocol, supplemented by independent COTS tracking and communication modules. All custom software runs on the SRP-platform (*Simple Rocket Platform*), written in C++20 and built on the AUTOSAR Adaptive runtime. Every service follows the same lifecycle: an `Initialize()` phase that discovers peer services and configures hardware, followed by a `Run()` loop. State is shared between services through the thread-safe `RocketStateController` singleton and propagated to the peer computer over SOME/IP events.

Engine computer (EC)(Fig. 4.75):

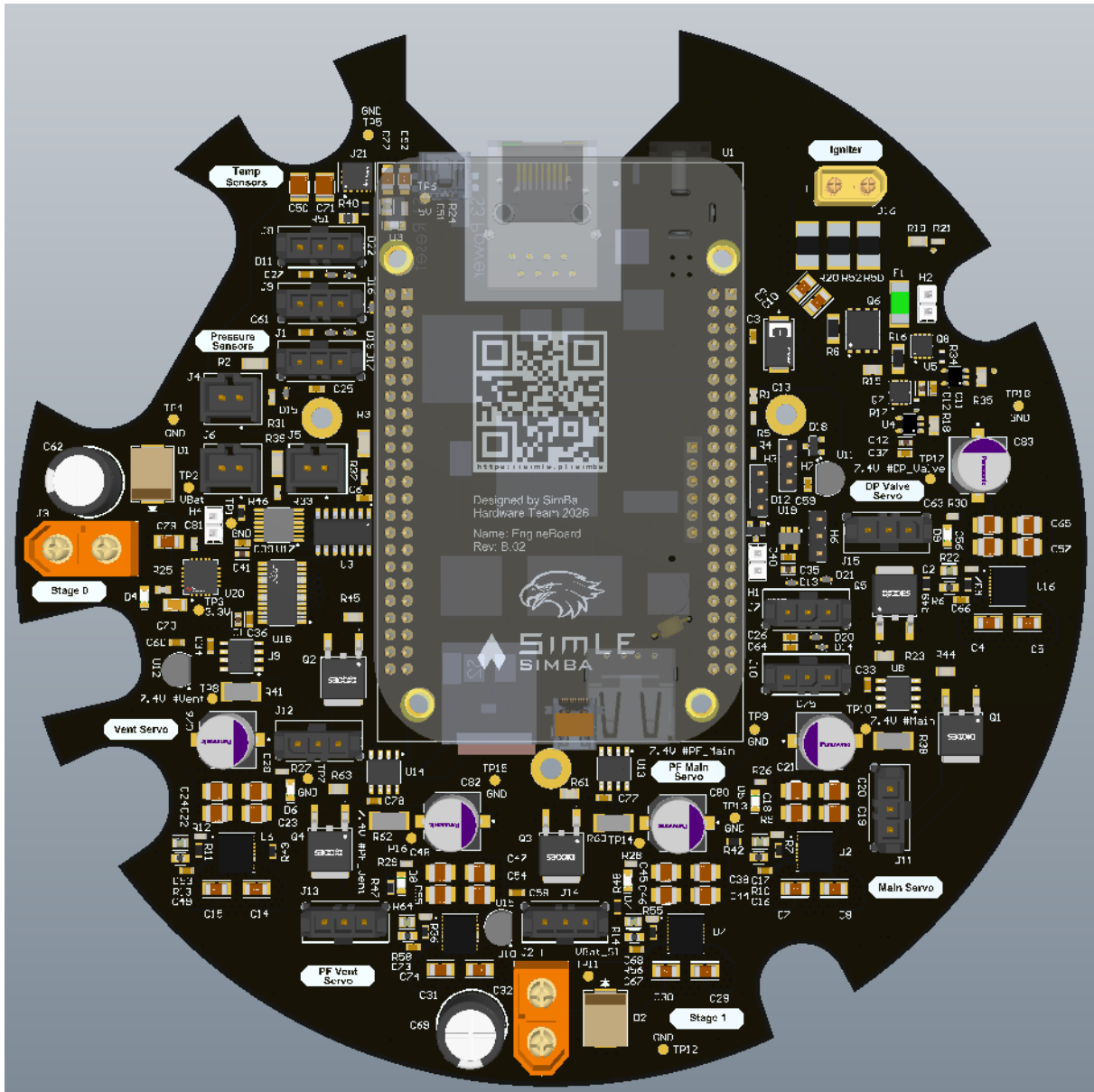


Figure 4.75: Engine computer board overview.

The Engine Computer is a BeagleBone Black single-board computer (Texas Instruments AM335x, ARM Cortex-A8 at 1 GHz, running Linux) assigned the static IP address 192.168.10.51 on the avionics network. It owns all engine-side actuation: igniter firing, propellant valve control, and tank pressure monitoring.

Services:

- **EngineService** – top-level state orchestrator on the engine side. On arm it drives a set of configurable GPIO arm-enable pins high, energising igniter and valve safety circuits. On launch it calls `PrimerService::StartPrime`, waits 1 000 ms for propellant pressurisation, then opens the main oxidiser

valve via `ServoService::SetMainServoValue(1)` and autonomously advances the shared state to flight. On apogee it executes the engine-shutdown sequence: vent-shutdown, pre-fill vent-shutdown, and main-shutdown. On abort the dump valve opens immediately. On `connection_lost` all arm pins are forced low unconditionally. The current state is broadcast as a SOME/IP event (`CurrentMode`) at 1 Hz over both IPC and UDP links.

- **ServoService** – controls the three propellant-system servo outputs (main oxidiser valve, vent valve, dump valve) via the PCA9685 16-channel PWM expander connected over I²C. Exposes `SetMainServoValue`, `SetVentServoValue`, and `SetDumpValue` as SOME/IP methods, each accepting a `uint8` position and returning a `bool` acknowledgement. Each valve position is also published continuously as a SOME/IP status event, allowing the radio service on the FC to include actuator state in ground-station telemetry.
- **PrimerService** – drives the pyrotechnic igniter through a GPIO-controlled MOSFET. Before every arm cycle the controller probes the igniter circuit via the ADS7828 ADC and classifies continuity as one of `not_connected`, `connected`, or `fired`; an ignition is rejected if continuity is not confirmed. The `StartPrime` method enables the output with an automatic timed disable. The igniter state is published as a `primeStatusEvent`.
- **EnvService** – aggregates environmental, tank, and combustion chamber sensor data. Tank pressure and combustion chamber pressure are sampled from up to three ADC channels each using the ADS7828 (12-bit, 8-channel I²C ADC). Ambient temperature is read from dedicated 1-Wire temperature sensors via the middleware temperature controller. All processed values are published as SOME/IP events.
- **SystemStatService** – reads CPU usage, memory utilisation, and disk occupancy from the Linux `/proc` filesystem and broadcasts them as a structured `SysStatType` SOME/IP event.
- **LoggerService** – collects log records from all EC services and writes them to a log file for post-flight analysis.

Hardware interfaces:

- **I²C**:
 - **PCA9685** – 16-channel PWM servo driver
 - **ADS7828** – 12-bit, 8-channel ADC (used for tank and combustion chamber pressure)
 - **INA219** – Voltage and current monitoring
 - **24LC32AT** – 4 kB EEPROM for persistent configuration
- **UART** – LoRa radio module for wireless telemetry
- **GPIO**:
 - primer MOSFET gate
 - servo motor MOSFET gates
 - Arm-enable pins
- **1-Wire** – Engine and Computer temperature sensors
- **Ethernet** – SOME/IP IPC and UDP inter-CPU link

Hardware Desing Overview

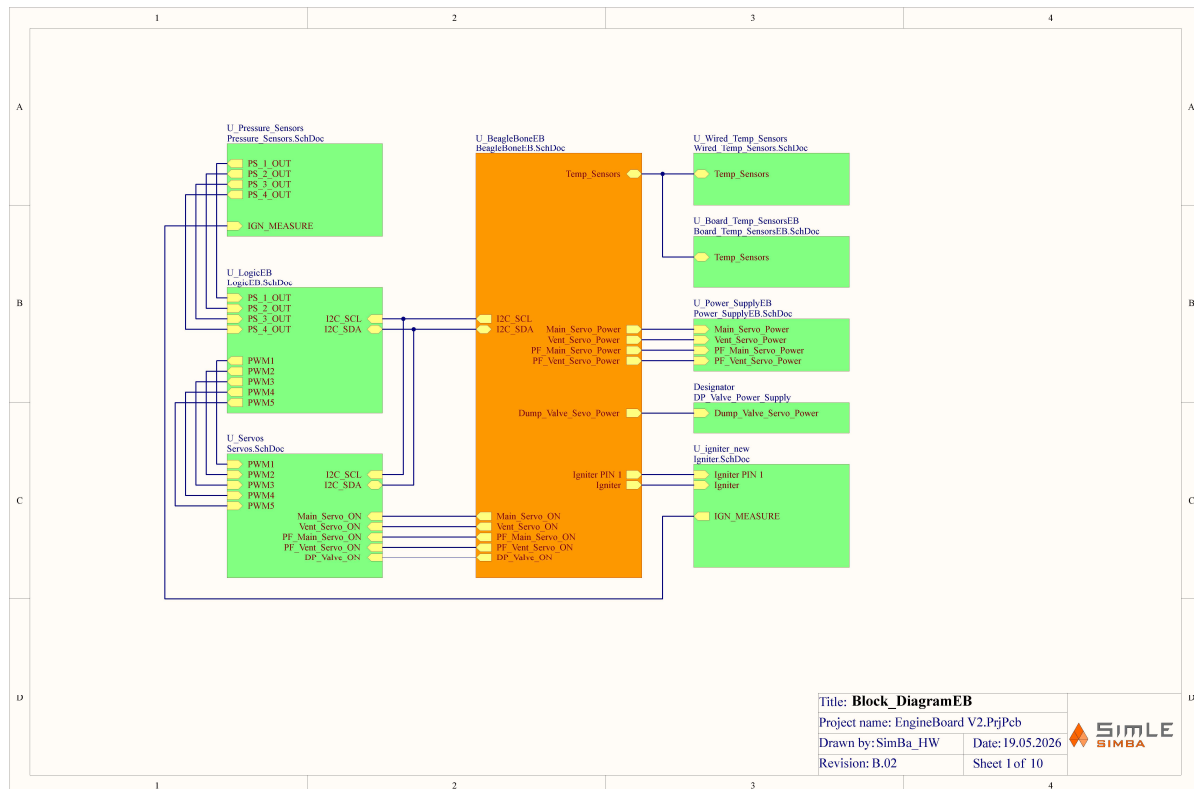


Figure 4.76: EC top level architecture

Engine comoputer diameter is 160mm. Board architecture insist of 9 functional blocks:

- **BeagleBone Section:** This section houses the EB main computer, defining all logical connections for the BeagleBone. Communication with the onboard systems is realised via an internal I2C interface.
- **Logic Block:** This block handles PWM management utilizing the PCA9685 controller, as well as pressure measurement using an ADC circuit based on the ADS7828EB/250 to acquire sensor data. Additionally, this section incorporates an EEPROM memory module for storing system data.
- **Servos Block:** The servos are controlled by PWM signals generated within the Logic Block. Servo power distribution is managed via MOSFET transistors toggled by control signals from the BeagleBone. This architecture significantly enhances safety by introducing an additional disarming layer for the system actuators. Furthermore, continuous current monitoring is implemented across all servos using INA219 current sensors, which improves system parameter telemetry and facilitates rapid actuator failure detection.
- **Temp Sensors Blocks:** Two temp sensors block are included on EC system. External(Wired) temperature sensors and board temperature sensors. Temperature sensing is realised on DS18B20 sensors with 1_Wire communication protocol. External temperature sensors connectors are protected by ESD diodes for mitigating failure risk.
- **Igniter Block:** The design of the igniter block prioritizes safety. At the hardware level, the risk of unintended ignition is mitigated by implementing both high-side and low-side MOSFET switches. An additional safety layer is introduced via a 7.4 V enable signal, which is strictly required to power the igniter circuit. Together, these features establish a robust, three-stage safety mechanism for engine ignition, minimizing the risk of inadvertent triggering.
- **Power supply blocks:** The Main Power Supply block is divided into two distinct sections. The first section consists of 3.3 V and 5 V power supplies, implemented using TPS7A4700RGWR and TPSM84209RKHT regulators. This section provides power to the system logic and is supplied by the STAGE_0 power block. The second section comprises 7.4 V switching power supplies dedicated to the servos, which are powered by the STAGE_1 block. Furthermore, all power regulators for actuators require an enable signal from the main computer, providing the capability for software-controlled disarming of the system actuators.

Flight computer (FC)(Fig. 4.77):

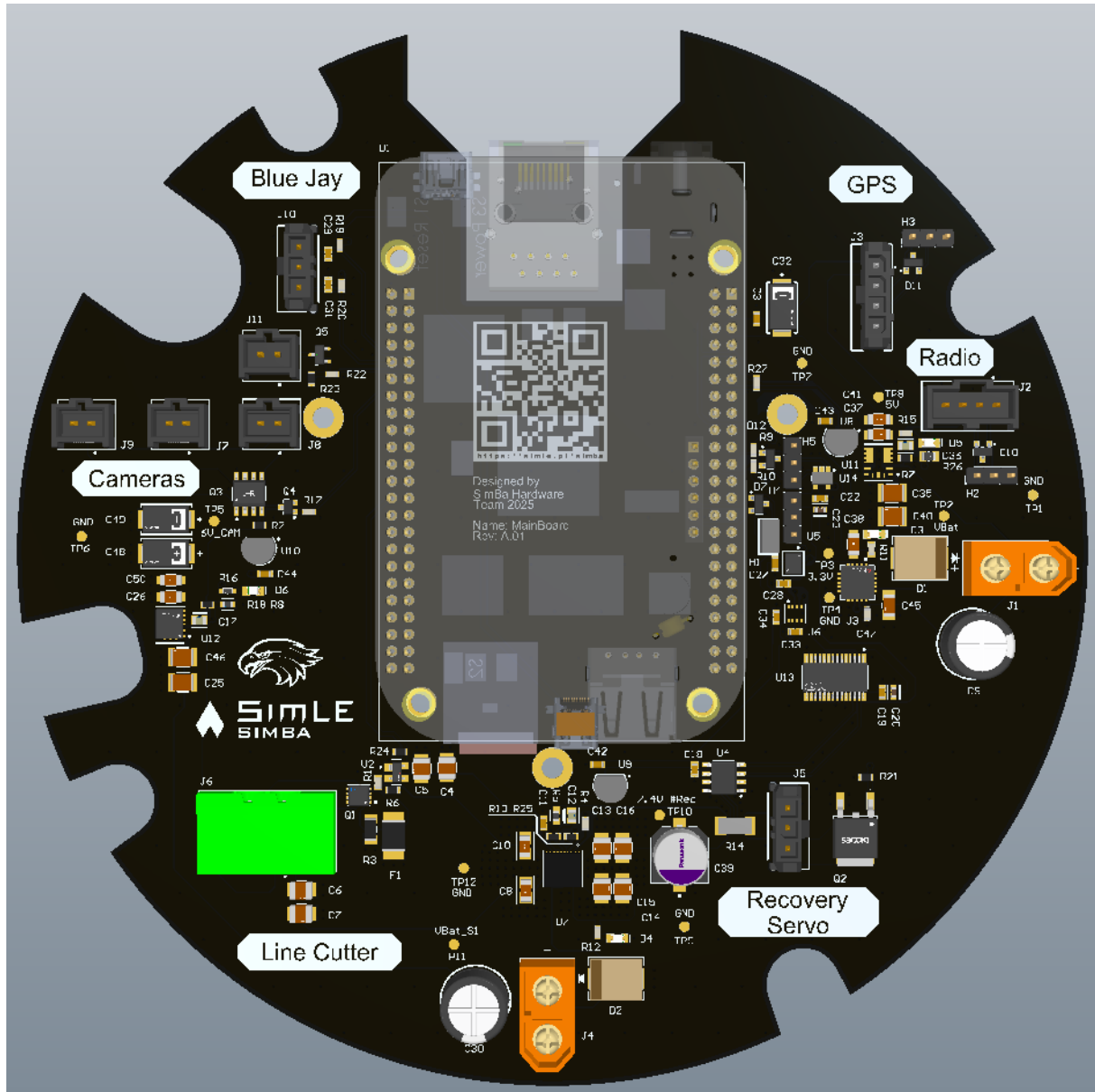


Figure 4.77: Flight computer board overview.

The Flight Computer is an identical BeagleBone Black platform, at IP address 192.168.10.52. It is the authority for the shared rocket state machine, manages parachute recovery, processes barometric and GPS navigation data, and handles all ground-station communication.

Services:

- **MainService** – the central flight state machine. It enforces the complete allowed-transition graph (see Section 4.5.6), guards the APOGEE transition behind the `apogee_detection_allowed` flag (set only after flight is entered, preventing premature deployment during the boost phase), and delegates physical actions to RecoveryService and EngineService via SOME/IP method calls. On every state change it propagates the new state to the EC EngineService (apogee, first_parachute, second_parachute, drop) so both computers remain synchronised.
- **RecoveryService** – controls two-stage parachute deployment through the ParachuteController singleton. The first stage (OpenReefedParachute) uses a PCA9685 servo channel to release the drogue; the second stage (UnreefeParachute) fires a GPIO-driven MOSFET linecutter to sever the reefing line, allowing full inflation. A linecutter activates at a configurable altitude (default 450 m AGL). Parachute deployment state is published as a SOME/IP event.
- **GPSService** – reads NMEA-0183 sentences (GGA, RMC, VTG) from the onboard GPS receiver over UART, parses them, and publishes position (latitude, longitude, altitude), ground speed, and fix quality as SOME/IP events.

- **RadioService** – bridges the custom *SIMBA* MAVLink dialect over UART between the RF telemetry transceiver and the internal SOME/IP bus. Outgoing telemetry is assembled by the `TelemetryProvider` using data collected across all services via the thread-safe `EventData` singleton.

The service transmits five message types at a 1 Hz frequency:

- `SIMBA_HEARTBEAT` – FC/EC states, primer state, and actuator flags
- `SIMBA_MAX_ALTITUDE` – maximum recorded altitude data
- `SIMBA_TANK_SENSORS` – pressure and temperature readings from the EC
- `SIMBA_GPS` – GPS coordinates and satellite data
- `Computer-telemetry frame` – CPU and memory usage statistics for both onboard boards

Incoming `SIMBA_GS_HEARTBEAT` frames carry ground-station command flags. Continuity of these incoming frames is monitored by the `GSHeartbeatGuard` thread, which triggers a `connection_lost` event if the link goes silent.

- **SystemStatService / LoggerService** – identical in purpose to the EC counterparts. The FC logger additionally records BME280 barometric altitude, humidity, and board temperatures to a CSV file with per-row timestamps.

Hardware interfaces:

- **I²C**:
 - **BME280** – Barometric pressure, temperature, and humidity sensor for altitude estimation
 - **INA219** – Power monitoring (voltage and current)
- **UART**:
 - **NMEA GPS** – GNSS receiver for position tracking
 - **RF Transceiver** – LoRa radio module utilizing the custom *SIMBA* MAVLink dialect
- **GPIO**:
 - Recovery linecutter MOSFET gate
 - Arm-enable pin
- **1-Wire** – Computer temperature sensors
- **Ethernet** – SOME/IP IPC and UDP inter-CPU link

Hardware Desing Overview

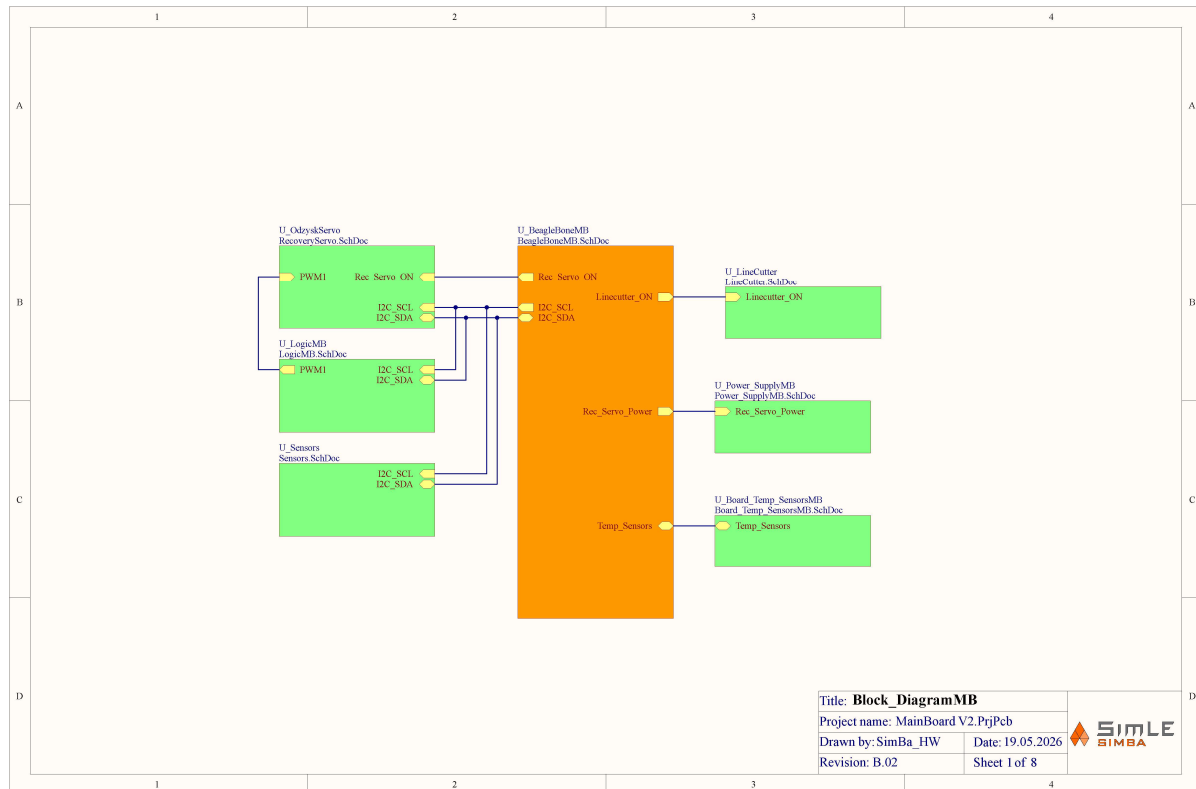


Figure 4.78: FC top level architecture

Flight computer board diameter: 160mm. FC architecture consist of functional blocks:

- **Recovery Servo and Linecutter** This two blocks are designed to realise rocket recovery functions. Recovery Servo block similarly to EC is controlled by PWM signal and powered up with Mosfet switch enabled by signal from main computer. Linecutter block High power mosfet switch, controlled by dedicated Gate controller MIC4416YM4. Linecutter is turn on by software with enabling signal from main computer.
- **Temp sensors** Flight computer board includes DS18B20 temperature sensors for monitoring Flight computer temperature.
- **Telemetry Sensors:** The system incorporates two primary telemetry modules. The first is an Inertial Measurement Unit (LSM6DSOXTR), a 6-axis IMU featuring a 3-axis accelerometer and a 3-axis gyroscope, which is configured for I2C communication. The second is an Environmental Sensor (BME280), a highly integrated device responsible for measuring barometric pressure, ambient temperature, and relative humidity. The acquired pressure data is specifically utilized by the main computer for precise altitude calculations.
- **Logic Block** FC use PWM controller for servos controlling and external EEPROM for data. Both of this are included in this block. PWM is realised by PCA9685 similarly as on EC. There is additional external I2C connector.
- **Power Supply:** The FC module utilizes four distinct power distribution lines. The logic circuitry is powered by a 3.3 V line, implemented using a TPS7A4700RGWR LDO regulator, and a 5 V line, based on a TPSM84209RKHT switching regulator. Both the 3.3 V and 5 V logic lines are supplied from the STAGE_0 block. Additionally, a 6 V line dedicated to camera power is implemented with a TPSM84209RKHT switching regulator, while a 7.4 V line, utilizing a TPSM86637RCGR switching regulator, provides power to the recovery servo. Both the 6 V and 7.4 V lines are supplied from the STAGE_1 block. Furthermore, the servo power supply requires a dedicated enable signal from the BeagleBone computer to activate.

Light APRS tracker

The Light APRS tracker is a COTS module used as a fully independent, redundant position beacon. It operates autonomously from the main avionics stack and requires no integration with SRP software. The module contains its own GPS receiver and a VHF transmitter; it broadcasts APRS position packets on 144.390 MHz throughout the flight, allowing the recovery team to locate the rocket even in the event of a complete avionics failure. Its battery

and power supply are independent of the main power bus.

LoRa Communication Module

The LoRa module provides a secondary, independent downlink channel dedicated to GPS position and max flight altitude tracking. Operating in the 915 MHz sub-GHz ISM band, it functions as a redundant backup beacon that transmits telemetry independently of the primary MAVLink RF link. Utilizing two physically and protocol-wise separate radio links significantly increases the probability of successful rocket recovery after touchdown, ensuring continuity even if the primary link suffers from terrain attenuation or unfavorable rocket attitude.

4.5.3 Power Safety

The power subsystem (Fig. 4.79) is designed with safety as the primary concern: several independent hardware mechanisms prevent unintended actuation of pyrotechnics and high-current loads regardless of software state, and these mechanisms are layered so that no single failure can defeat all of them. Subsystem architecture contains of two main blocks, PMS board and safet pins board.

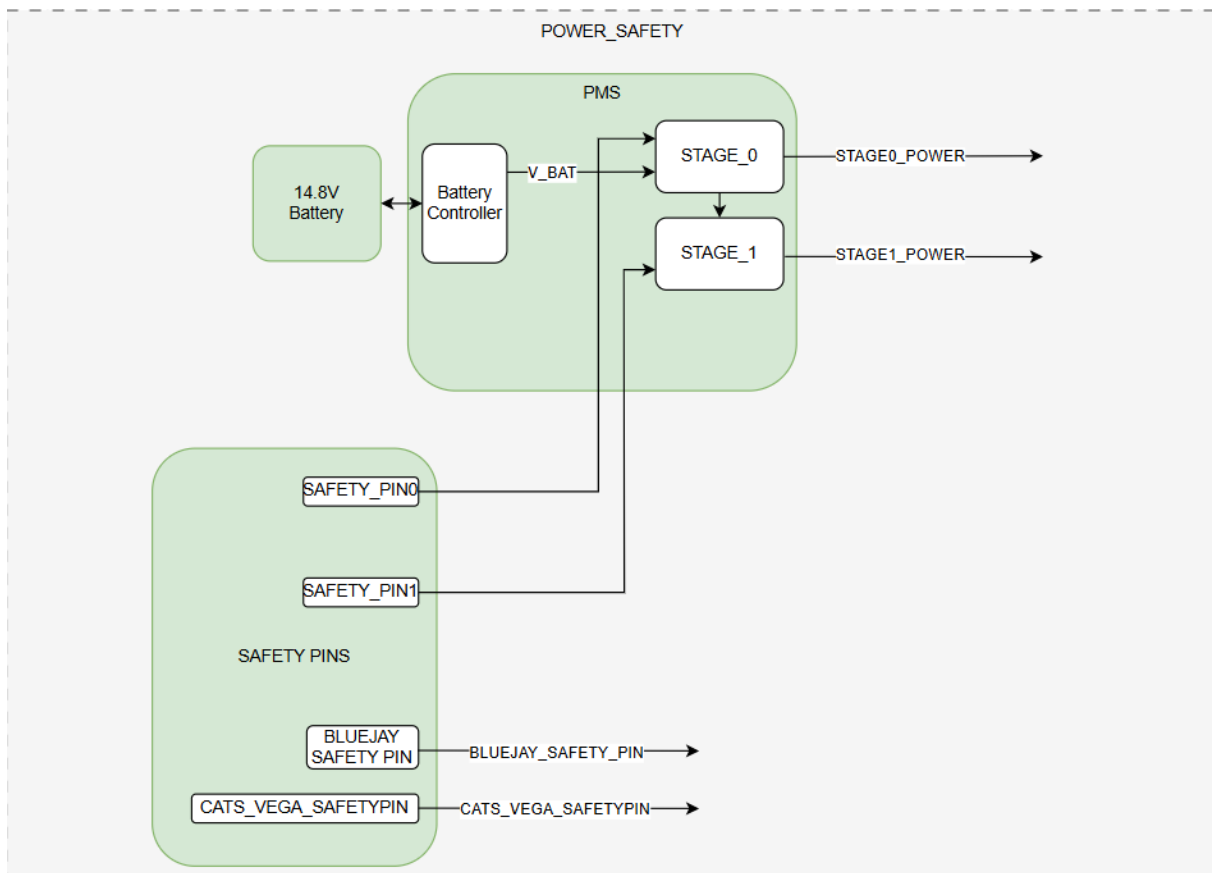


Figure 4.79: Power system architecture diagram

Power management system (PMS)

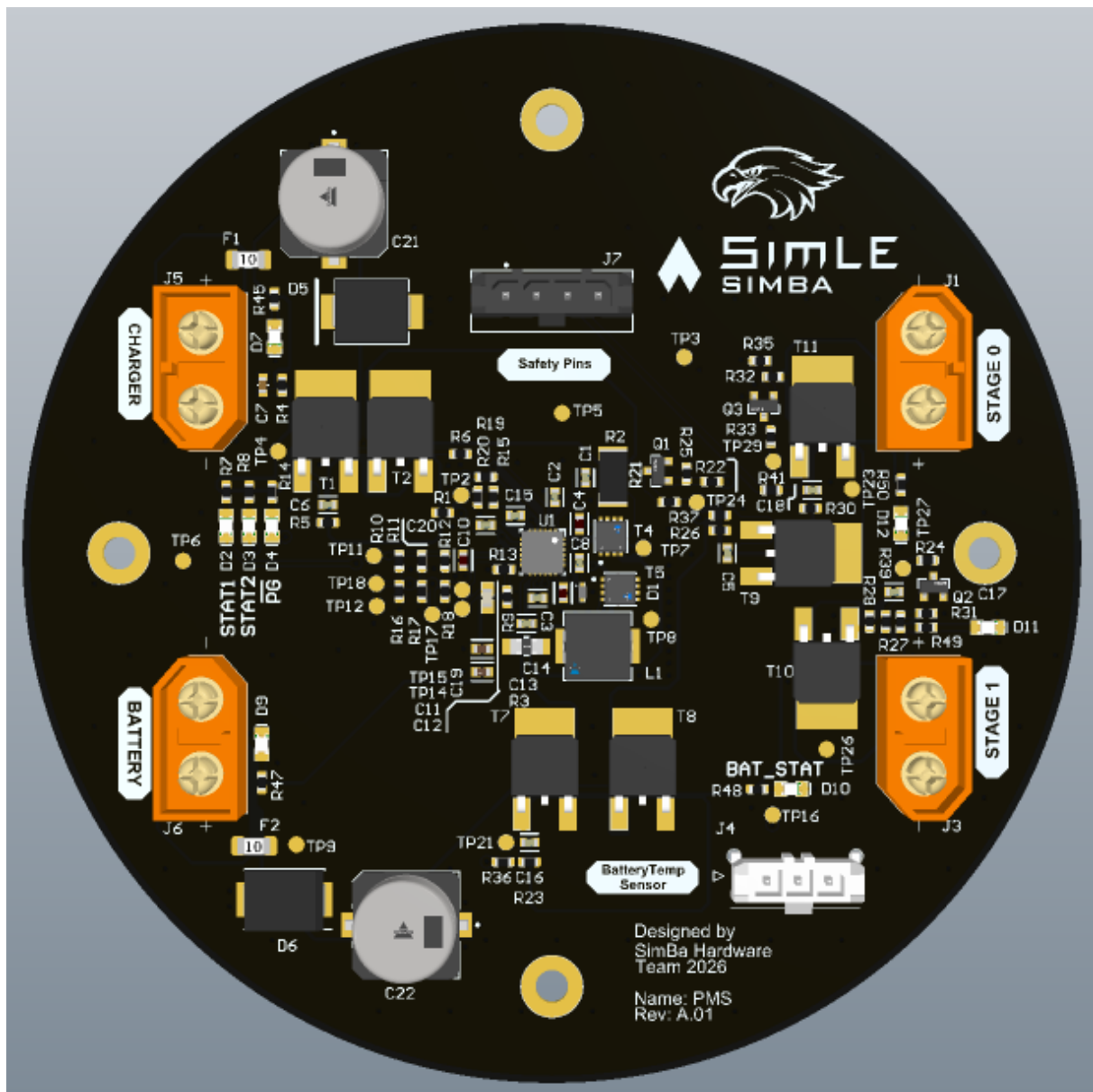


Figure 4.80: PMS board overview.

The Power Management System board is the central power distribution unit. It supplies voltage to the EC and FC modules and provides 4S2P battery charging. The PMS enforces orderly power sequencing at startup and can isolate a faulted subsystem.

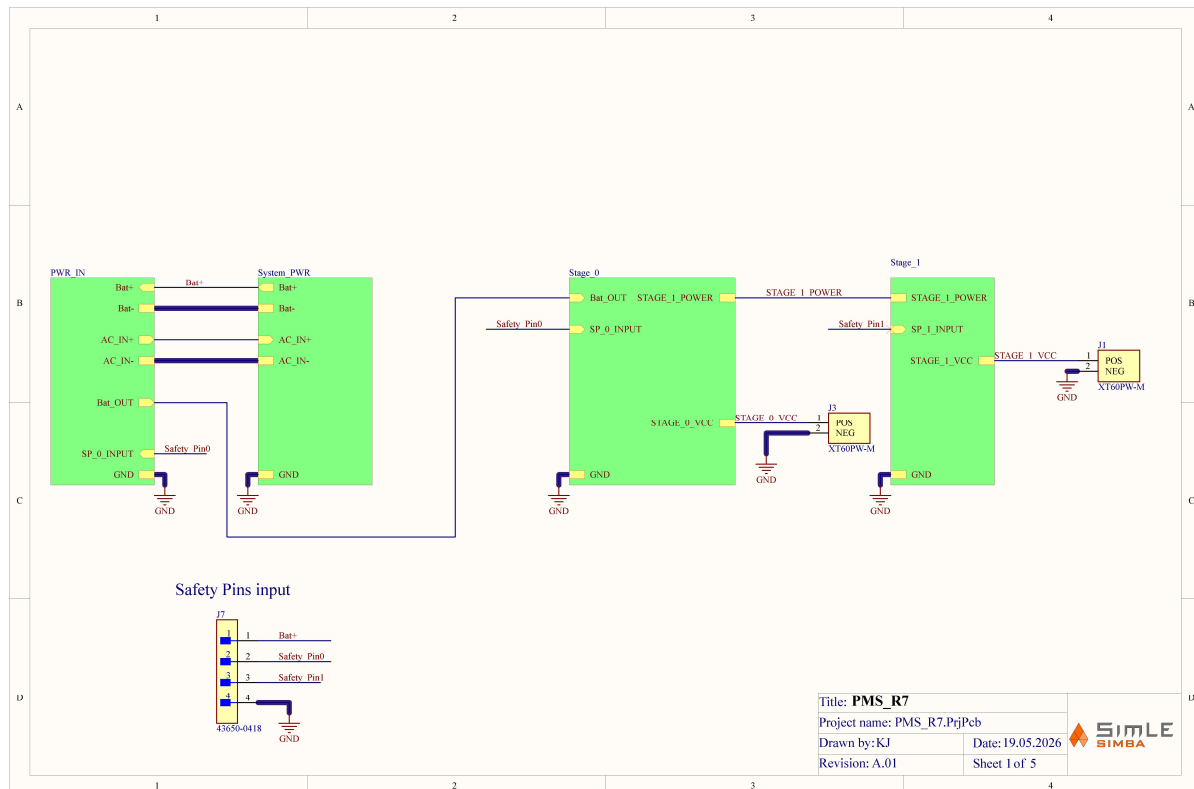


Figure 4.81: PMS top level architecture

Power Management System is divided into sequential stages:

- **System PWR:** This block includes Battery charging unit, which provides 4S2P LI-ION battery charging with 3A charging current, undervoltage, overvoltage and thermal battery protection.
- **Stage 0 (Primary Distribution & Subsystem Routing):** This stage encompasses a primary bidirectional MOSFET-based circuit responsible for switching the main battery voltage. Furthermore, it incorporates two independent soft-latch circuits implemented with power MOSFETs. The first latch routes power directly to the logic circuitry, while the second latch supplies power to Stage 1. This soft-latch design ensures low power dissipation and prevents accidental shutdown in the event of wiring damage or an inadvertent short circuit across the primary safety pins.
- **Stage 1 (Actuator Arming Sequence):** This stage is strictly dedicated to the actuator system and is supplied by the corresponding latch from Stage 0. Stage 1 is activated by an additional, separate safety pin. Only upon the explicit triggering of this subsequent safety pin are the rocket's actuators powered, thereby securely enabling the arming sequence

PMS board dimensions: diameter 104mm.

Safety pins

Safety pins are physical interlock connectors that must be manually removed before launch to enable the high-current actuator circuits (igniter, valve MOSFETs). With a pin inserted the corresponding output is hard-wired open at the hardware level, regardless of any GPIO or software state. The EC software reinforces this with the *arm-pins* mechanism: the EngineService maintains a configurable list of GPIO arm-enable outputs and drives all of them low unconditionally on every disarm or connection_lost event, providing a complementary software interlock that mirrors the hardware one.

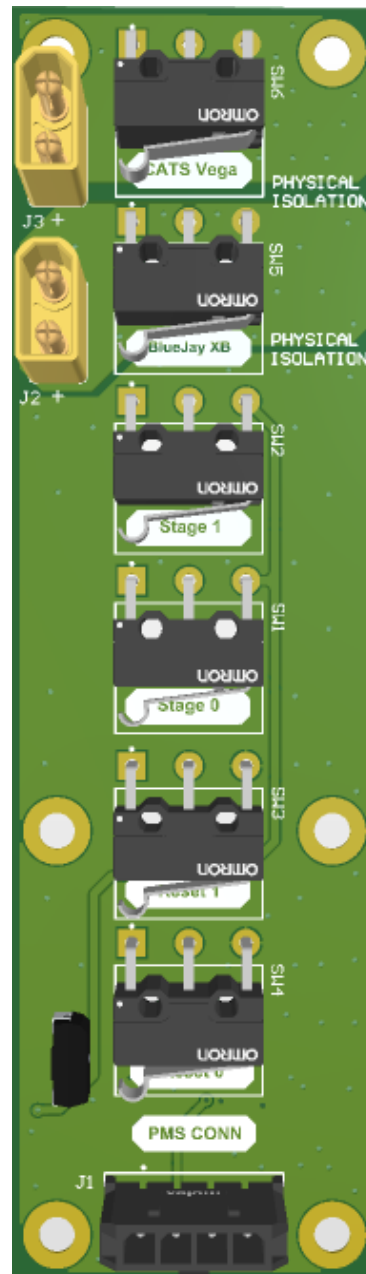


Figure 4.82: SAFETY PINS board overview

- **SRAD Section:** This section integrates the safety pins for STAGE_0 and STAGE_1, along with a flip-flop circuit designed to prevent accidental power disconnection. To safely disarm the rocket, the system utilizes two independent reset switches. Activating both reset switches simultaneously is required to cut off the rocket's power supply. Implementing this dual-reset mechanism significantly enhances overall safety by mitigating the risk of inadvertent power loss.
- **BLUEJAY Section:** This dedicated section implements the safety pin interface specifically for the Bluejay system.
- **COTS Section:** This section provides the safety pin integration for the COTS circuitry. The COTS system utilizes an auxiliary safety pin board, which is detailed in the subsequent section.

CATS safety pins(Fig. 4.83)

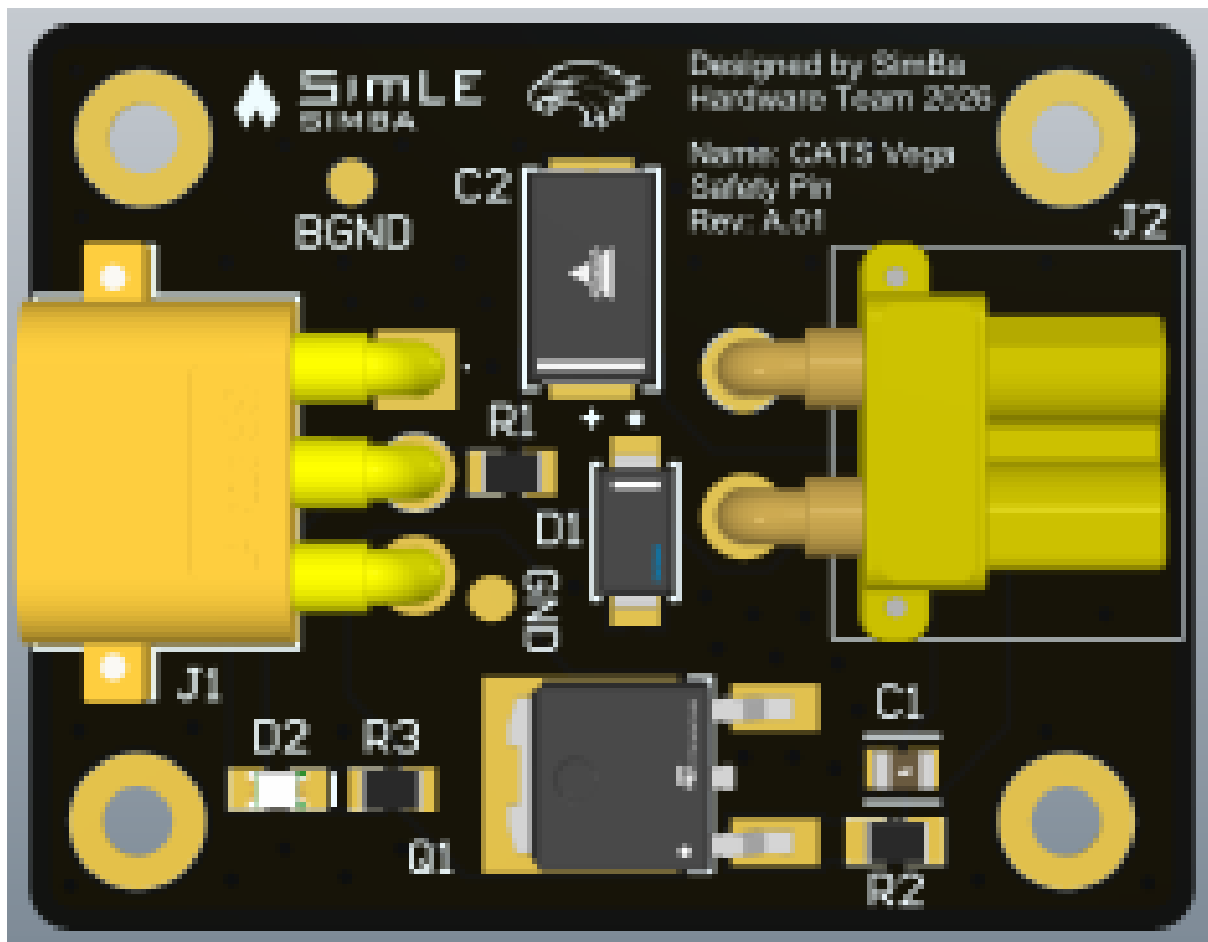


Figure 4.83: CATS VEGA SAFETY PIN Board overview. Board dimensions: 39.8x30.8mm

CATS safety pin provide an additional hardware interlock layer dedicated to the pyrotechnic recovery charges. They operate on the same physical-connector principle as the main safety pins but are separate connectors wired exclusively into the recovery subsystem circuits. Removing the CATS pins is the last step of the pre-launch checklist, performed only after the rocket is vertical, personnel have cleared the pad, and the main safety pins are already pulled. This two-pin separation ensures that a single absent or incorrectly seated connector cannot simultaneously arm both the engine igniter and the recovery charges.

4.5.4 COTS systems

COTS system architecture consist of two independent systems: COTS_1 - CATS VEGA and COTS_2 - Bluejay altimeter board with Bluejay extension board. This solution minimize risk of recovery system failure due to independent work of the both COTS systems.

CATS VEGA

The CATS Vega board function as a highly integrated, COTS (Commercial Off-The-Shelf) flight computer primarily responsible for managing the rocket's flight profile, telemetric data acquisition, and recovery system deployment. The system employs an internal Finite State Machine (FSM) to continuously track and transition between flight phases based on real-time data acquired from its onboard sensor suite, which includes a high-precision barometer, a 6-axis IMU, and a GNSS module.

Key capabilities of the CATS Vega board include:

- **Recovery System Control:** The module is equipped with two dedicated pyrotechnic channels and two servo channels. These are typically configured to manage the sequential deployment events of the recovery system, such as releasing the drogue and main parachutes at predetermined altitudes.
- **Telemetry and Data Logging:** The board features a 2.4 GHz telemetry link, transmitting critical flight metrics (including altitude, velocity, GNSS coordinates, battery voltage, and current flight phase) to the

Ground Station at a 10 Hz update rate. Concurrently, high-frequency sensor data is logged to an onboard 16 MB flash memory for post-flight analysis.

- **Configurable Event Triggering:** The system allows for highly customizable deployment events and the implementation of backup timers for every state transition. This configurable redundancy significantly mitigates the risk of recovery failure and ensures a safe descent.

Bluejay Altimeter(Fig. 4.84)

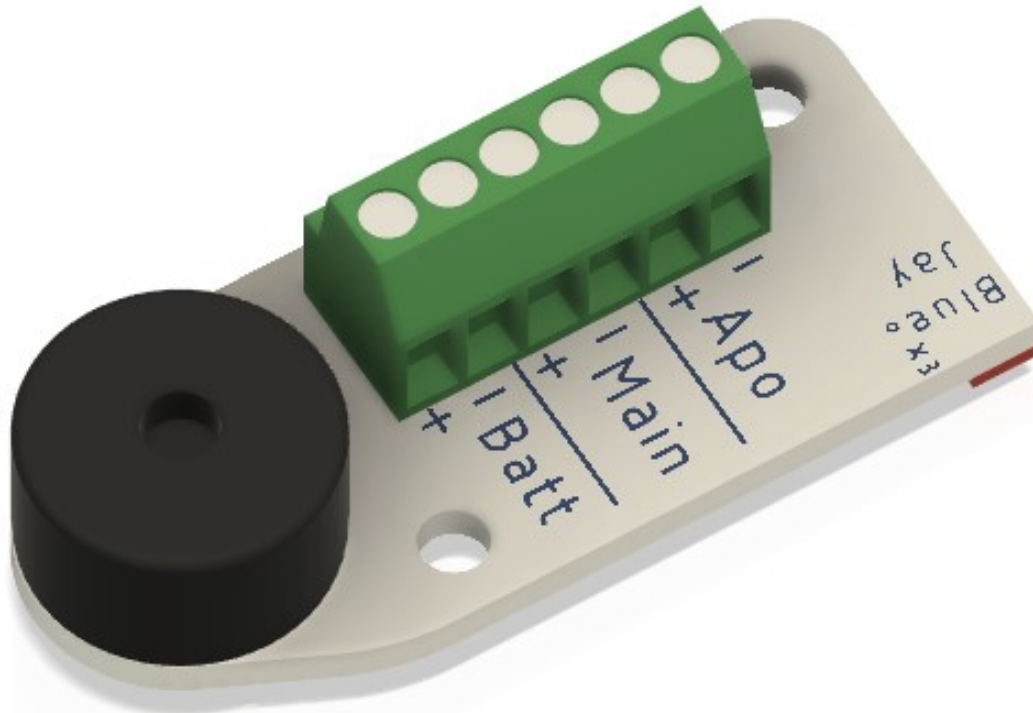


Figure 4.84: Blue Jay Altimeter board overview.

The Bluejay altimeter board serves as a highly compact, Commercial Off-The-Shelf (COTS) flight computer designed primarily for dual-deployment recovery and flight data logging in experimental rocketry, functions as a highly reliable event sequencer, utilizing high-resolution barometric and inertial sensor data to accurately determine flight apogee and monitor the descent profile.

Key capabilities of the Bluejay altimeter include:

- **Recovery System Control:** The module features two dedicated high-current output channels optimized for pyrotechnic e-matches. These are typically configured to execute a standard dual-deployment sequence, independently triggering the drogue parachute at the detected apogee and the main parachute at a user-defined altitude.
- **Wireless Configuration and Logging:** The board integrates a Bluetooth communication module, enabling seamless interaction via a dedicated mobile application. This interface facilitates pre-flight parameter configuration, real-time pad readiness monitoring, and rapid post-flight data extraction, detailing peak altitude, velocity, and precise event timing.
- **Integrated Arming Mechanism:** A defining feature of this board is its built-in magnetic solid-state switch. This mechanism allows the avionics to be safely armed or disarmed from outside the rocket's airframe using a magnet immediately prior to launch, which significantly streamlines pad operations and reinforces safety protocols.

2.2 BlueJay Extension board(Fig. 4.85)

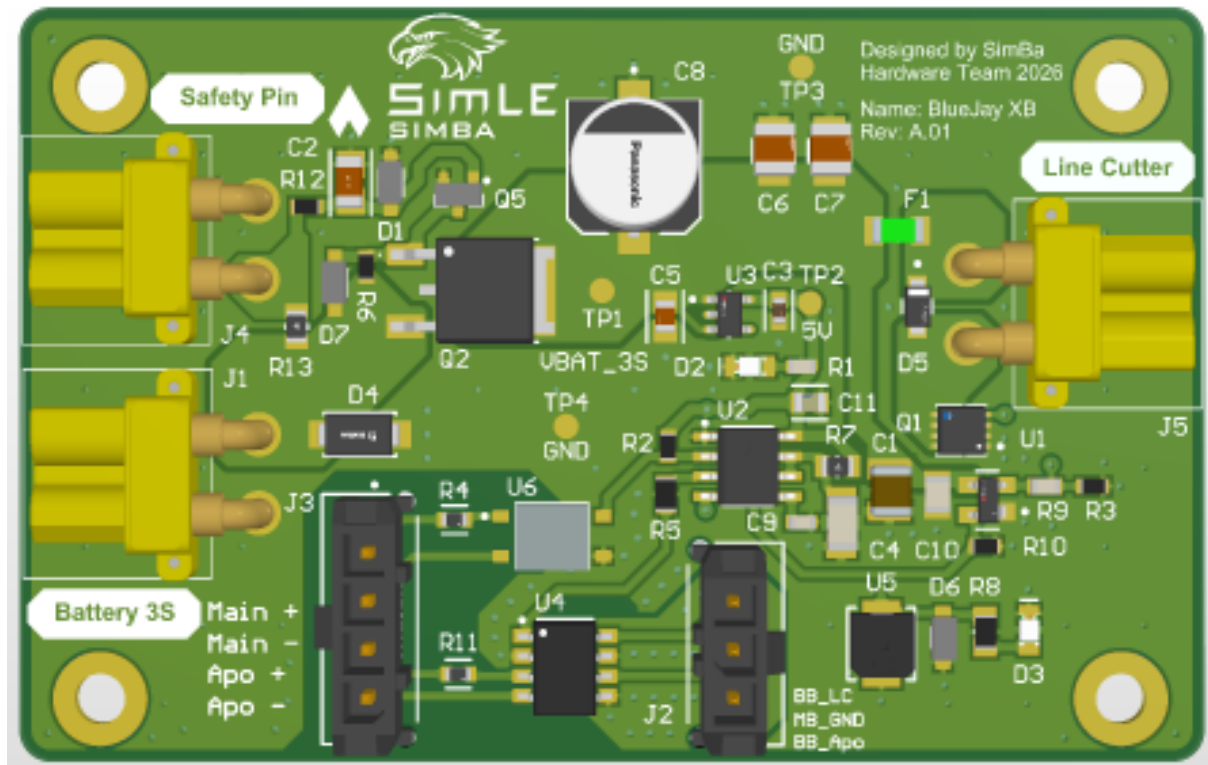


Figure 4.85: Blue Jay Extension Board overview.

The Bluejay Extension Board was designed to integrate the Bluejay altimeter with our custom safety pin architecture and to condition the deployment signals. Specifically, the board prolongs the linecutter activation pulse from the standard 1-second output provided by the Bluejay altimeter to a 6-second duration. Additionally, it relays critical event telemetry—such as apogee detection and linecutter activation—directly to the main Flight Computer (FC). BlueJay EX board dimensions: 75.5x48mm

To mitigate the risk of component failure, the extension board design incorporates galvanic isolation between its circuitry and the Bluejay altimeter.

4.5.5 Battery System:

Avionics Power Supply system includes 4 batteries:

- **SRAD Battery:** 4S2P 16.8V 8000mAh LI-ION battery
- **CATS VEGA Battery:** 3S 1500mAh LIPO battery
- **Bluejay altimeter Battery:** 2S 600mAh LIPO battery
- **Bluejay Extension board Battery:** 3S 600mAh LIPO battery

The battery capacity was calculated to ensure a minimum of 6 hours of system operation without an external power supply.

Power Budget and SRAD Battery Calculations

Table 4.4: Flight Computer Power Budget

Component	Voltage [V]	Current	Nom. Power [W]	Peak Power [W]	Time [h]
BeagleBone	5.0	500 mA	2.50	5.00	6.00
Linecutter	14.4	5000 mA	72.65	72.65	0.003
3x DS18B20 (per unit)	3.3	3 mA	0.01	0.015	6.00
PCA9685PW,118	3.3	15.5 μ A – 10 mA	0.00005	0.033	6.00
24LC32AT-I/OT	3.3	1 μ A – 3 mA	0.000003	0.01	6.00
Recovery Servo	7.4	6000 mA	44.40	44.40	0.004
3x Camera	6.0	0.65 A	11.70	11.70	0.25
LSM6DSOXTR	3.3	0.55 mA	0.0018	0.0018	6.00
BME280	3.3	3.6 μ A – 0.7 mA	0.00001	0.0023	6.00
GPS	5.0	0.15 A	0.75	1.00	6.00
Radio	5.0	0.25 A	1.00	1.00	6.00
Total Energy [Wh]			28.74	45.56	

Table 4.5: Engine Computer Power Budget

Component	Voltage [V]	Current	Nom. Power [W]	Peak Power [W]	Time [h]
Main Servo	7.4	6000 mA	44.40	44.40	0.0005
Vent Servo	7.4	6000 mA	44.40	44.40	0.0005
PT5402	3.3	4 – 20 mA	0.045	0.066	6.00
LM324DR	5.0	0.96 – 1.2 mA	0.0048	0.006	6.00
PCA9685PW,118	3.3	15.5 μ A – 10 mA	0.00005	0.033	6.00
24LC32AT-I/OT	3.3	1 μ A – 3 mA	0.000003	0.0099	6.00
ADS7828EB/250	3.3	0.32 mA	~0.001	~0.001	6.00
3x DS18B20	3.3	3 mA	0.000003	0.0049	6.00
Dump Valve Servo	7.4	6000 mA	44.40	44.40	0.003
BeagleBone	5.0	500 mA	2.50	5.00	6.00
Igniter	7.4	5.24 A	10.00	39.00	6.00*
Total Energy [Wh]			21.16	37.07	

Table 4.6: Total Power Budget and 4S2P Battery Capacity Summary

Parameter	Nominal Condition	Peak Condition
Flight Computer Energy Demand [Wh]	28.74	45.56
Actuators & Ignition Energy Demand [Wh]	21.16	37.07
Total Energy Required [Wh]	49.90	82.63
Minimum Required Capacity (at 14.8 V) [Ah]	3.37	5.58
Battery Pack Specifications (4S2P)		Design / Available Value
Assumed Cell Specification	Li-ion (3.7 V, 4000 mAh)	
Pack Nominal Voltage [V]	14.8	
Pack Total Capacity [Ah]	8.00 (8000 mAh)	
Total Available Energy [Wh]	118.40	
Energy Safety Margin [%]	+137.3%	+43.3%

All inter-process and inter-CPU communication in the SRP platform uses SOME/IP (Scalable service-Oriented MiddlewarE over IP), an AUTOSAR-standardised protocol. Services expose two communication patterns: *methods* (request–response, analogous to remote procedure calls) and *events* (publish–subscribe, typically emitted on a fixed period or on state change). Service interfaces are defined as JSON files under `deployment/system_definition/` and processed at build time by the SRP platform code generator, which produces typed C++ skeleton (server) and proxy (client) classes.

Service	ID (dec)	ID (hex)	Host
EnvService	514	0x0202	EC
ServoService	515	0x0203	EC
PrimerService	516	0x0204	EC
FileLoggerApp	517	0x0205	EC
EngineService	518	0x0206	EC
GPSService	519	0x0207	FC
RecoveryService	520	0x0208	FC
MainService	521	0x0209	FC
SysStatService	522	0x020A	EC
FcSysStatService	523	0x020B	FC
EnvAppFc	529	0x0211	FC
RadioService	530	0x0212	FC
FcFileLoggerApp	531	0x0213	FC

Table 4.7: SOME/IP service identifiers

Service Registry

4.5.6 The Flight Control Algorithm

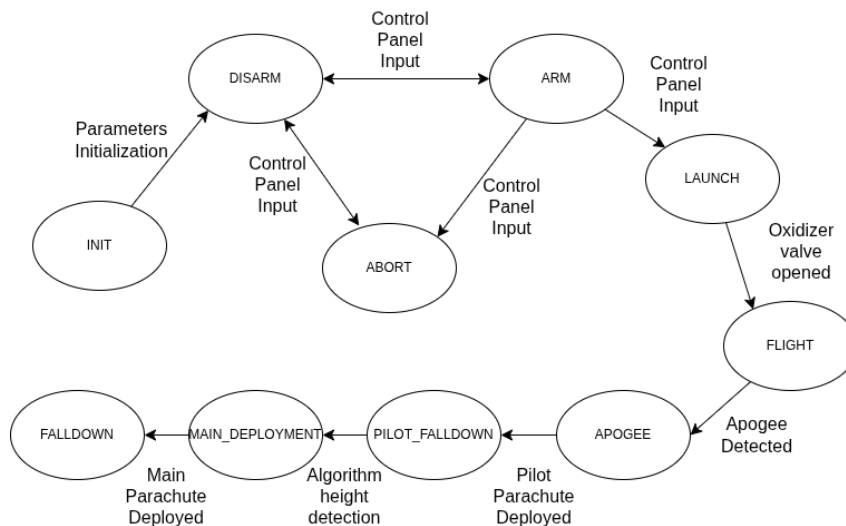


Figure 4.86: Rocket State Machine

The state machine illustrated in Figure 4.86 consists of several distinct states that govern the rocket's behavior during flight:

- INIT** The initial state after powering on. The system performs hardware self-tests, sensor calibration, and battery voltage checks. Once initialization is successful, the system automatically transitions to the **DISARM** state.
- DISARM** In this state, full telemetry and sensor data logging to the SD card is active. However, for safety reasons, all electrical power to the actuators is completely cut off, meaning all valves remain in their default closed positions. No physical actions can be triggered.
- ARM** Similar to the **DISARM** state regarding data logging and sensor readings, but power is now supplied to the actuators. This state enables ground operations such as propellant tanking and venting. It also serves as the final safety gate, allowing the launch procedure to be initiated.
- LAUNCH** This state initiates the ignition sequence. It immediately fires the igniter and, after a precise 1 s delay, opens the main propellant valve. Immediately after completing this timed sequence, the system automatically transitions to the **FLIGHT** state.
- FLIGHT** The rocket is in active flight. The flight controller continuously logs high-frequency telemetry and monitors inertial and barometric data. The system stays in this state until it detects that the rocket has reached its peak altitude (apogee), triggering a transition to the **APOGEE** state.

APOGEE Triggered at the exact moment of apogee detection. The system deploys the pilot parachute and immediately opens both the Vent Valve and the Dump Valve. Once these actions are executed, the state machine automatically advances to PILOT_FALLDOWN.

PILOT_FALLDOWN The rocket descends under the pilot parachute. The algorithm continuously monitors the current altitude until it drops below a pre-configured threshold, at which point it transitions to the MAIN_DEPLOYMENT state.

MAIN_DEPLOYMENT The system triggers the recovery mechanism to deploy the main parachute, ensuring a safe terminal descent velocity. After successful deployment, it moves to the final FALLDOWN state.

FALLDOWN The rocket continues its slow descent under the main parachute until touchdown. Sensor monitoring remains active to assist in recovery tracking until the vehicle safely comes to a rest on the ground.

ABORT A critical safety state that can be triggered at any moment prior to entering the LAUNCH state. Activating an abort immediately disarms the ignition logic, opens the Dump Valve to safely vent propellants, and safeties the vehicle. The only permitted path out of this state is a manual reset back to DISARM.

4.6 Ground Support Equipment

This section details the design, architecture, and implementation of the Ground Support Equipment (GSE) developed for sounding rocket operations, specifically tailored for the SimBa "R7 Orzeł" project. The primary objective of the GSE is to provide a complete, fully remote-controlled ground infrastructure essential for the safe preparation, fueling, and launch of the experimental sounding rocket. The ground segment is divided into three main subsystems (Fig. 4.87):

- Launch pad
- Mission control
- Radio communication network

The Launch Pad infrastructure encompasses the automated fueling system, mass measurement mechanisms, the decoupling system (decoupler), and the central launch pad control unit. Concurrently, the Mission Control Center integrates a physical control panel and a custom computer application to monitor all critical parameters and securely issue full remote commands to the system. Recently a long range radio receiver station was added to the Mission Control. The following subsections will provide a comprehensive overview of the hardware components, software architecture, and the communication protocols (including Ethernet, ROS2, and radio links) that ensure the stable, secure, and reliable operation of all GSE subsystems during the mission.

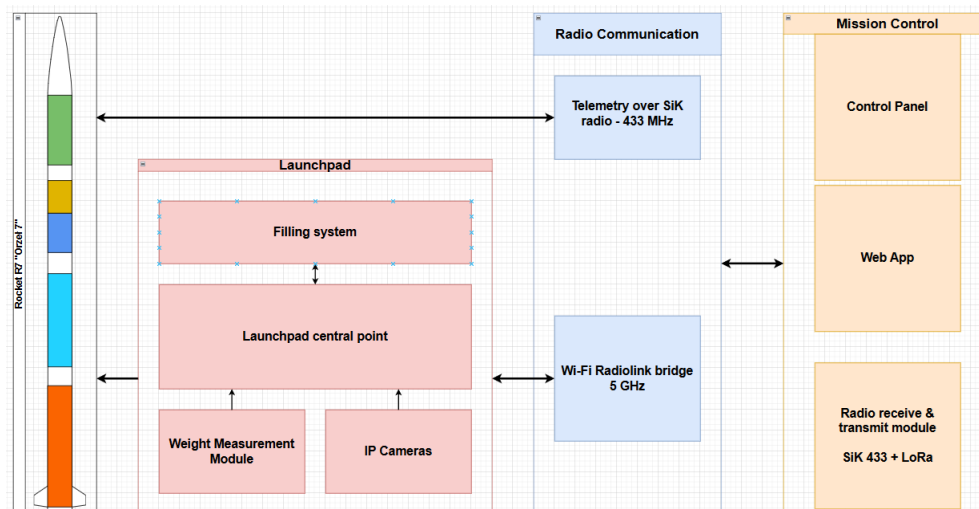


Figure 4.87: Ground Segment - high level diagram

4.6.1 Launchpad

The launchpad subsystem is responsible for remote-controlled oxidizer filling operations and real-time monitoring of the fueling process. All launchpad operations are performed remotely from Mission Control at distances of up to 1.5 km to ensure crew safety during tanking procedures.

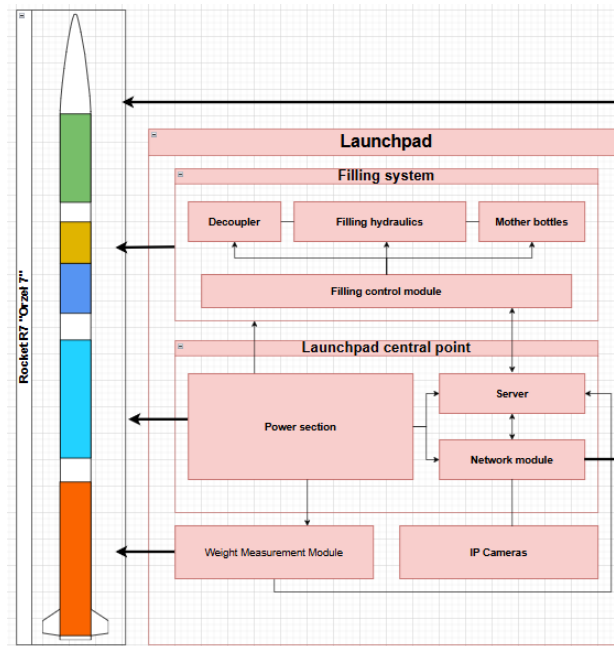


Figure 4.88: Ground Segment - level 2 diagram of the Launchpad

Filling system

The filling subsystem (Fig.4.91) is responsible for transporting oxidizer and pressurization gas from the source tanks to the rocket while enabling safe and controlled remote fueling operations. The system consists of high-pressure hoses, valves, vent lines, quick-disconnect fittings, sensor modules, and a dedicated control electronics module integrated into a modular V-slot frame structure.

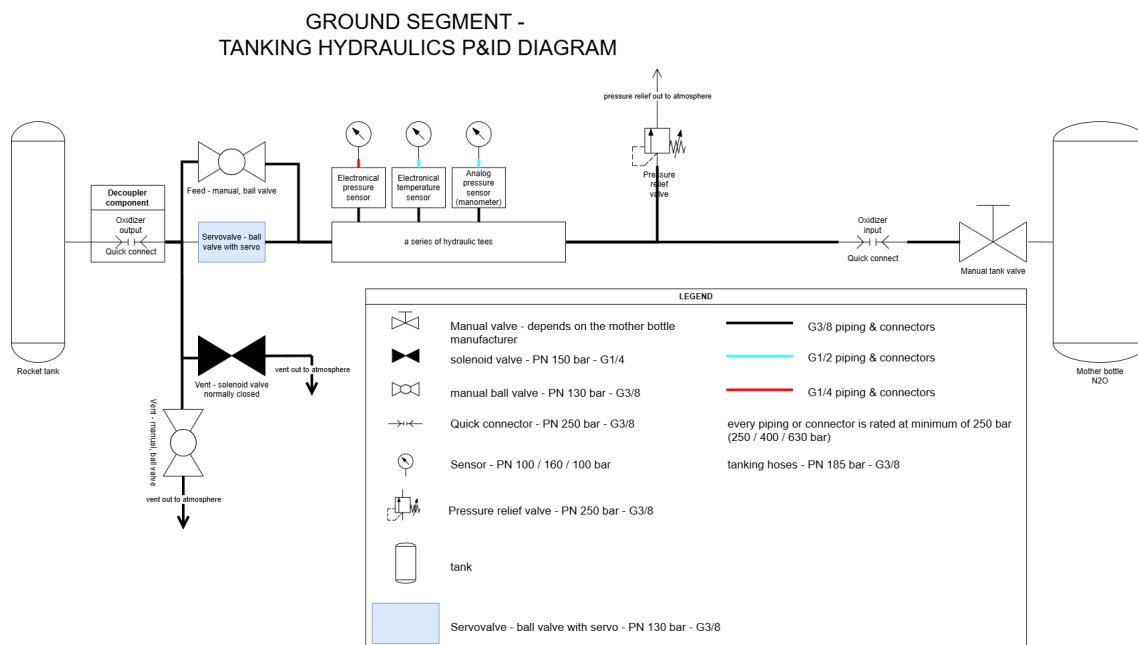


Figure 4.89: Hydraulics

All components were selected for compatibility with nitrous oxide operation and rated for high-pressure conditions, with the majority exceeding 200 bar pressure ratings. The installation includes dedicated filling and venting sections, remotely controlled and manual shutoff valves, pressure relief protection, and pressure and temperature monitoring for both local and remote supervision.

A microcontroller-based control module is responsible for receiving commands from Mission Control, actuating valves and disconnectors, acquiring sensor measurements, and continuously transmitting subsystem telemetry.

Safety logic includes automatic safe-state handling in case of communication loss and an emergency abort procedure capable of isolating and venting the system remotely. The complete subsystem was validated during static fire testing campaigns and enables fully remote fueling operations from distances up to 1.5 km.

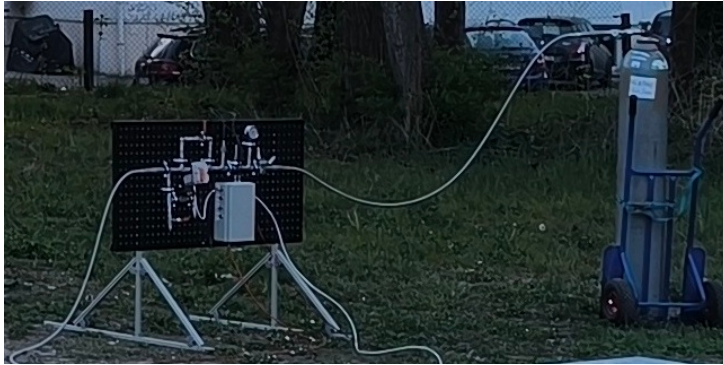


Figure 4.90: Filling setup



Figure 4.91: Filling hydraulics

Servovalve A custom servo valve subsystem (Fig.4.93) was developed as part of the rocket oxidizer filling infrastructure to provide remotely controlled flow regulation with integrated position feedback and emergency manual operation capability.

The system combines a chemically resistant ball valve rated for pressures up to 150 bar with a $46\text{ kg} \times \text{cm}$ servo mechanism capable of fully actuating the valve within approximately one second. To improve reliability and operational safety, closed-loop position feedback was introduced. A rotary potentiometer was selected over an incremental encoder because it provides absolute position information immediately after power-up without requiring recalibration.

A custom gear transmission was designed to match the angular ranges of the individual components: 90° for the valve, 180° for the servo, and 270° for the potentiometer. The gears and mounting plate were CNC laser-cut from aluminum sheets with thicknesses of 3 mm and 5 mm respectively. The assembly also includes a manual override mechanism enabling emergency valve operation and providing a direct visual indication of valve position.

The servo valve uses a modular GX16 5-pin interface carrying servo power, PWM control, potentiometer supply, feedback voltage, and ground connections. The housing was designed specifically for the assembly and manufactured using PETG 3D printing due to its improved thermal resistance compared to PLA. Electromagnetic interference protection was achieved using a shielded CAT7 S/FTP cable, while duplicated power conductors reduced voltage drop under peak servo current conditions. The final design forms a compact, modular subsystem that can be integrated into future iterations of the ground support equipment.

Decoupler

The decoupler (Fig. 4.94) subsystem provides rapid mechanical separation between the rocket and ground support equipment during launch or emergency procedures. The mechanism disconnects the hydraulic filling line together with attached electrical and signal interfaces.

The design is based on a quick-disconnect fitting integrated with two electrically actuated linear actuators controlled by the fueling control module. In the default state, the actuators keep the coupling mechanically locked. Applying reversed polarity retracts the actuators, releases the coupling sleeve, and initiates automatic separation. The actuators provide a significant force margin to ensure reliable operation under adverse conditions.

Following release, separation occurs passively due to gravity and internal line pressure acting on the quick-disconnect assembly. The detached assembly simultaneously disconnects attached electrical interfaces, including modified XT60 power connectors and signal connections.

The subsystem is controlled using a dedicated $\pm 12\text{V}$ interface and connected through an 8 m GX16-based cable harness. The mechanism was validated during both laboratory and field testing.

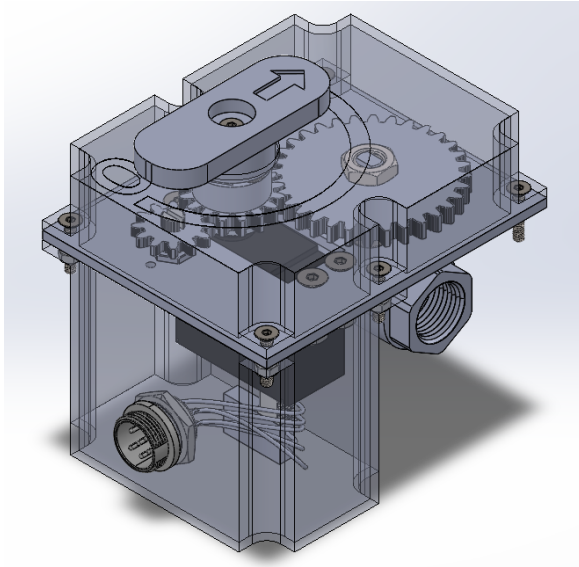


Figure 4.92: 3D Model: Servovalve

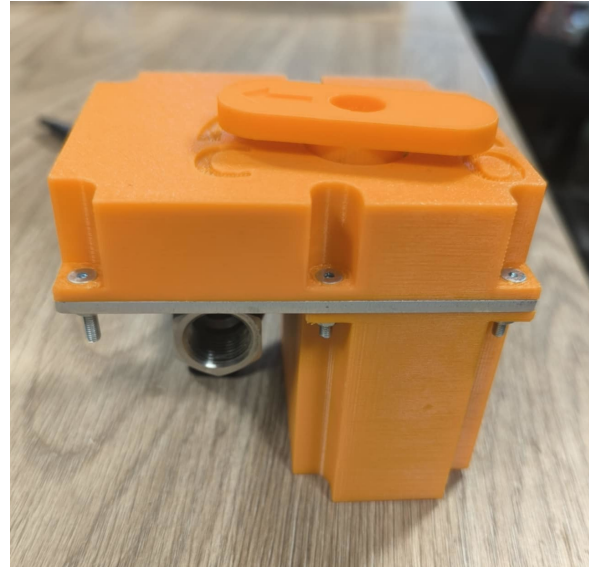


Figure 4.93: Servovalve

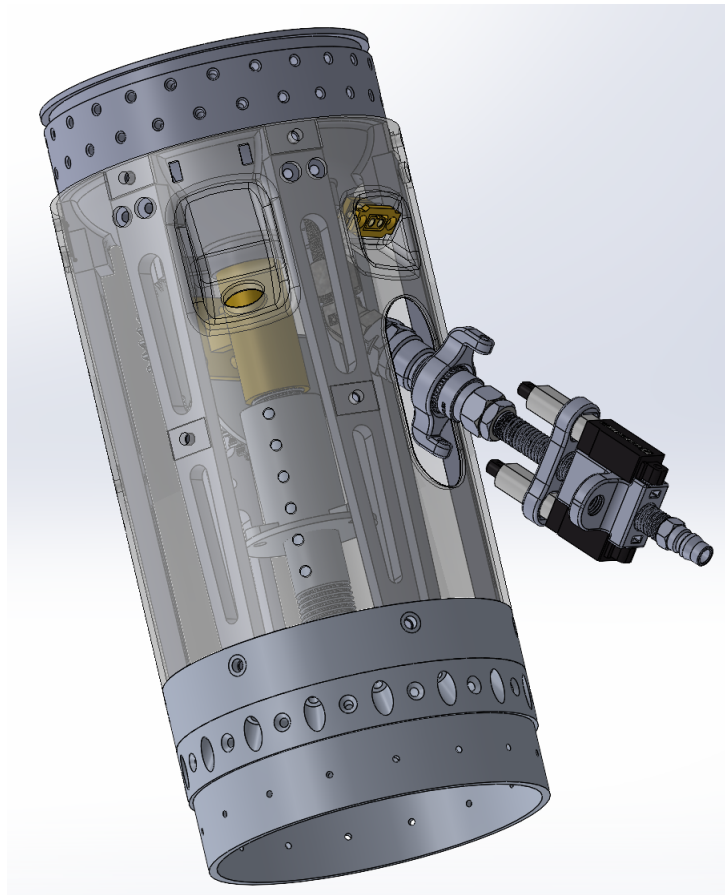


Figure 4.94: 3d Model: Decoupler locked into rocket's "feed" subsystem

Weight measurement module (WMM, pol. MPM) (Fig. 4.95) was developed to determine the rocket mass on the launch rail during fueling operations while withstanding harsh environmental conditions generated by the rocket exhaust plume. The system is designed for repeated operation with fully loaded vehicles exceeding 100 kg. The mechanical structure uses two load cells arranged in a load-sharing configuration, replacing the previously used single centrally mounted sensor. This approach increases measurement reliability and moves sensitive components away from the direct exhaust stream. The load cells are connected by a flat steel structural element oriented edge-

on relative to the exhaust flow to minimize thermal and mechanical exposure. Additional shielding protects the sensors, wiring, and electronics from high-temperature gases.

The electronics module consists of an Arduino-based acquisition system interfacing with dedicated load cell amplifiers. Raw sensor measurements are streamed to the launchpad central controller over the GSUART communication protocol, while calibration, taring, and launch rail inclination compensation are performed externally by the supervisory system.

Calibration tests performed using reference masses demonstrated good linearity of the measurement system. Calibration coefficients were determined using a least-squares fitting method, resulting in measurement accuracy within a few grams, significantly exceeding system requirements.

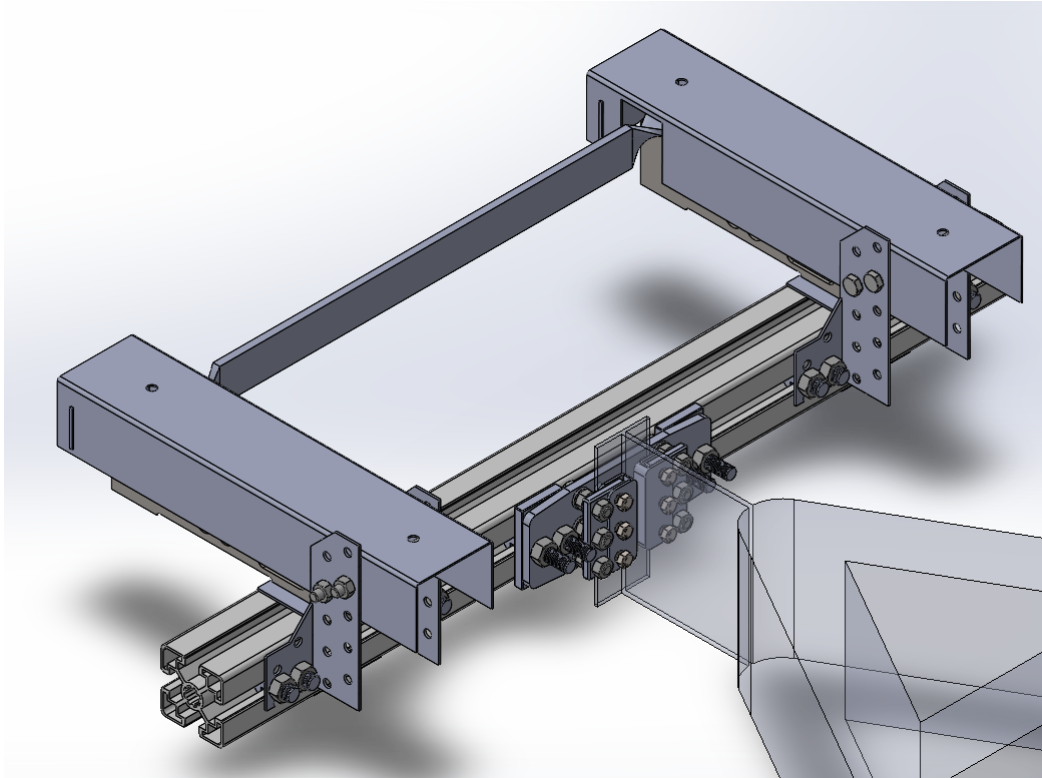


Figure 4.95: 3d Model: Weight measurement module

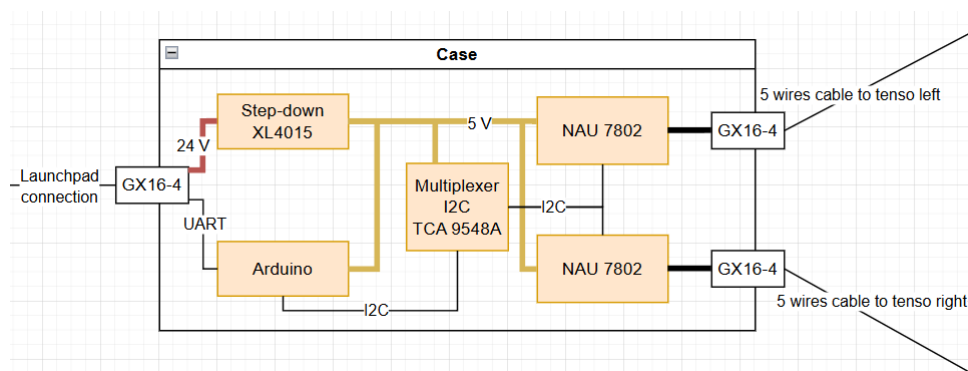


Figure 4.96: Diagram: Weight measurement module - electronics

Launchpad central point (Fig. 4.97) is the main integration hub of the ground segment in the launchpad area, responsible for power distribution, Ethernet communication, and centralized control of all subsystems. It interfaces with the Mission Control Center and exposes Ethernet, GSUART (GX16), XT60 power outputs, an emergency stop, and an IEC C14 AC input for external power or portable operation.

The power system ensures at least 6 hours of autonomous operation and supports both grid-based and off-grid deployment, where the primary off-grid solution is a Jackery portable power station that can additionally be recharged using photovoltaic panels. AC-to-DC conversion is handled by an HRP-300-24 switching power supply (110–240 V input range, compatible with both European and US standards), providing a regulated 24 V rail with built-in electrical protections. System safety is further ensured by circuit breakers and a master switch, while local voltage regulation is distributed across subsystem converters.

The network layer is based on a MikroTik router and TP-Link switch, forming the Ethernet backbone with PoE support for devices such as IP cameras. External communication is provided via a Wi-Fi radio link to Mission Control.

The server runs on a Raspberry Pi 4B with Ubuntu 22.04 and ROS2, hosting nodes that translate between ROS2 and GSUART and manage subsystem control. Key nodes include the mass measurement system (with tilt compensation and multi-level tare averaging), fueling system interface, and central point monitoring node aggregating power, PoE, and wireless link telemetry.

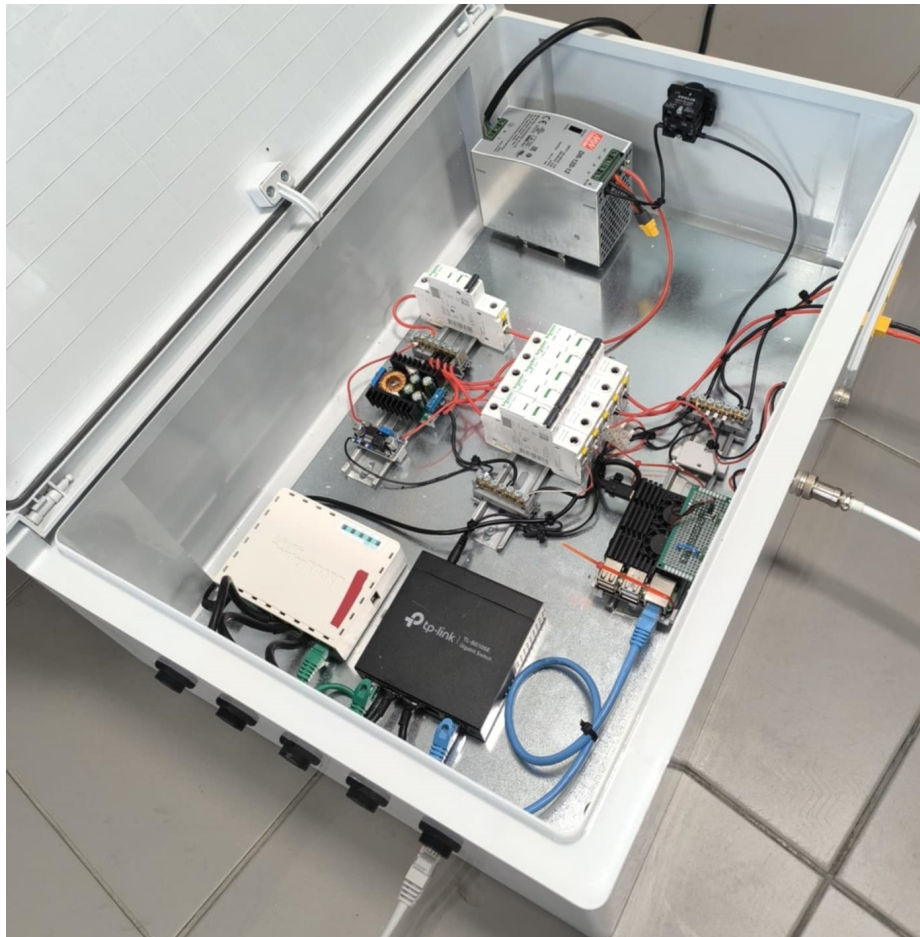


Figure 4.97: Launchbox - Launchpad central point

GSUART (Ground Segment UART - Fig. 4.98) is a custom link-layer protocol for inter-subsystem communication on the launch platform. Wired communication was selected over wireless (WiFi, Bluetooth) due to reliability requirements. Among wired options (Ethernet, CAN, RS485, I²C, SPI), UART was chosen as a minimal-overhead interface with native microcontroller support, eliminating external transceivers. Short-range buses (I²C, SPI) were excluded due to distance constraints (10–15 m). Tests over Cat7 S/FTP cabling showed stable UART transmission with PER $\approx$ 1 percent.

Physical implementation uses shielded twisted-pair Cat7 cabling. Three variants are defined: (1) full GSUART

1.0 with RX/TX plus power delivery over additional pairs (e.g., mass measurement system), (2) 1.0 simple with data-only RX/TX (e.g., fueling system), and (3) experimental 2.0 including additional power pair and single-ended shield termination for improved EMI robustness, not deployed due to preference for separated power routing. RX/TX lines are cross-connected for consistent port abstraction.

Frame structure includes start/end delimiters, payload, and 8-bit checksum (modulo-256 sum excluding delimiters). Byte stuffing is used to escape reserved control bytes within payload.

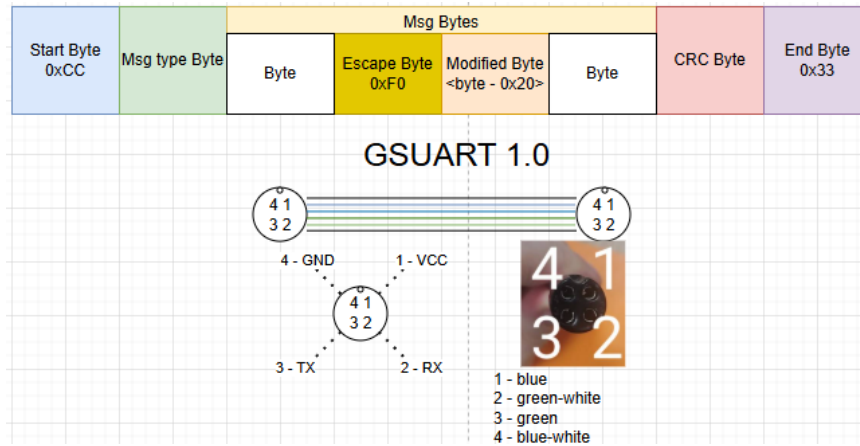


Figure 4.98: GSUART - overview



Figure 4.99: Hikvision IP Camera

IP cameras - the ground-based vision system is used for monitoring and documenting rocket fueling and launch operations. It is based on two Hikvision IP cameras (Fig. 4.99): DS-2CD1A43G0-IZU (fixed, high-resolution surveillance) and DS-2DE2C400MW-DE (PTZ camera for dynamic tracking). Both units are mounted on the radiolink mast to provide coverage of the fueling station and launch pad area.

Cameras are powered via PoE (Power over Ethernet), reducing cabling complexity and enabling combined power and data transmission over a single Ethernet link. Video streams are available in real time and integrated into the control application, which supports remote PTZ control and continuous recording. The system architecture allows additional IP cameras to be integrated in the future without changes to the underlying network infrastructure.

The recorded footage serves both operational and regulatory purposes, enabling post-flight analysis of fueling and launch events while also fulfilling competition requirements for ground-recorded video (minimum 1080p, 30 fps).

4.6.2 Mission Control

The Mission Control (MC) serves as the central command point of the ground segment as well as the rocket. Its primary task is the real-time aggregation of telemetry data, visualization of flight parameters, and providing a reliable interface for issuing control commands. To eliminate the limitations of previous monolithic versions of the system, the new architecture was designed to be highly modular and distributed. This enables simultaneous operation by multiple operators (multi-operator support) and ensures fault tolerance in case of individual component failures.

The system is divided into two main segments:

- **Control Panel** – a dedicated input/output device providing hardware control over critical procedures.
- **Server Application** – responsible for data processing, network communication, and the graphical user interface (GUI).

Control Panel

The physical control panel (Fig. 4.100) has been integrated into a secure, portable transport case and is based on the EuroRack mechanical standard, which facilitates servicing and potential reconfiguration of the modules. The computational heart of the panel is a Raspberry Pi 4B minicomputer, working in conjunction with an Arduino Mega 2560 microcontroller, which is dedicated to directly handling physical switches and buttons. Time autonomy and precise event logging without external network access are ensured by an RTC DS3231 real-time clock module.



Figure 4.100: Control Panel - Top View

The panel is divided into the following functional sections:

- **Power and Network Interface (1 & 2):** Offers a field power from a 7.4V LiPo battery or custom power supply (using an XT60 connector). Wired connectivity with the rest of the ground infrastructure is provided by an Ethernet (RJ45) port, seamlessly integrating the panel into the ROS2 (Robot Operating System 2) network.

- **Calibration and Diagnostics** (3 & 4): Equipped with dedicated buttons to operate the launch pad scale (taring the empty rocket and the oxidizer). Connection status, IP address, and database state are continuously displayed on a local OLED screen (1.3”).
- **Mission Abort Module** (5): A critical safety section equipped with an Emergency Stop (E-Stop) switch protected by a flip-up cover. Its activation immediately sends a request to depressurize and vent the tanks (via ROS2) alongside an abort command to the rocket’s onboard computer (via the MAVLink protocol).
- **Fueling and Launch Control** (7 & 8): Access to this section is hardware-locked using key switches. It enables the safe selection of the transferred medium, valve control, remote disconnection of the fueling hose (decoupler), and the final authorization of the launch sequence (Launch command).

Server Application

The software layer of the Mission Control Center has been optimized for low latency, high data throughput, and reliable offline operation during launch campaigns.

- **Frontend:** A lightweight web application created using the Svelte framework, chosen for its minimal memory and CPU overhead. The main Dashboard (Fig. 4.101) features dynamic SVG graphics visualizing the state of valves and fluid systems, advanced telemetry charts with data buffering, and a map module operating 100% offline. The frontend also integrates video streams from IP cameras, including support for PTZ (Pan-Tilt-Zoom) control.
- **Backend:** Built in Python using the asynchronous FastAPI framework. Communication with operator panels is executed via the WebSocket protocol in full-duplex. A key element of the backend is the Telemetry Bridge component, which acts as a translator and message broker between the MAVLink protocol (used by the rocket) and the ROS2 publish-subscribe architecture (used by the ground infrastructure).
- **Database:** To store rapidly changing telemetry data, a time-series database – InfluxDB, running in a Docker container, was utilized. This solution guarantees optimal performance for writing thousands of samples per second compared to traditional relational databases.



Figure 4.101: Main view inside the app

4.6.3 Communications

The Ground Support Equipment (GSE) utilizes a multi-layered communication architecture to ensure continuous command and control, reliable telemetry acquisition, and safe recovery of the R7 Orzeł. To manage different bandwidth and range requirements, the system is divided into three distinct links: a local WiFi network for launch pad infrastructure, a 433 MHz radio link for flight telemetry, and a LoRa link for recovery tracking. All data is routed to Mission Control and visualized for the team on the Main Control Panel.

Local Pad Infrastructure (Radiolink WiFi)

A Point-to-Point WiFi network connects Mission Control directly to the Launch Pad. The network is built on commercial off-the-shelf routers powered via PoE (Power over Ethernet) and configured to create a local bridge. This high-bandwidth link handles all ground-side data. It transmits pressure and temperature readings from the propellant tanks, sends actuation commands to the refueling valves from the physical Control Panel, and streams low-latency video from IP cameras mounted by the pad for visual verification.

Telemetry & Command Link (433 MHz Radio)

In-flight telemetry and critical vehicle commands are handled by a dedicated 433 MHz radio link. This frequency was chosen for its optimal balance of range and signal penetration. The system uses SiK Telemetry Radios. The ground station is equipped with a directional Yagi antenna to maximize signal gain, while the rocket utilizes a lightweight omnidirectional antenna. The radios utilize the MAVLink protocol, which natively handles data packet structuring and error rejection. To comply with local amateur radio regulations, the transmission power is capped at 20 dBm.

Long-Range Recovery (LoRa)

To ensure the vehicle can be safely located after touchdown, a secondary LoRa (Long Range) module is integrated into the system. Operating independently of the main 433 MHz radio, this low-power, low-bandwidth link transmits a signal with the rocket's final GPS coordinates, allowing the recovery team to track the R7 Orzel even in difficult terrain.

4.7 Payload

The R7 Orzel is designed to accommodate a 3U CubeSat form-factor payload within the designated Service Bay. The primary objective of the payload subsystem is to successfully transport mission packages to the target apogee while maintaining structural integrity and data acquisition capabilities. For the FAR-OUT 2026 competition, the integrated payload suite consists of an engineering payload provided by Apator Metrix and a custom outreach mass simulator.

4.7.1 Main payload: Apator Metrix device

The primary payload compartment houses an industrial gas meter provided by Apator Metrix S.A., serving as a commercial and engineering demonstration unit. This device is integrated into the R7 Orzel rocket as part of a strategic corporate partnership. By subjecting standard consumer gas measurement technology to the rigorous launch profile of the FAR-OUT 2026 competition, the project evaluates how internal mechanical and electronic components withstand severe mechanical stress, providing valuable telemetry data and structural feedback for civilian engineering applications.

4.7.2 Secondary payload: "Jebediah Kerman" High-G Test Pilot

For the rocketry enthusiasts our secondary payload requires no introduction. However, for the sake of official documentation: flying aboard the R7 Orzel is none other than Jebediah Kerman, the relentlessly optimistic veteran pilot from the Kerbal Space Program aerospace simulation game (Fig. 4.102).



Figure 4.102: Jebediah Kerman mascot

Included as a tactical morale booster and an homage to the digital roots of many modern rocket engineers, this bespoke mass simulator was custom-fabricated by the sister of one of our team members. Jebediah has been engineered to withstand extreme launch forces and will provide critical moral support to the avionics bay during the ascent profile.

- Height: 15 cm
- Width: 4 cm
- Mass: 50 g
- Material composition: High-density, energy-absorbing aerospace felt
- Planet of origin: Kerbin
- Certifications: Rockets, Space Shuttles, and surviving Rapid Unplanned Disassemblies (RUDs)

To ensure nominal flight operations and prevent our pilot from inadvertently causing a short circuit, Jebediah is securely tethered to the internal special seat presented on figure 4.103, ensuring he remains safely at his post through apogee and recovery.

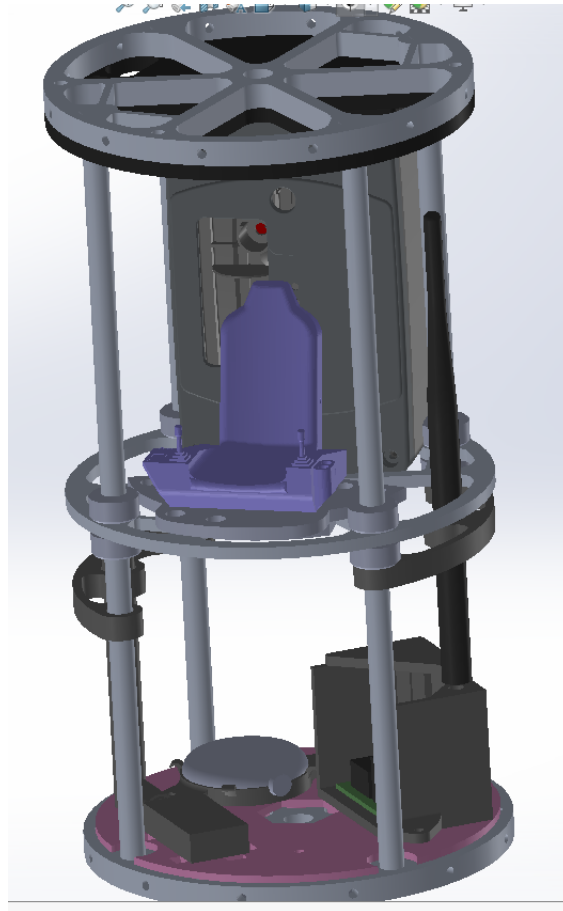


Figure 4.103: Jebediah Kerman seat in payload module

5 Simulation

Simulation is an important part of rocket design and construction. Before building and launching the rocket, it is crucial to understand how it will behave in the air. Simulation allows us to examine the rocket's projected flight parameters - such as altitude, speed and acceleration - as well as the factors that determine safety. The data gathered help us optimize the rocket's weight and ensure a safe recovery.

5.1 Open Rocket

OpenRocket is an open-source model rocket simulator. This software allows to build and simulate the flight of rockets. It is our main source of information regarding rocket performance.

The rocket model shown in (Fig. 5.2) is composed of eight segments: the nose cone, recovery section with parachute, service section, top radax, tank with brackets, bottom radax, motor and boat tail. Service section fits main on-board, electronics and payload. R7 main parameters are listed in Table 5.1, all parameters are in table E.1.

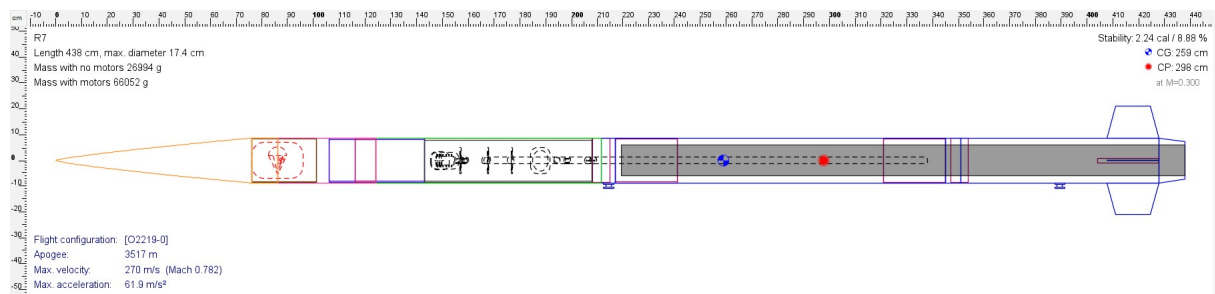


Figure 5.1: Structure of the rocket R7

Table 5.1: Model parameters in OpenRocket

Parameter	Value	
Rocket length	438,0 cm	172,44 in
The length of the body itself	351.8 cm	138.50 in
Rocket diameter	17.4 cm	6.85 in
The mass of the rocket with the engine	65762 g	2320 oz
Main chord length of the fin	20.3 cm	7.99 in
End chord length of the fin	13.6 cm	5.35 in
The length of the fin sweep	3.5 cm	1.38 in
Fin span	12.2 cm	4.8 in
Fin thickness	0,6 cm	0.24 in

5.1.1 Vertical Motion

The Vertical Flight Profile (Fig. 5.2) illustrates the simulated flight trajectory of the rocket. The plot shows changes of altitude, vertical velocity and vertical acceleration over time. Key phases can be distinguished:

- motor ignition to burnout, with rapid acceleration and reaching peak vertical velocity
- apogee, when the rocket reaches its maximum altitude
- drouge descent phase
- main parachute deployment
- ground hit

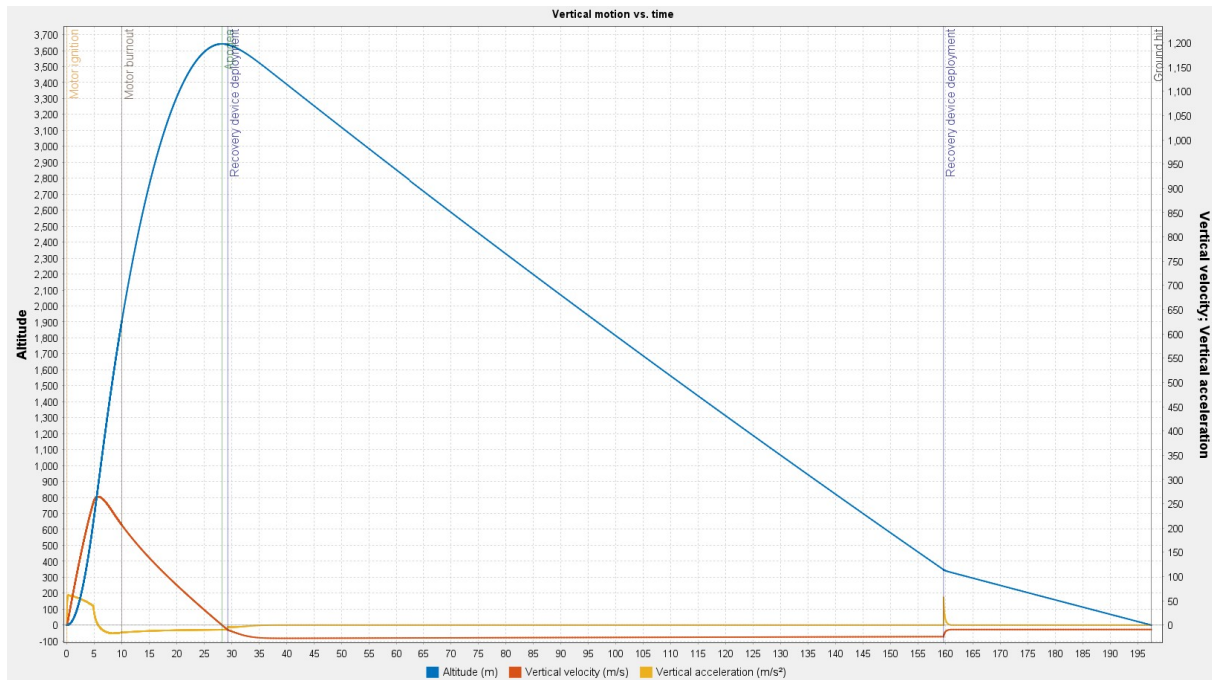


Figure 5.2: Vertical motion vs. time plot

As a result of the flight simulation performed on the prepared model (Fig. 5.2), the following results were obtained in Table 5.2

Table 5.2: Flight simulation parameters

Parameter	Value		Comment
Apogee	3642 m	11949 ft	
Maximum speed	272 $\frac{m}{s}$	892 $\frac{ft}{s}$	0.786 Mach
Maximum acceleration	62,3 $\frac{m}{s^2}$	204 $\frac{ft}{s^2}$	
Center of gravity (CG)	259 cm	102 in*	
Center of pressure (CP)	298 cm	117 in*	

*counted from the tip of the rocket

5.1.2 Center of Pressure and Center of Gravity

Center of Pressure is the point where lift and drag forces acting on the rocket are balanced. It is determined by the surface area and geometry of the rocket: the shape of the nose cone, body tube and, especially, the size and placement of the fins. Center of Gravity is the average location of the weight of the rocket. CP and CG plot is shown on Figure 5.3.

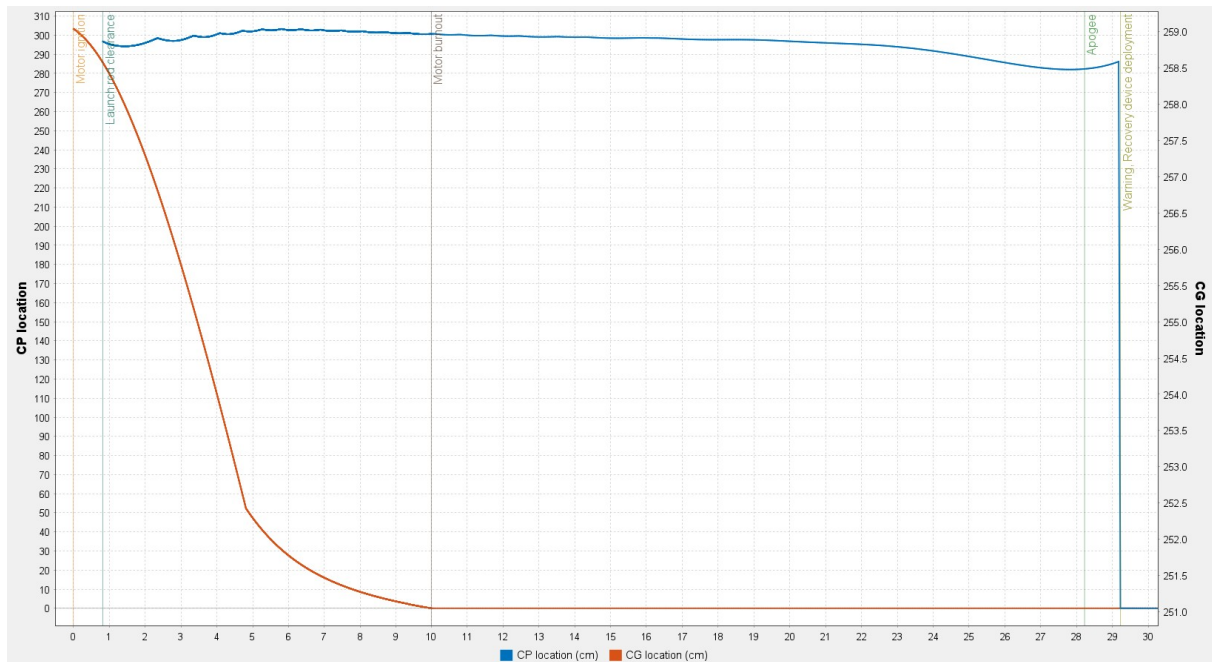


Figure 5.3: The CP location and CG position vs. time characteristics

5.1.3 Stability

Rocket stability determines whether a rocket flies straight or tumbles out of control. It depends on the relation between rocket center of gravity (CG) and center of pressure (CP). For a stable flight CG must be in front of the CP. The stability margin in calibers is calculated by dividing the distance between the CP and CG by the rocket diameter and expressing it as a multiple of calibers. Optimal stability is between 1 and 3 calibers. The stability of the R7 is within the assumed safe stability range throughout the flight (Fig. 5.4).

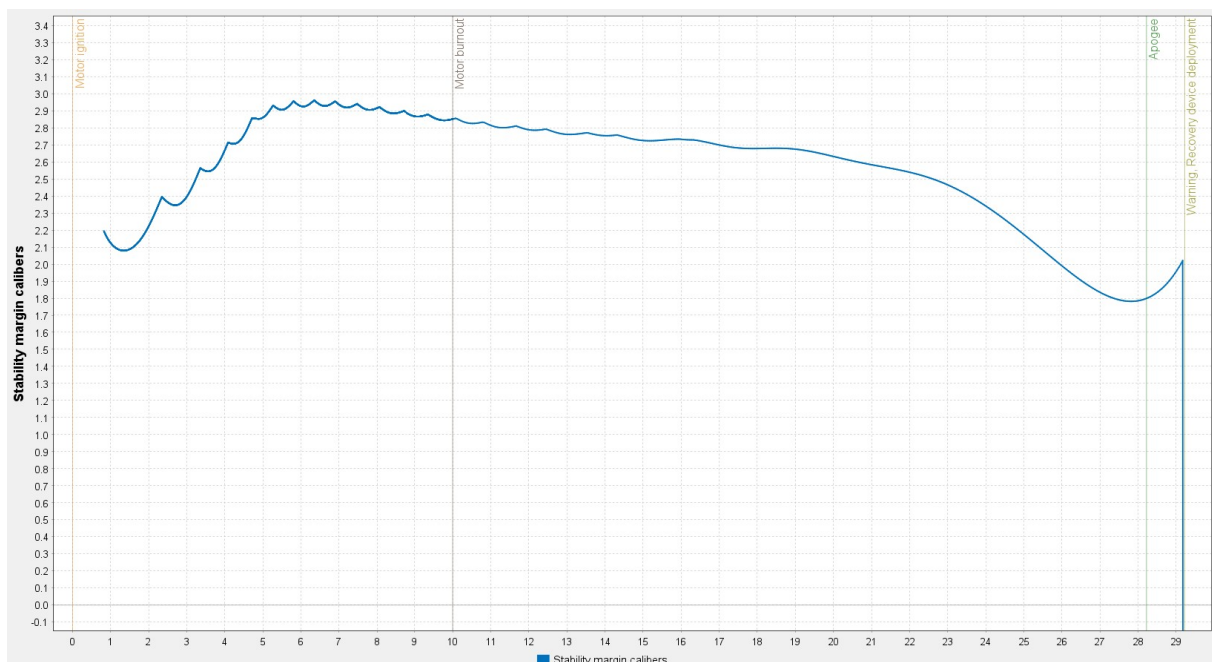


Figure 5.4: Stability margin vs. time characteristics

5.1.4 Angle of attack

Angle of attack is the angle between the rocket's nose and the actual oncoming airflow.

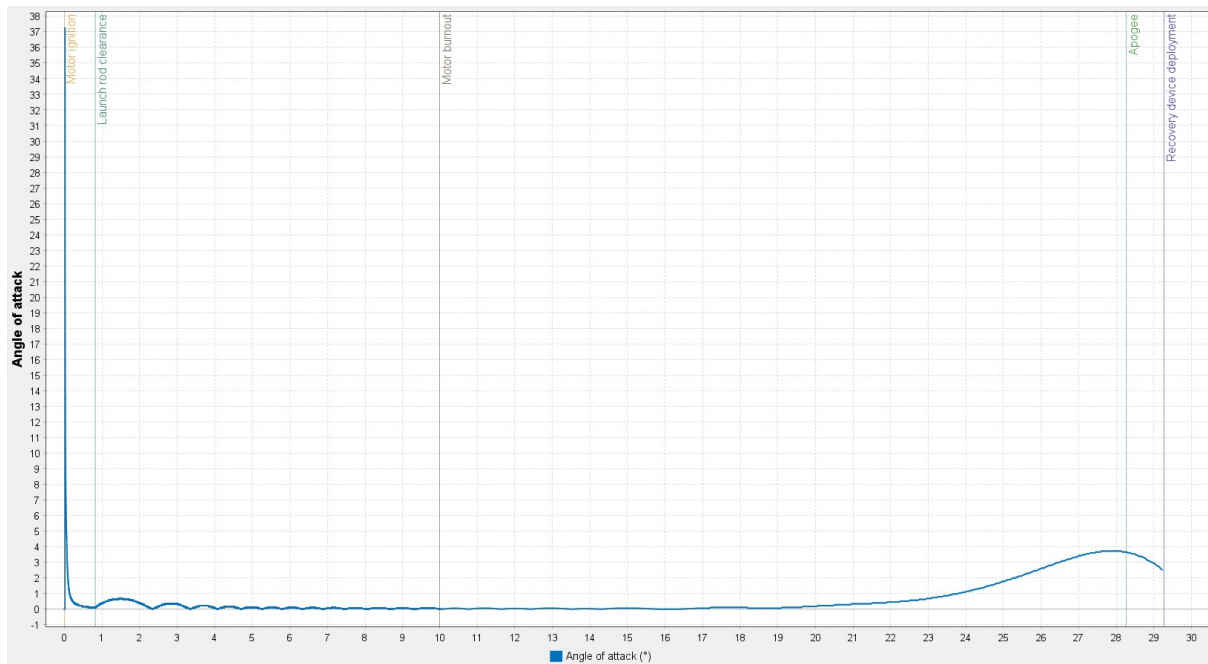


Figure 5.5: Angle of attack vs. time characteristics

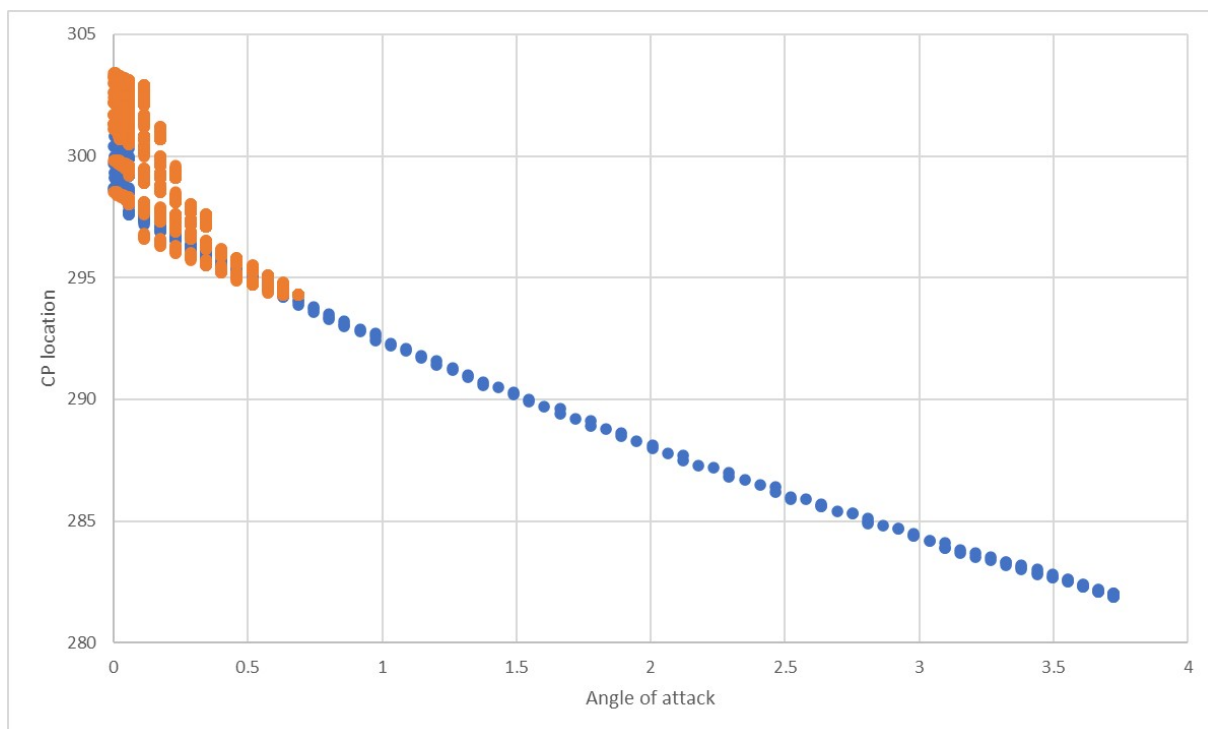


Figure 5.6: CP location vs. angle of attack characteristics

Angle of attack vs time plot (Fig. 5.5) shows R7 angle of attack during the ascent phase and cp location vs angle of attack plot (Fig. 5.6) illustrates CP location in function of angle of attack. This plot shows how the rocket's aerodynamic center changes as the angle of attack increases during flight. The orange points represents the first 10 seconds of powered flight, during which the motor is active and the rocket rapidly accelerates. These plots shows that rocket remains safely stable throughout its entire flight profile. The CP only shifts forward to 282 cm from the tip of the rocket, when CG is 259 cm from the tip.

5.2 RocketPy

RocketPy is a Python library, that allows for a six degrees of freedom simulation of a rocket's flight trajectory. This library allows to draw rocket representation highlighting the tank, fuel grains, nozzle, center of mass and center of pressure. Visualization of R7 Orzël is shown in Figure 5.7.

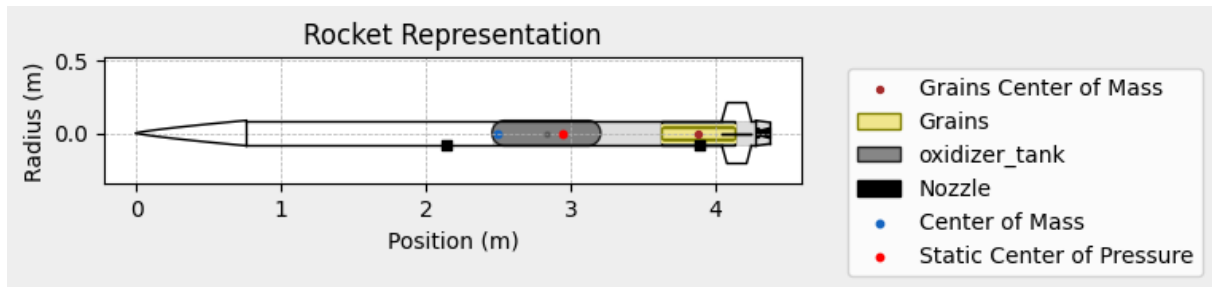


Figure 5.7: Structure of the rocket R7

5.2.1 Flight trajectory

Flight trajectory plot (Fig. 5.8) shows R7 flight direction during flight without wind. Flight parameters are listed in Table 5.3, rail departure state in Table 5.4 and apogee state in Table 5.5.

Flight Trajectory

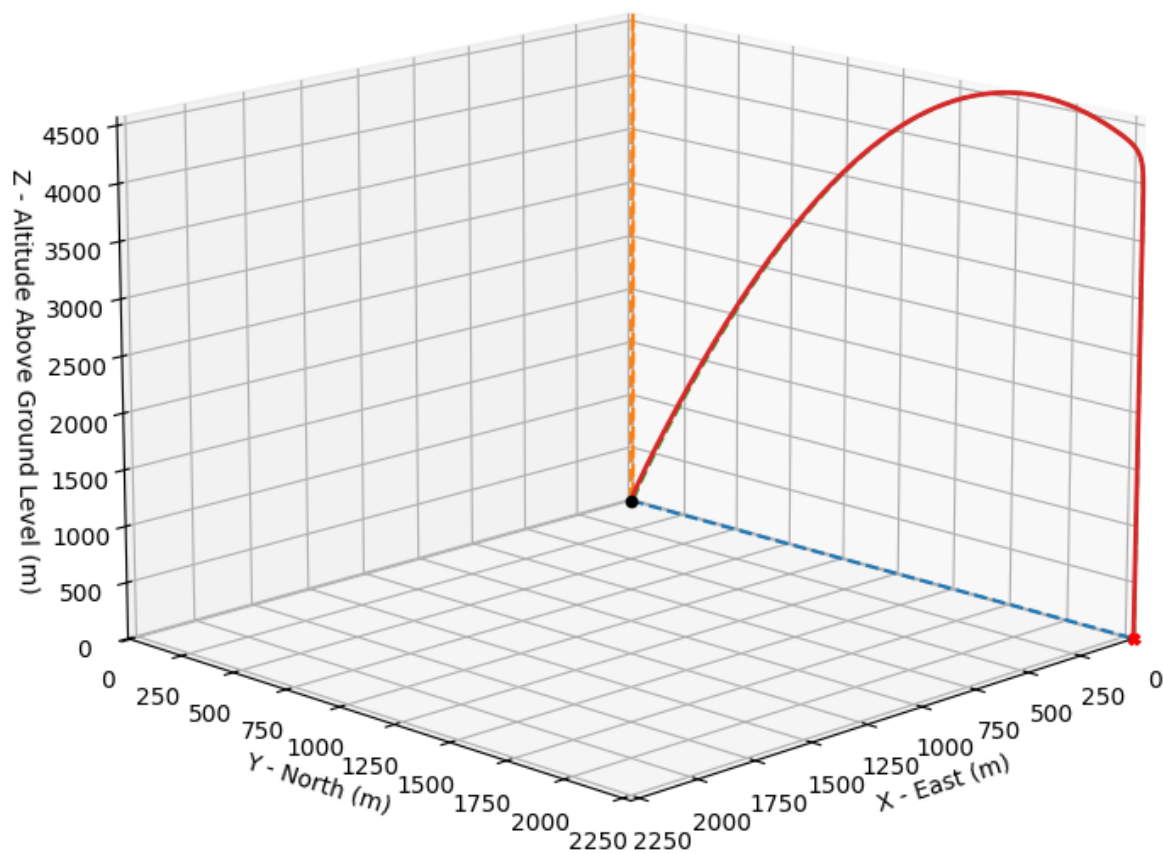


Figure 5.8: Flight trajectory the rocket R7

Table 5.3: Flight parameters in RocketPy

Parameter	Value
Rail length	18 m / 60 ft
Inclination	80°
Heading	0° (North)

Table 5.4: Rail departure state in RocketPy

Parameter	Value
Time	0.770 s
Velocity	44.217 m/s / 145.069 ft/s
Stability margin	2.774 c
Thrust-Weight Ratio	7.269

Table 5.5: Apogee state in RocketPy

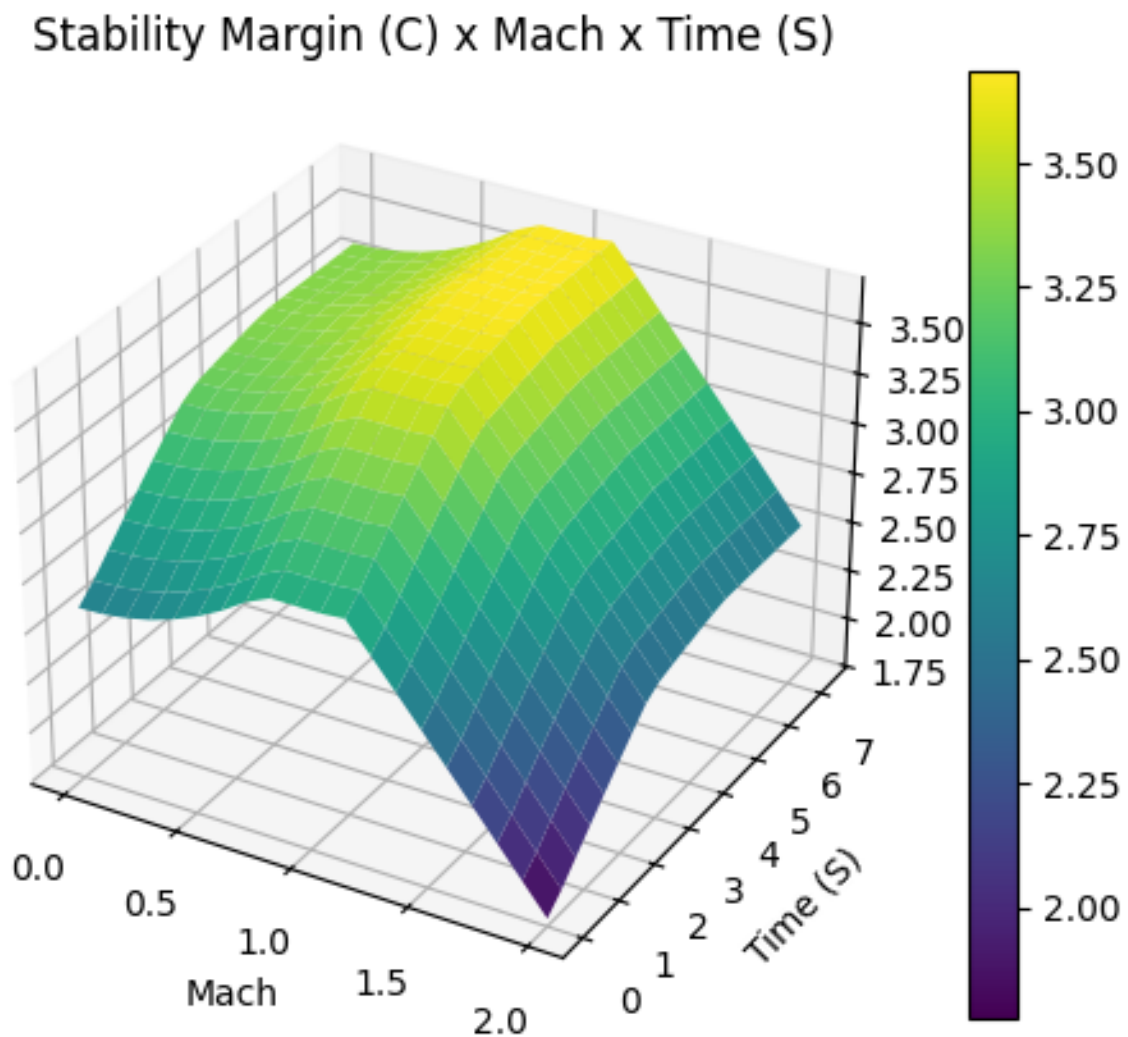
Parameter	Value
Time	32.120 s
Altitude	4570.920 m / 14996.460 ft
Freestream speed	56.932 m/s / 186.784 ft/s

5.2.2 Stability

Stability margin is a crucial parameter of rocket. It depends on a location of the CG (center-of-gravity) and the CP (center-of-pressure). Equation to calculate stability margin is given below.

$$\frac{CP - CG}{Diameter} = \text{Margin of Stability}$$

Figure 5.9 shows R7's Stability Margin vs Time vs Mach number and Figure 5.10 shows stability margin during flight.

**Figure 5.9:** Stability margin vs mach vs time plot

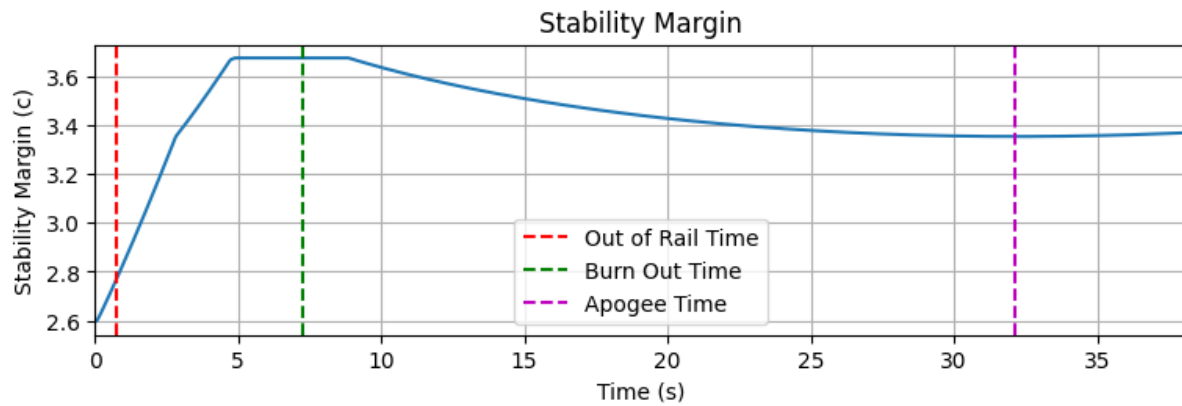


Figure 5.10: Stability margin during flight

When R7 leaves the launch rail, its stability is around 2.8 c, which is safe margin. During entire flight stability margin is between 2.6 and 3.7 calibers and increases sharply right after launch. These plots show that the rocket is highly stable.

5.2.3 Thrust

Thrust is the force that lifts the rocket off the ground and keeps it moving. Motor is providing thrust during powered flight, it causes acceleration and increasing drag. Average thrust for R7 Orzel is 3044.713 [N] and maximum thrust is 4667.222 [N] at 0.273 s after ignition. Thrust during the entire flight is plotted on Figure 5.11.

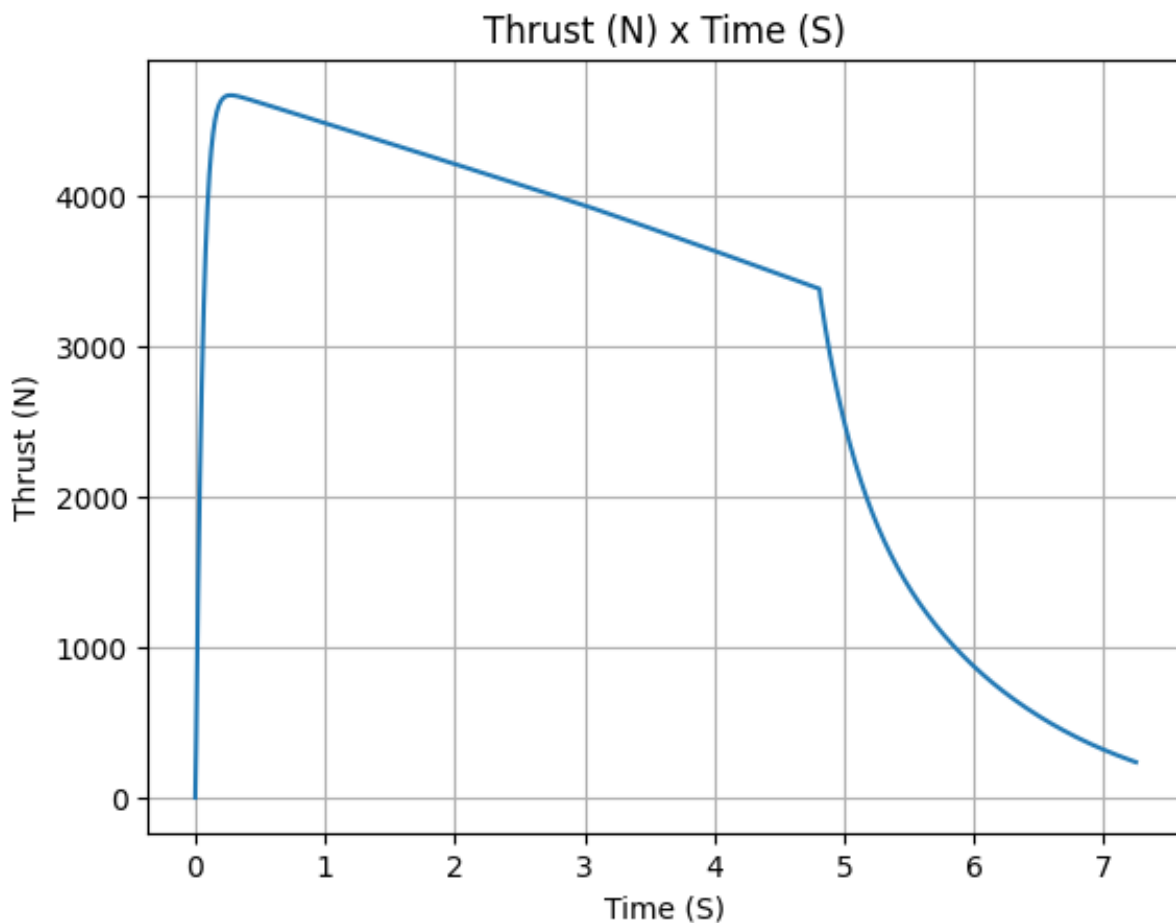


Figure 5.11: Thrust vs time plot

5.2.4 Velocity and acceleration

Profile of velocity and acceleration of the rocket during entire flight is shown in Figure 5.12.

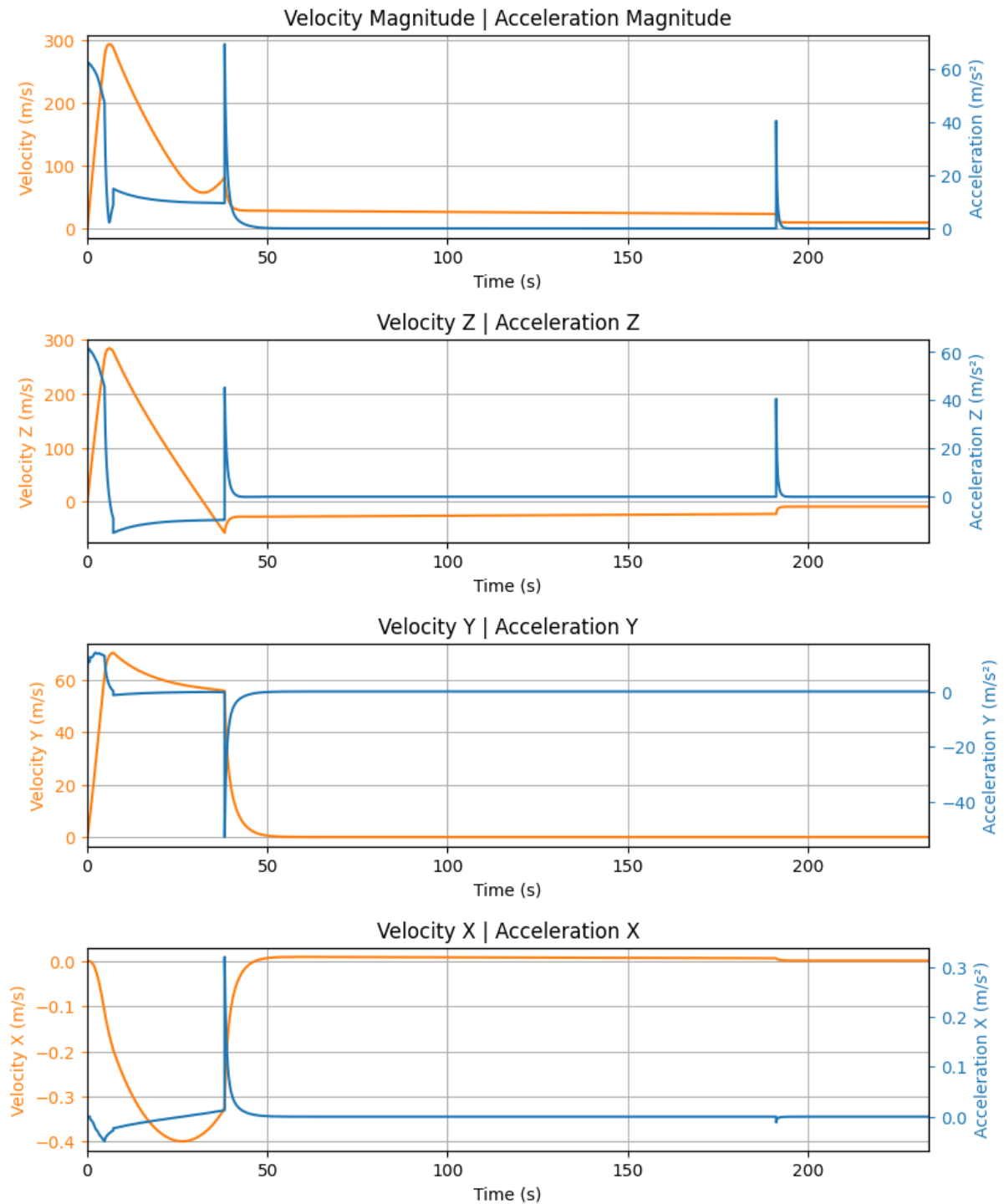


Figure 5.12: Velocity and acceleration plot

During launch and motor burn rocket instantly accelerate. Total velocity peaking at 295 m/s. After motor burnout, velocity starts dropping, because of gravity and drag. When rocket achieving apogee and the drogue parachute deploys velocity falling sharply.

5.3 RASAero II

RASAero Aerodynamic Analysis and Flight Simulation Software features simulation models with multi-stage capability. Can be used for various rocket types, accurately predicting aerodynamic coefficients across flight regimes from Mach 0.01 to Mach 25. Calibrated against NASA and wind tunnel data, it delivers professional engineering accuracy, with flight tests demonstrating an average apogee altitude error of just 3.47%. RASAero enables the plotting of graphs for—among other parameters—altitude, velocity, stability, CP, and CG over time.

5.3.1 Altitude

The altitude chart for R7 (Fig. 5.13) shows that the apogee will reach an altitude of 15,020 ft, which corresponds to 4,578 m and the entire flight will last approximately 220 seconds.

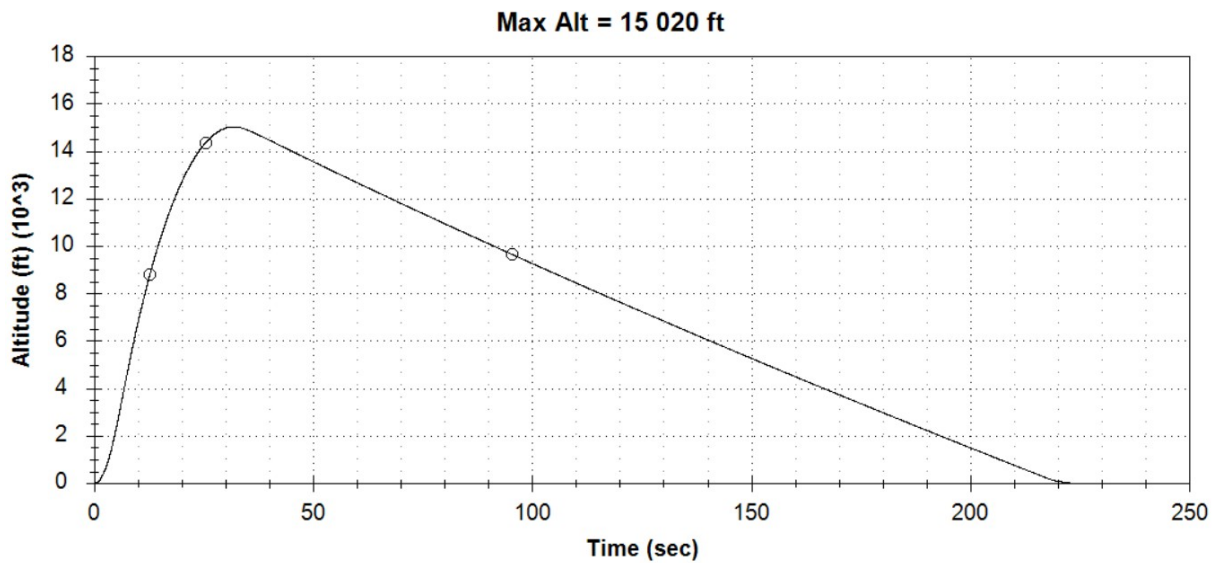


Figure 5.13: R7 altitude plot

5.3.2 Stability

Stability of the rocket depends on its center of gravity and center of pressure. Figure 5.14 shows CP and CG vs plot for R7 Orzel. Calculated stability is plotted in figure 5.15.

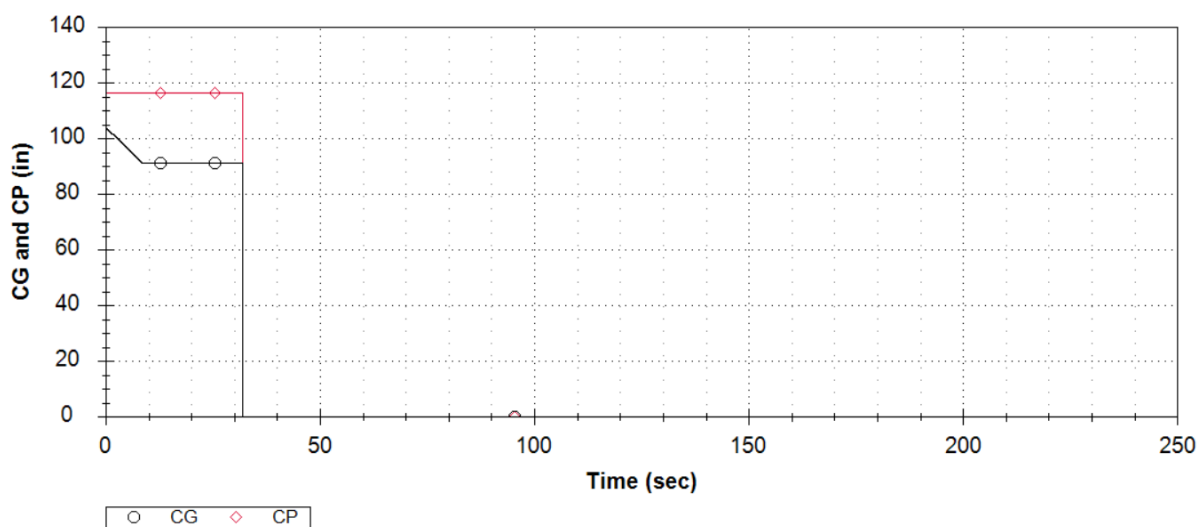


Figure 5.14: Center of pressure and Center of gravity vs time plot

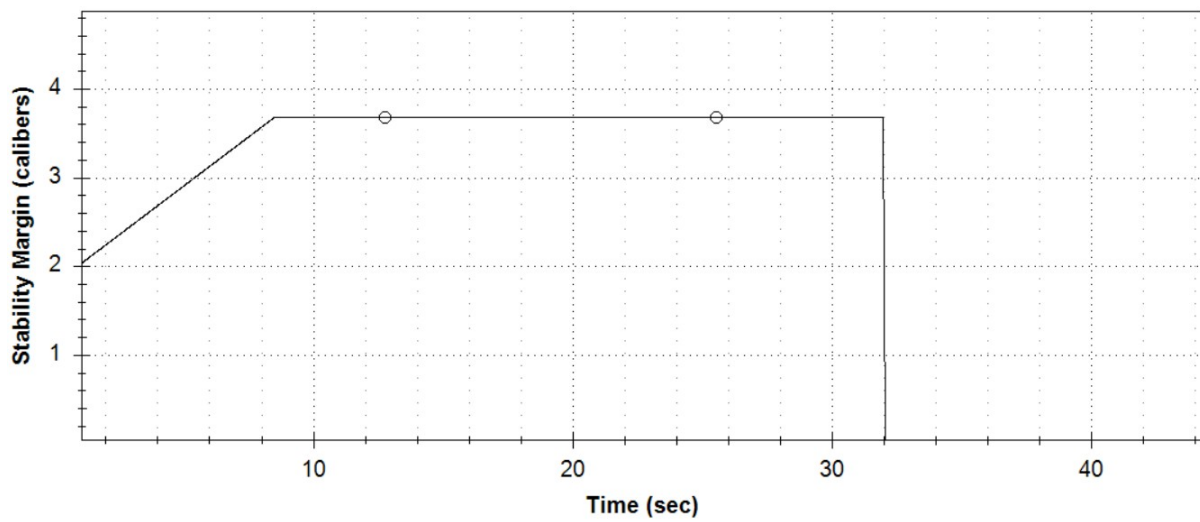


Figure 5.15: Stability Margin vs time

5.3.3 Velocity

RASAero provides information regarding total, vertical, and horizontal velocity. Velocity of R7 is shown on figure 5.16.

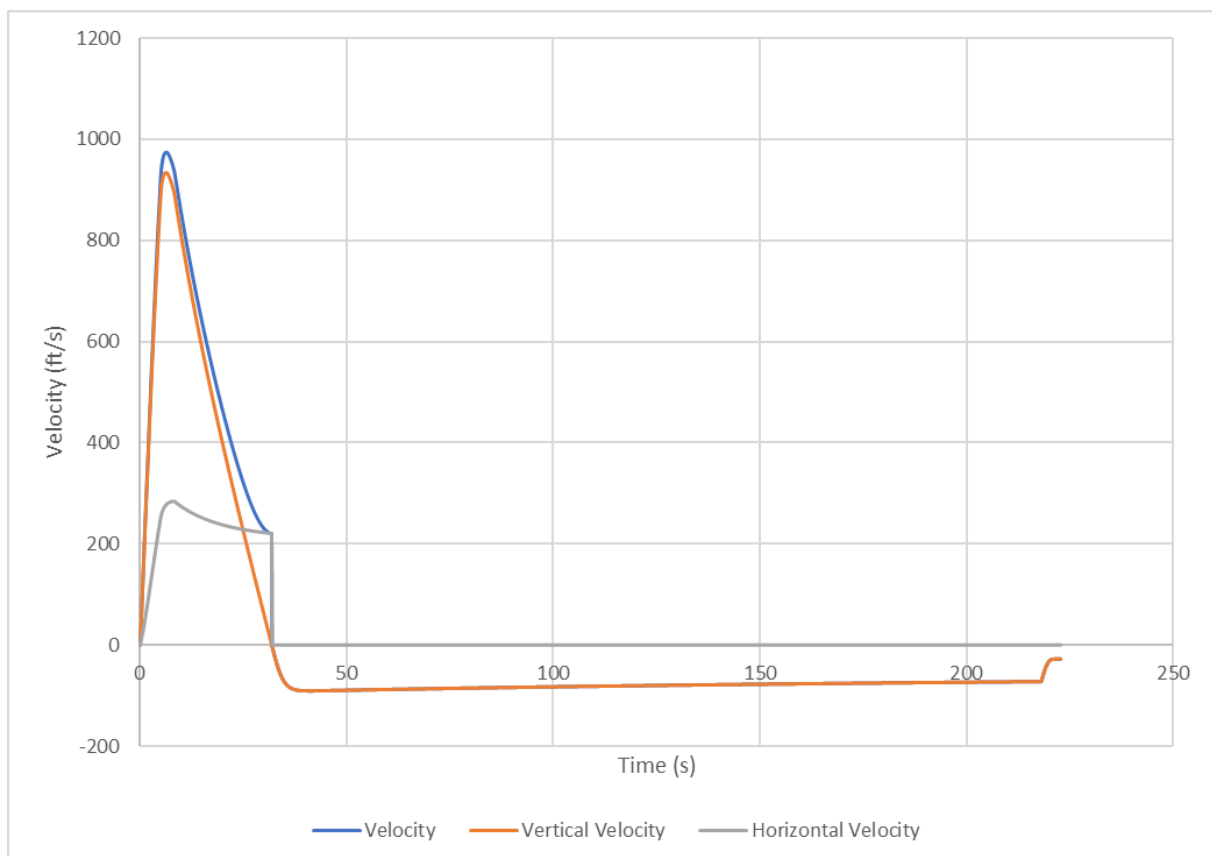


Figure 5.16: R7 velocity profile

6 Concept of Operations

The mission concept of operations (CONOPS) for the R7 rocket, developed for the FAR-OUT 2026 competition, is divided into six primary phases.

6.1 Rocket Preparation

Estimated duration (nominal): 30–60 minutes

Estimated duration (off-nominal): up to 2 hours

Start condition: Rocket segments and equipment delivered to the team setup area

1. Set up the workspace, including two 10x10 tents, foldable tables, and chairs to support assembly operations.
2. Assemble the rocket structure according to the vehicle integration checklists.
3. Connect all electronic systems following the Hardware checklist.
4. Secure all external cables and interfaces.
5. Perform final integration checks to verify mechanical, electrical, and system readiness.
6. Go through the safety check-in process.
7. Transport the fully-assembled rocket and GSE to the launchpad.

End condition: Fully assembled rocket and ground support equipment (GSE) transported to the launchpad

6.2 Site Setup (Green Flag Operations)

Estimated duration (nominal): 30–60 minutes

Estimated duration (off-nominal): up to 2 hours

Start condition: Fully assembled rocket and ground support equipment (GSE) transported to the launch pad

1. Deploy radio masts.
2. Set up the oxidizer tanking system and verify all connections.
3. Set up the control panel in the bunker.
4. Position the oxidizer mother bottle at the designated location and secure it.
5. Mount the Weight measurement module onto the launch rail.
6. The rocket is loaded onto the launch rail in a horizontal configuration.
7. Raise the rocket to a vertical position.
8. Connect the Decoupler between the rocket and GSE.
9. Remove SRAD systems safety pins in accordance with safety procedures.
10. Verify sensor readings and valve actuation.

End condition: Rocket ready to begin launch procedures

6.3 Launch Preparation (Yellow Flag Operations)

Estimated duration (nominal): 1–5 minutes

Estimated duration (off-nominal): up to 20 minutes

Start condition:

1. Remove COTS systems safety pins in accordance with safety procedures.
2. Open mother bottle valve

End condition: Vehicle ready to begin filling procedures

6.4 Launch Execution (Red Flag Operations)

Estimated duration (nominal): 5–10 minutes

Estimated duration (off-nominal): up to 40 minutes

Start condition: Range closure and red flag conditions declared

1. Arming of onboard and ground systems by a critical-badged rocketeer
2. Oxidizer fill according to Propulsion CONOPS
3. Ignition command and liftoff

End condition: Successful ignition and liftoff

6.5 Flight

Estimated duration (nominal): up to 3 minutes

Estimated duration (off-nominal): down to 2s

Start condition: Liftoff

1. Powered ascent
2. Unpowered ascent
3. Apogee
4. Reefed parachute deployment
5. Drogue descent
6. Unreefing
7. Parachute descent
8. Touchdown

End condition: Vehicle touchdown

6.6 Recovery

Estimated duration (nominal): 30–60 minutes

Estimated duration (off-nominal): up to 2 hours

Start condition: Vehicle touchdown

1. Tracking of the vehicle using telemetry and GPS data
2. Search and physical location of the rocket
3. Safing of all onboard systems
4. Transport back to the designated area
5. Go through the recovery check-in process.

End condition: Rocket safely retrieved and transported from the field

7 Conclusions and Lessons Learned

7.1 Technical Development and Testing

The development of the R7 Orzeł launch vehicle provided an invaluable learning experience for the SimBa team, emphasizing the critical importance of iterative testing and failure analysis. A major technical lesson stemmed from the manufacturing of the hybrid rocket's paraffin-based fuel grain. Initial attempts at gravity casting resulted in failures, specifically elevated grain porosity and internal cracking due to uneven solidification. Rather than abandoning the method, the team analyzed the failure and successfully mitigated the issues by introducing a vacuum degassing step and optimizing the fuel mixture, which greatly improved the reliability of the propulsion system. Additionally, structural design choices were heavily influenced by past failures. Experience with the previous R6 vehicle demonstrated that standard aluminum threads quickly wore down and failed after repeated assembly cycles. To resolve this, Helicoil inserts were implemented across all aluminum components, shifting the mechanical interface to steel-on-steel and significantly extending the lifespan of the hardware. The demanding environment of the FAR-OUT competition also drove the decision to replace traditional tube-in-tube couplers with custom Radial-Axial (RADAX) connectors, minimizing the risk of sand and dust contamination while simplifying field assembly.

7.2 Project Management and Corporate Knowledge Transfer

From a project management perspective, the R7 Orzeł campaign represented a critical recovery phase for the SimBa program. Following the 2023 campaign, the team experienced a massive attrition of senior personnel. Because rigorous documentation standards had not yet been fully institutionalized, this departure resulted in a severe loss of corporate knowledge, forcing the team to spend significant time reverse-engineering previous subsystems. To prevent such an event from occurring in the future, the team has instituted a strict mandate on technical documentation and knowledge transfer. The current management structure enforces operational discipline through the systematic archiving of CAD models, simulation data, and trade studies. Furthermore, we have established a strategic knowledge transfer pipeline: rising underclassmen are actively paired with senior subsystem leads to facilitate hands-on mentorship. This ensures that the complex intricacies of hybrid propulsion, composite lamination, and avionics architecture are continuously preserved and passed down to future generations.

7.3 Final Remarks

The challenges encountered during the design, manufacture, and testing of the R7 Orzeł have catalyzed significant engineering and organizational growth. Every setback served as a foundation for refining our approach, resulting in a highly capable hybrid sounding rocket that meets the rigorous safety and performance standards of the FAR-OUT 2026 competition. The lessons learned throughout this project have not only yielded a robust vehicle but have also established a resilient, sustainable engineering culture within the Gdańsk University of Technology's SimLE SimBa team.

Hazardous material	Handling	Storage procedure	Transportation	Mitigation approach	 Team
Nitrous oxide	Propellant. Gas under pressure. Avoid inhalation, cold burns, heat, flames, oil, grease, and combustible materials.	In a certified pressure bottle.	In a enduring, sealed, certified tank. Take care to ensure transport of the bottle in the cabin where people are not present.	In case of discharging - keep away from body parts. Handle the bottle carefully, as it contains compressed gas. Limit the number of people to the bare minimum.	Silnik
Igniters and flares	Pyrotechnic devices. Keep away from heat, sparks, flames, friction. Do not modify or disassemble.	Store in original packaging in a dry, locked, marked container.	Transport in protective packaging, away from fuels, oxidizers, batteries, and heat sources.	Install as late as practical. Keep ignition circuits inhibited until final arming.	Silnik
Paraffin wax	Combustible solid fuel. Avoid flames, sparks and inhalation of fumes during casting.	Store cool, dry place, away from heat, ignition sources, nitrous oxide.	Transport in protective packaging. Prevent deformation, contamination, and mechanical damage.	Inspect fuel grains for cracks, voids, chips, loose fragments, or contamination. Do not use damaged or contaminated fuel grains.	Silnik
Cotton phenolic liner	Low risk during normal handling. Machining may create irritating dust; use eye protection, gloves, and dust extractor.	Store dry and clean, protected from moisture, heat, flame, and mechanical damage.	Transport wrapped in bubble wrap to prevent cracking.	Machine with dust extraction. Clean dust after work and inspect parts for cracks, delamination, or overheating marks.	Silnik
Graphite	Machining can create irritating and potentially combustible dust. Avoid inhalation, sparks, and dust accumulation.	Store dry in a closed container. Protect parts from chipping.	Transport wrapped in bubble wrap to prevent cracking.	Machine with dust extraction and PPE. Inspect graphite nozzle for cracks and erosion before assembly.	Silnik
High-temperature red silicone	Uncured sealant may irritate skin, eyes, and airways. Use gloves, eye protection, and ventilation during curing.	Store in original sealed packaging.	Transport sealed and protected from crushing, puncture, and leakage.	After applying inspect seal quality and ensure no contamination of the sealing.	Silnik

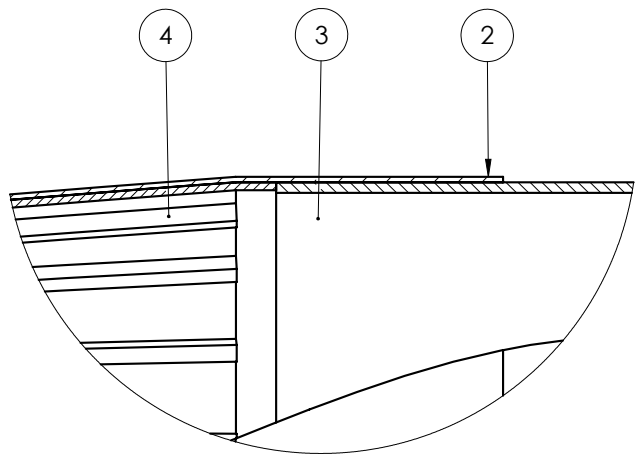
Risk	Consequence	🔍 Probability	🔍 Severity	Mitigation	Risk level	🔍 Team
Laptop malfunction	Simulations can't be performed.	Likely	Significant	Backup laptops with simulation software	Med Hi	Symulacje
Damaged RADAX surface/edge	Structure can't be assembled.	Likely	Severe	Adequate packing for shipping. Preparation for sanding.	High	Struktura
GSE wi-fi radiolink connection loss.	No remote control of tanking.	Unlikely	Severe	Prepare 100m of ethernet cable.	Med Hi	GS
BP charge igniter preemptive ignition.	Rapid nosecone ejection.	Very unlikely	Severe	Following the CONOPS properly.	Medium	Odzysk
Accidental damage of composite part.		Unlikely	Severe	Secure parts with foam cover (pool noodle). Bring composite repair kit.	Med Hi	Struktura
Laptop malfunction	Software cannot be maintained.	Unlikely	Minor	Backup laptops with linux.	Low Med	Software
Problem with downloading weather forecast.	No accurate simulation.	Very likely	Significant	Prepare simulation for the day in the morning.	High	Symulacje
Wiring disconnection between CATS Vega and CATS Vega Safety Pin	Complete loss of power to CATS Vega, resulting in total failure of its recovery systems (apogee black powder charge and linecutter deployment).	Possible	Significant	The module is located in immediate proximity to the CATS Vega unit and is secured within a dedicated housing. This integration, combined with high-reliability connectors, minimizes the risk of wire detachment from the CATS Vega WAGO terminal.	Med Hi	Hardware
Tearing/Mechanical failure of Safety Pin wiring	No impact on the power of the subsystems during flight.	Possible	Minor	Subsystems are designed as "Normally Powered". The safety pins are used exclusively for ground operations to pull MOSFET gates to ground, thereby disabling power for safety during pre-launch handling. If wires are torn, the gates will naturally float or be pulled high, maintaining the "Power ON" state.	Low Med	Hardware
Wiring disconnection between BlueJay and BlueJay XB	Upon reaching the 700ft threshold, BlueJay will be unable to transmit the deployment signal to the BlueJay XB module, failing to activate the resistance wire linecutter.	Possible	Significant	System-wide triple redundancy is implemented. Independent linecutter deployment capabilities remain active on both the CATS Vega and the MainBoard systems	Med Hi	Hardware
Wiring disconnection between BlueJay and the Black Powder Charge	Failure to deploy the parachute at apogee, leading to potential loss of the airframe upon impact.	Possible	Significant	Double redundancy of the recovery ignition system. The CATS Vega unit maintains an entirely independent ignition circuit and logic to trigger the black powder charge for parachute deployment.	Med Hi	Hardware
Electrostatic Discharge (ESD)	Irreversible damage to sensitive BeagleBone GPIO ports.	Unlikely	Severe	Implementation of dedicated ESD protection diodes (e.g., SM05-02HTG) on all communication interfaces and sensor connectors to suppress high-voltage transients.	Med Hi	Hardware
Mechanical failure of electrolytic capacitors due to high G-loads	Capacitors breaking off the PCB surface, leading to loss of power filtering and potential subsystem failure.	Possible	Significant	Mechanical stabilization and securing of large electrolytic capacitors using silicone to prevent vibration-induced fatigue.	Med Hi	Hardware
Electromagnetic Interference (EMI) from radio transmitters, CATS Vega, and high-current wiring	Signal corruption on the I2C bus, resulting in erroneous sensor data and failure to correctly identify apogee or the 700ft deployment altitude.	Possible	Significant	Implementation of low-value pull-up resistors (2.2 k) to enhance I2C bus noise immunity; use of shielded cabling for all servo and sensor interconnections to minimize cross-talk.	Med Hi	Hardware

Risk	Consequence	🔍 Probability	🔍 Severity	Mitigation	Risk level	🔍 Team
Desert dust contamination	Potential short circuits on PCBs	Unlikely	Significant	Execution of pre-flight diagnostics, electrical measurements, and subsystem integrity tests prior to launch to ensure operational readiness.	Medium	Hardware
Unintentional ignition of the black powder ejection charge	Accidental firing of the ejection charge on the ground	Unlikely	Significant	Implementation of 10k pull-down resistors on the gates of the ignition control MOSFETs to ensure they remain in a cutoff state and prevent activation.	Medium	Hardware
Connector disconnection during flight between PMS and MainBoard and EngineBoard	Complete loss of power of MainBoard and EngineBoard	Unlikely	Moderate	Implementation of connectors with mechanical locking mechanisms to prevent vibration-induced detachment.	Low Med	Hardware
Overheating of Li-Po and Li-Ion batteries	Reduction in peak discharge current performance and overall battery capacity.	Possible	Moderate	Selection of battery packs with high continuous discharge ratings and a capacity overhead ensuring over 6 hours of operation for each independent subsystem.	Medium	Hardware
Thermal shutdown of voltage regulators	Loss of power to critical actuators or logic	Possible	Significant	Continuous temperature monitoring using sensors placed directly to power regulation stages	Med Hi	Hardware
Main battery fuse failure	Complete power blackout of the SRAD system	Unlikely	Severe	Use of a 25A fuse providing a significant safety margin relative to nominal current draw; rigorous pre-flight verification of total system current consumption under peak operational load.	Med Hi	Hardware
Breakdown of the switching MOSFET in the PMS	Uncontrolled short circuit between the ground segment power supply and the onboard battery, leading to potential cell damage	Unlikely	Severe	Utilization of high current MOSFETs designed for power switching ; implementation of TVS diodes to protect MOSFET gates from high-voltage transients	Med Hi	Hardware
Reverse polarity at the battery input	Immediate destruction of PMS circuitry and a significant risk of battery fire.	Unlikely	Severe	Use of XT60 connectors to prevent incorrect battery connection; inclusion of dedicated protection diodes to block reverse-current flow	Med Hi	Hardware
Contact bounce on the Safety Pin input line	Unintended power state transitions (ON/OFF) for Stage 0 and Stage 1 subsystems	Possible	Significant	Integration of RC filters to stabilize MOSFET gate voltages against contact bounce ; application of "Active Hight" control logic using drivers to ensure a stable and reliable power	Med Hi	Hardware
The battery pack breaks loose because of the high G-force during takeoff.	The loose battery flies around inside the avionics bay and damages other subsystems	Possible	Significant	The battery pack is secured inside a rigid, custom-designed enclosure that is bolted directly to the rocket's metal structural frame. This ensures mechanical stability and prevents any displacement or movement during high-G acceleration.	Med Hi	Hardware
Hydraulic system leakage	Loss of pressure or flow control, reduced engine performance, uncontrolled oxidizer release.	Possible	Significant	Perform leak checks before each test and launch; use pressure-rated fittings and seals compatible with nitrous oxide; use checklists; monitor pressure during filling and operation.	Med Hi	Silnik
Burn-through of thermal insulation	Hot gases may damage the combustion chamber or surrounding structure, causing loss of pressure, fire, or structural failure of the engine.	Unlikely	Significant	The insulation wall thickness shall be verified during a hot-fire static test. The insulation wall thickness shall be verified during a hot-fire static test. Stepped joints shall be used to prevent fire getting into contact with aluminum surface.	Medium	Silnik

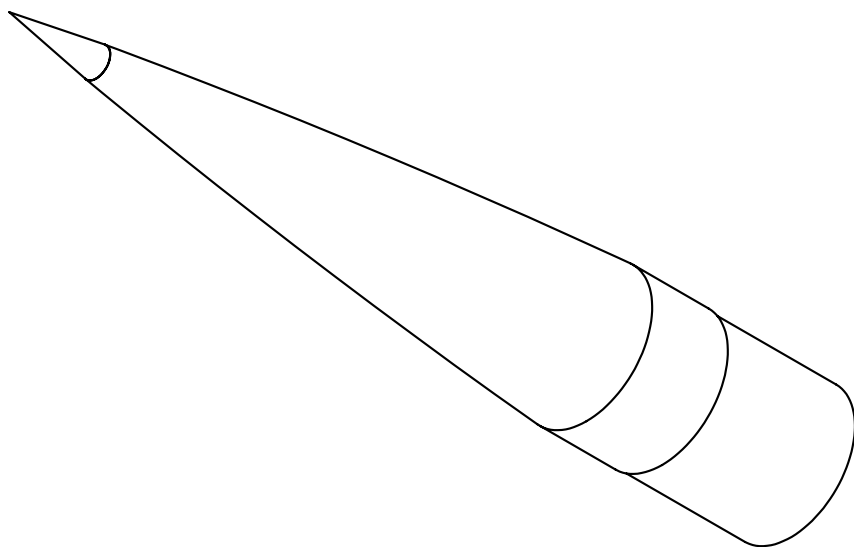
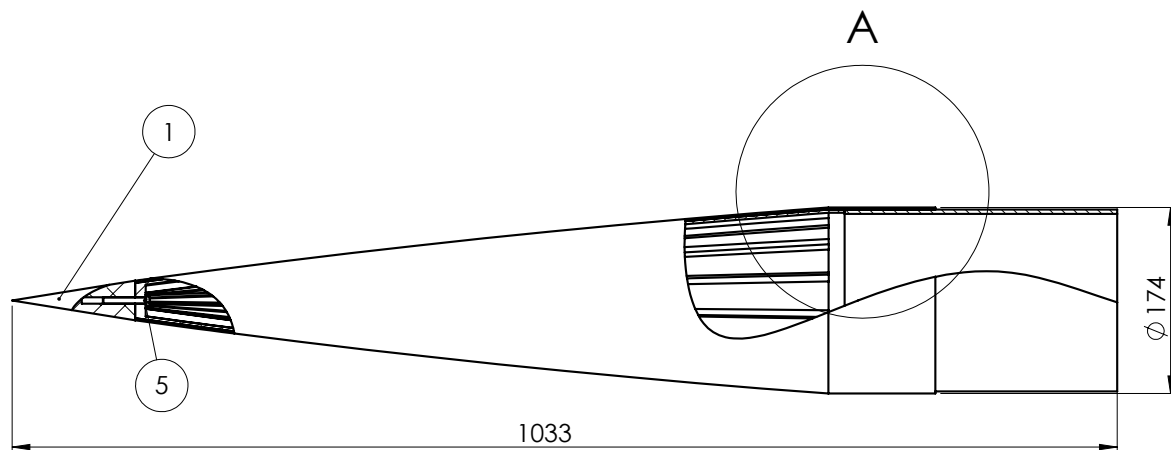
Risk	Consequence	🔍 Probability	🔍 Severity	Mitigation	Risk level	👤 Team
Oxidizer tank explosion during F2F time	Pressure tank rupture, rapid nitrous oxide release, injury.	Very unlikely	Moderate	Fill only using a checklist and remote operation; use pressure-tested components, relief devices, and controlled venting; keep personnel outside venting zone; continuously monitor tank pressure and temperature; stop filling if limits are approached.	Low Med	Silnik
Stripped thread in tank cap/combustion chamber	System is not safe to pressurize; threaded joint may fail under pressure or vibration, causing leakage or structural separation.	Likely	Significant	Replace or repair the damaged threaded interface; install qualified HELICOIL inserts.	Med Hi	Silnik
Damaged fuel grain.	No launch or unstable combustion if damage is not detected; cracks or broken fuel may cause lowering regression and thrust instability.	Unlikely	Significant	Transport the grain in a protected way; inspect it before installation; bring a spare fuel grain to the launch site.	Medium	Silnik
Nozzle fracture	Loss of chamber pressure, hot gas leakage.	Unlikely	Severe	Inspect the nozzle for cracks, erosion, and impact damage before assembly; protect it during transport; use checklists during assembly.	Med Hi	Silnik
Catastrophic failure of hybrid engine during startup	Rapid engine disassembly, blast, fragments, fire, damage to test stand or rocket, and possible severe injury.	Unlikely	Severe	Use remote startup, perform leak tests and hot static fire tests to ensure reliability of the engine.	Med Hi	Silnik
Catastrophic failure of hybrid engine during ascent phase	Rocket breakup, uncontrolled trajectory, fire at impact, total mission loss, and risk to property.	Unlikely	Severe	Check structure; use launch-site safety distances and officials approval; monitor telemetry; launch only under approved weather and range conditions.	Med Hi	Silnik
Explosion of oxidizer tank during filling operations	Sudden nitrous oxide release, pressure blast, fragments, cold-gas injury, fire intensification.	Unlikely	Severe	Keep all personnel clear while the oxidizer system is pressurized; vent to a safe outdoor location; include in your project burst disc, manual relief valve and dump valve; monitor pressure and temperature continuously; perform filling only by trained operators following a checklist.	Med Hi	Silnik
Main valve closing after launch, causing engine to stop	Loss of thrust during ascent, unstable trajectory, failure to reach safe altitude, possible crash, debris hazard, and mission loss.	Unlikely	Severe	Test servomechanism power and command logic before launch; protect valve wiring from disconnection; monitor valve status where possible.	Med Hi	Silnik

C Engineering Drawings

C.1 Structure



DETAIL A
SCALE 1 : 2



No.	NUMBER	TITLE	QTY.
5	DIN EN 24014 - M6 x 40 x 18-N		1
4	R7_STR_1203_NoseconeLaminationBase	Printed Base	1
3	R7_STR_1201_NoseTube	Nose Tube	1
2	R7_STR_1200_NOSEBODY	Nose Body	1
1	R7_STR_1100_TIP	Tip	1

UNLESS OTHERWISE SPECIFIED,
ALL DIMENSIONS ARE IN
MILLIMETERS

GROUP
AEROSTRUCTURE



WEIGHT
kg

MATERIAL

TITLE
Nosecone

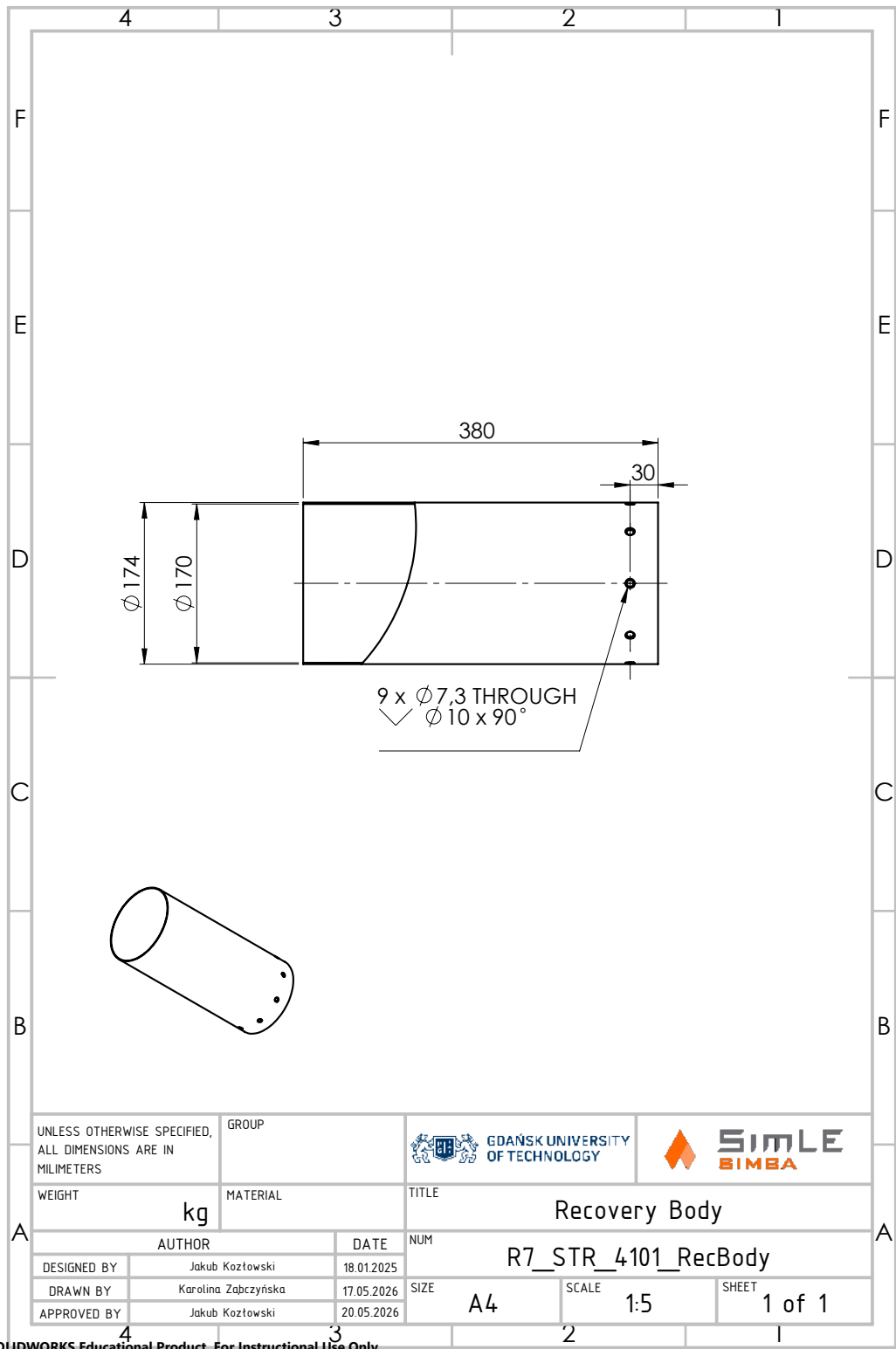
AUTHOR
DESIGNED BY Antkowiak-Kozłowski-Zabczyńska

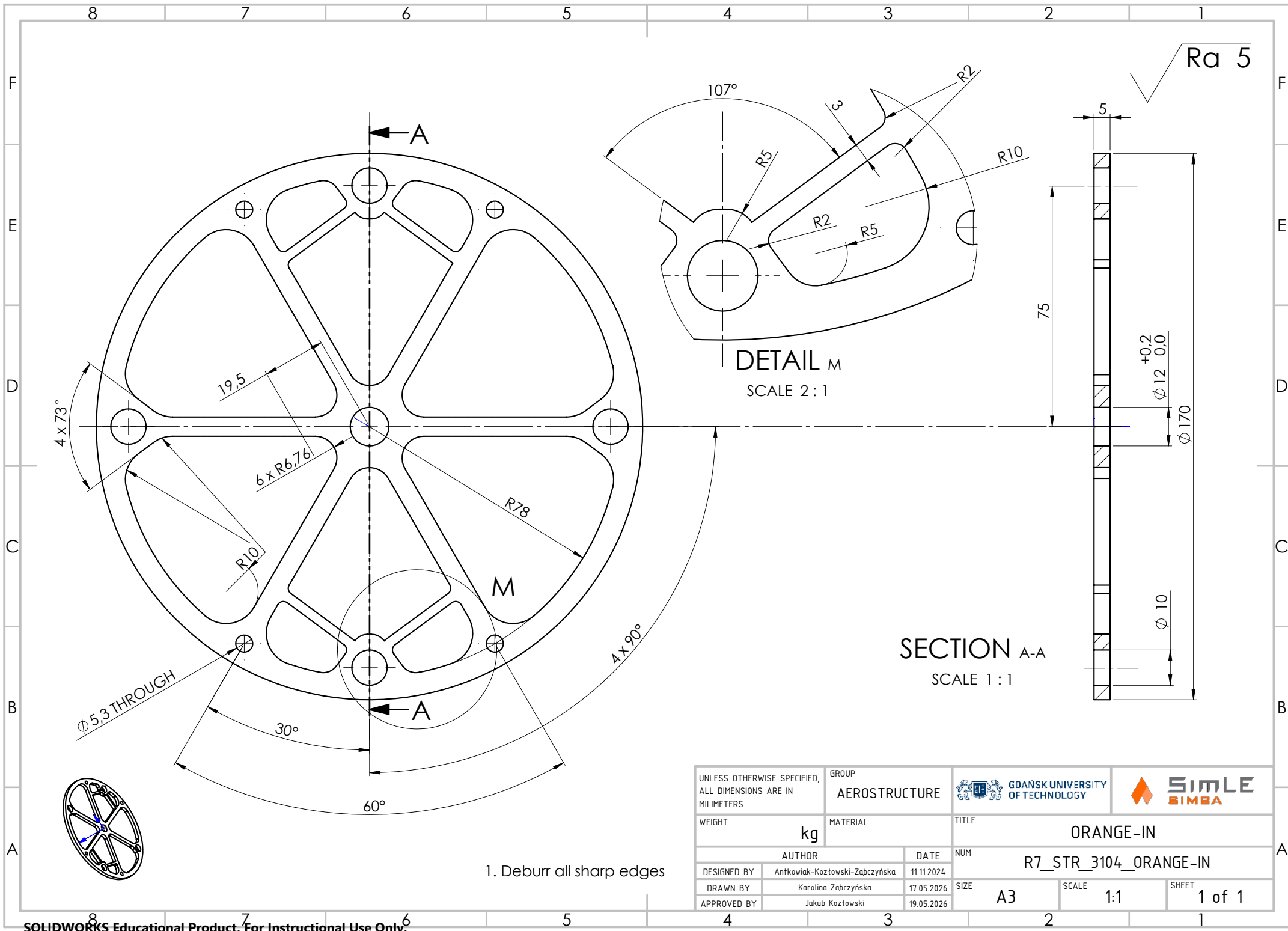
NUM
R7_STR_6000_Nosecone

DRAWN BY Karolina Zabczyńska
APPROVED BY Jakub Kozłowski

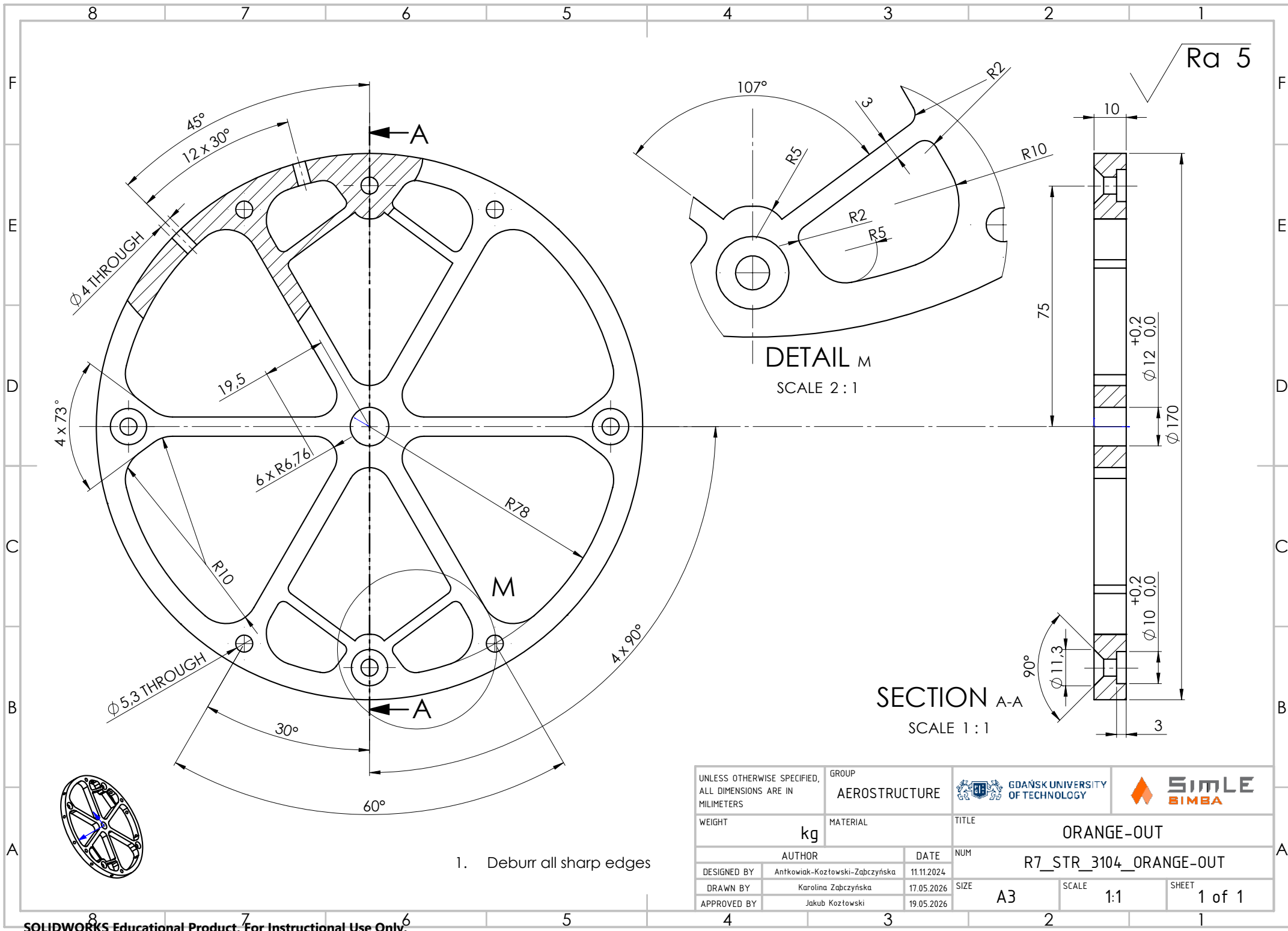
DATE 11.11.2024
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19.05.2026

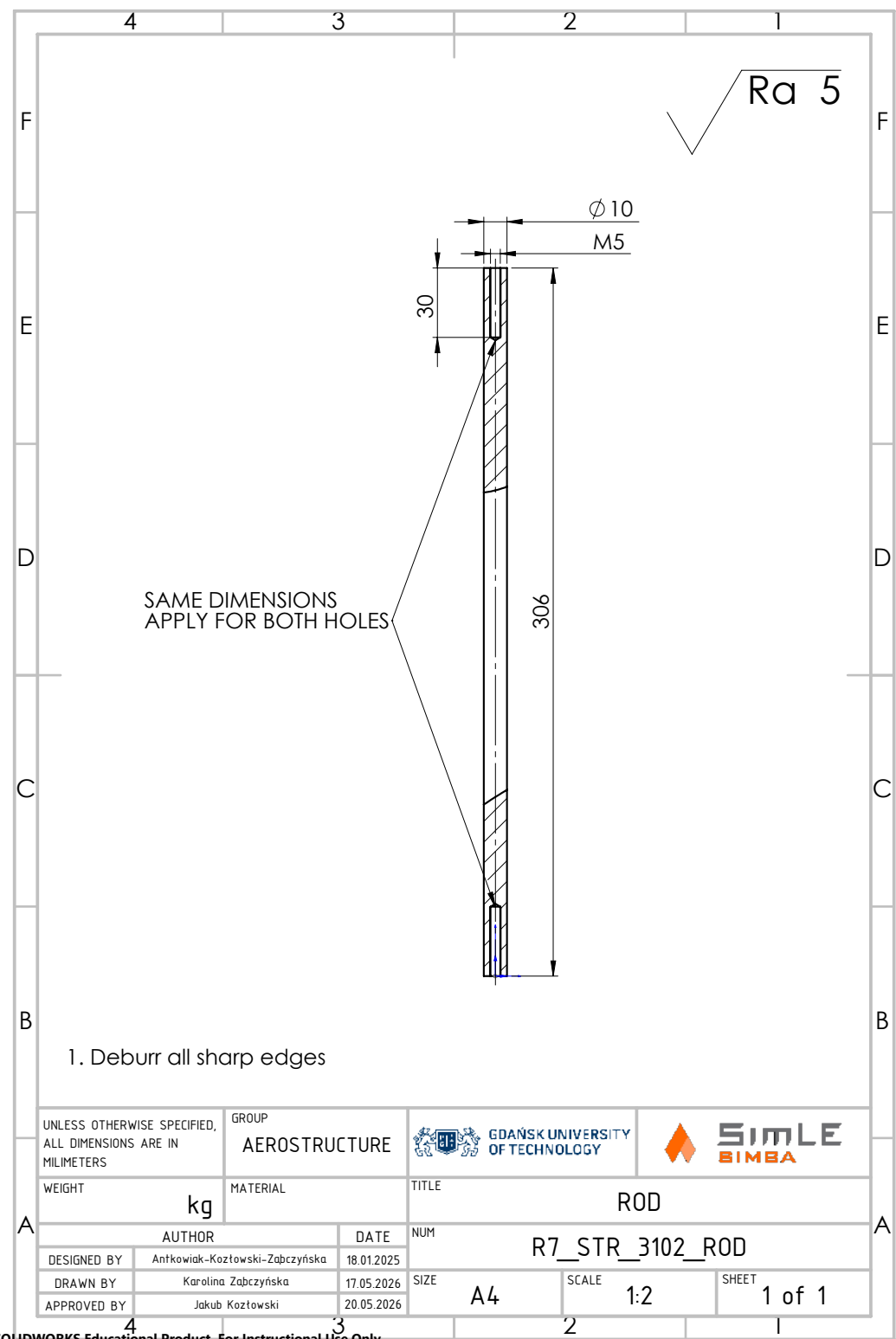
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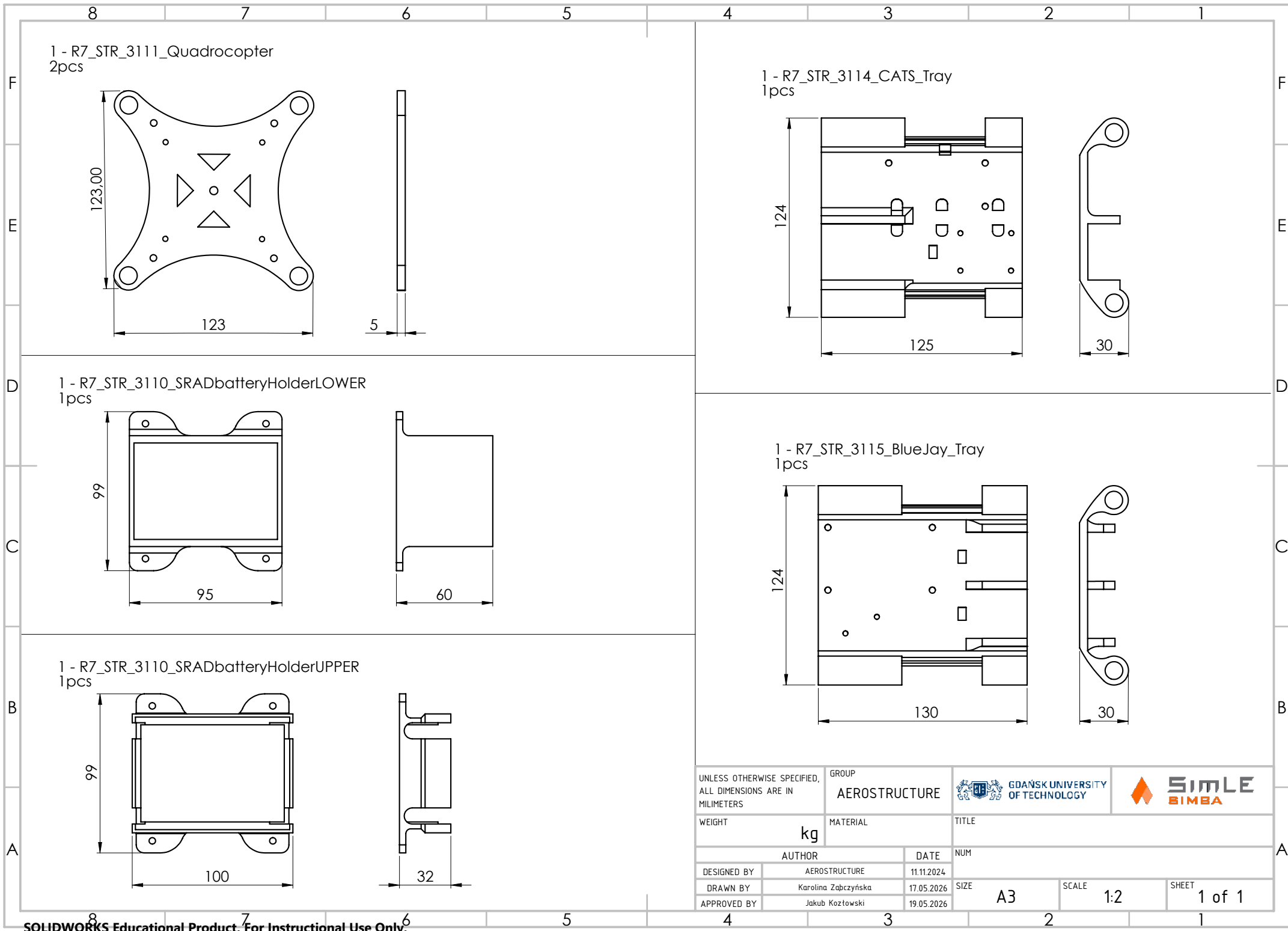


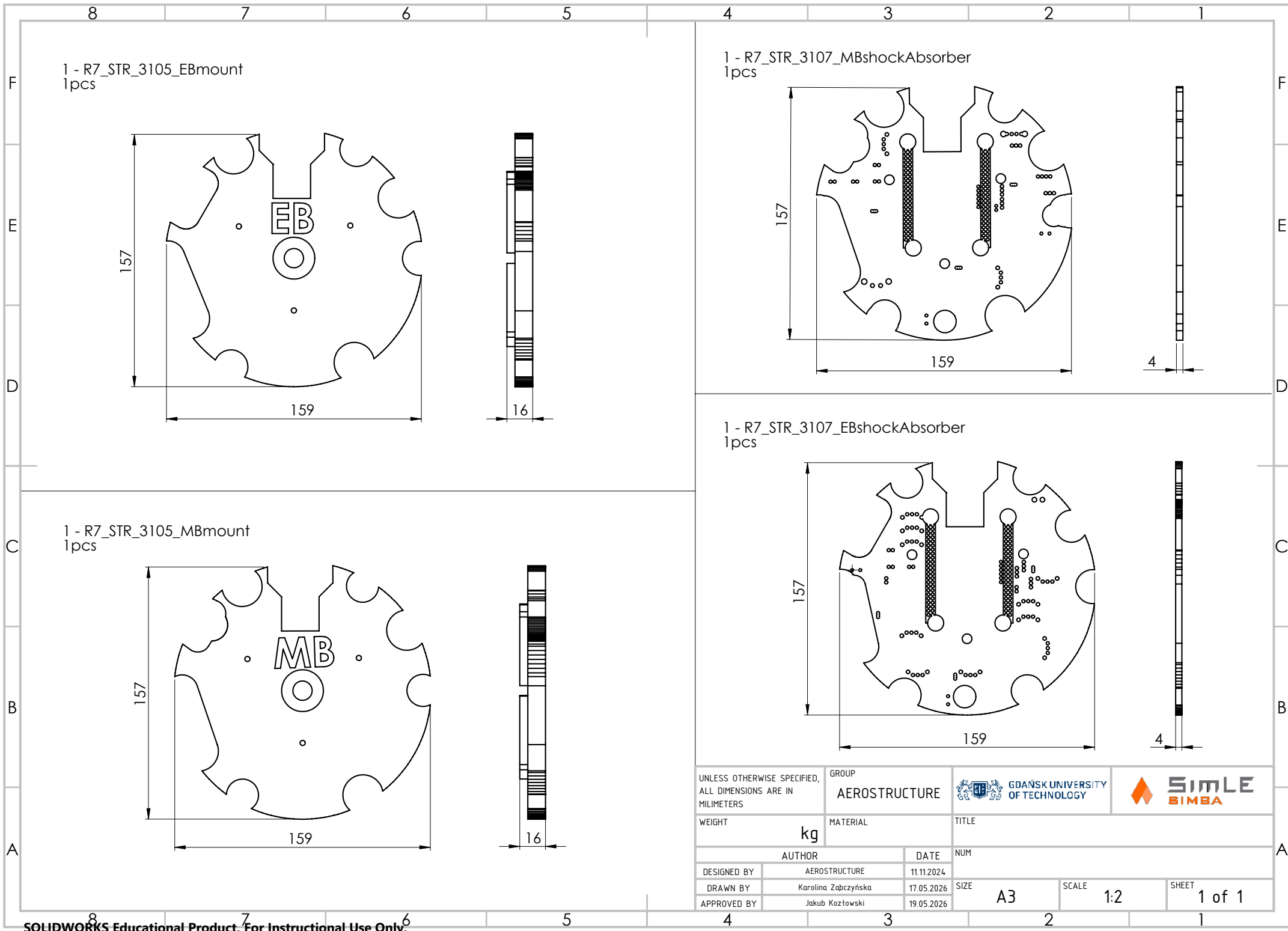


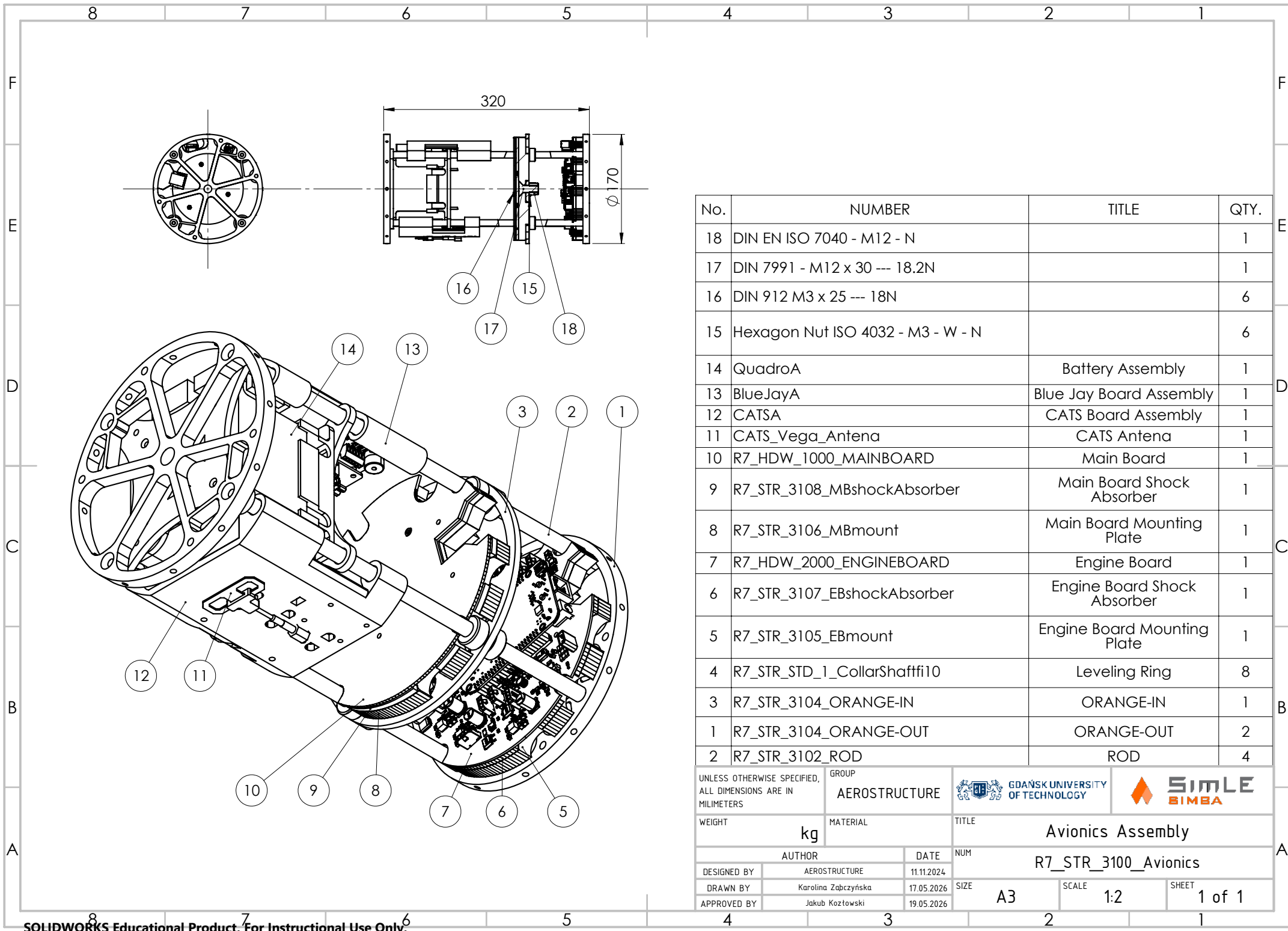
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA	
WEIGHT kg		MATERIAL		TITLE ORANGE-IN			
AUTHOR		DATE		NUM R7_STR_3104_ORANGE-IN			
DESIGNED BY	Antkowiak-Kozłowski-Zabczyńska	11.11.2024		SIZE A3		SCALE 1:1	SHEET 1 of 1
DRAWN BY	Karolina Zabczyńska	17.05.2026					
APPROVED BY	Jakub Kozłowski	19.05.2026					





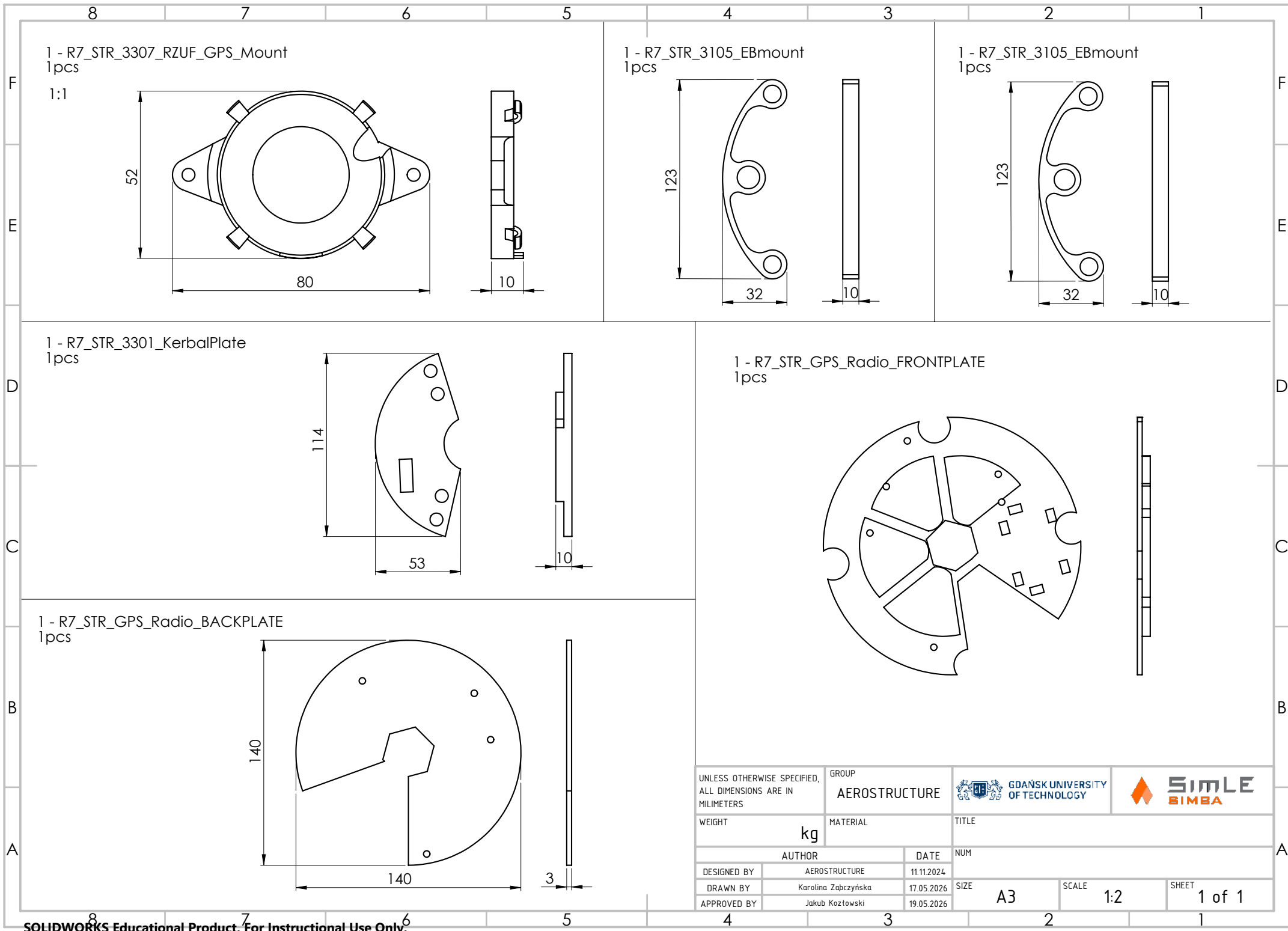


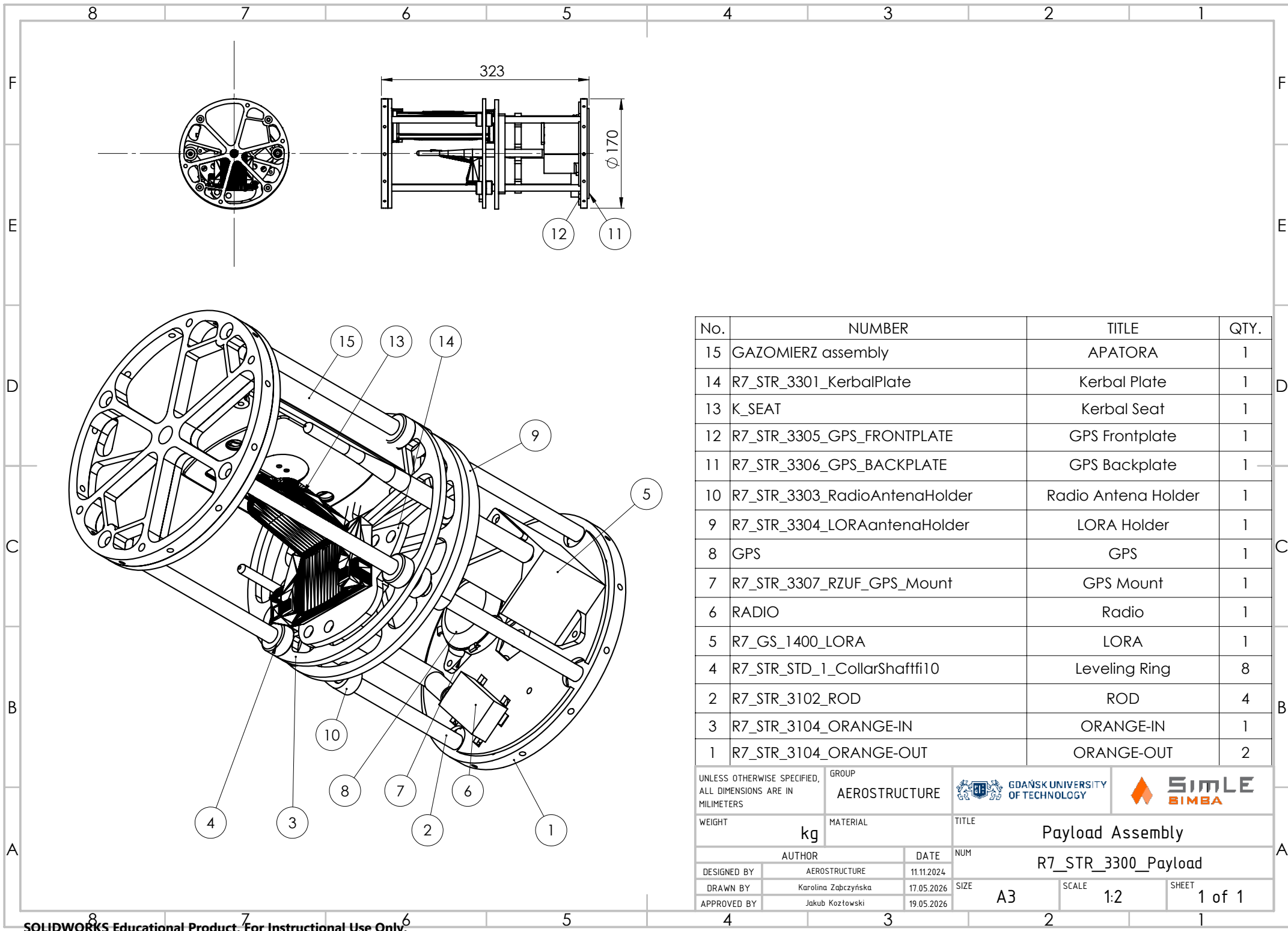


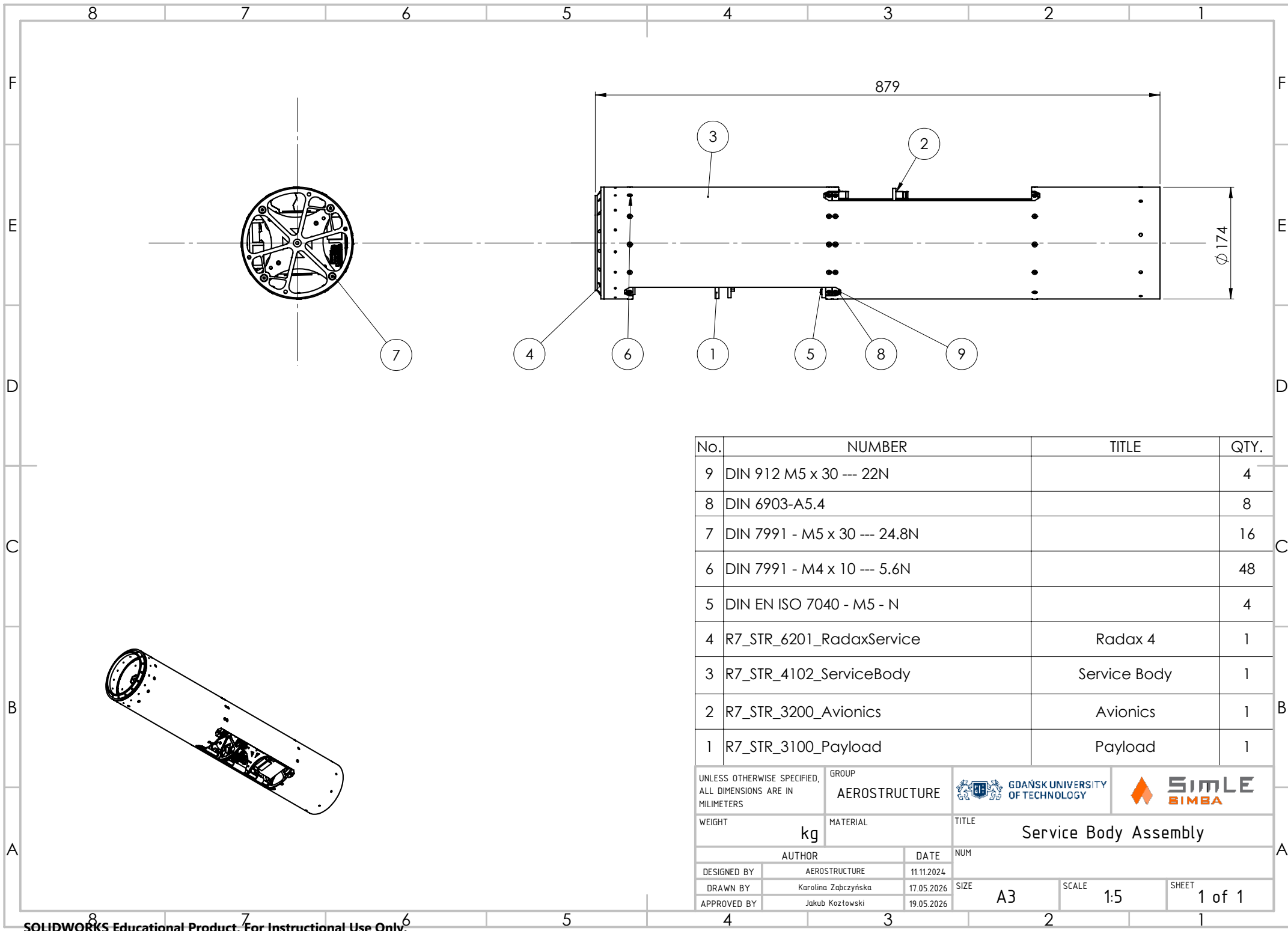


No.	NUMBER	TITLE	QTY.
18	DIN EN ISO 7040 - M12 - N		1
17	DIN 7991 - M12 x 30 --- 18.2N		1
16	DIN 912 M3 x 25 --- 18N		6
15	Hexagon Nut ISO 4032 - M3 - W - N		6
14	QuadroA	Battery Assembly	1
13	BlueJayA	Blue Jay Board Assembly	1
12	CATSA	CATS Board Assembly	1
11	CATS_Vega_Antena	CATS Antena	1
10	R7_HDW_1000_MAINBOARD	Main Board	1
9	R7_STR_3108_MBshockAbsorber	Main Board Shock Absorber	1
8	R7_STR_3106_MBmount	Main Board Mounting Plate	1
7	R7_HDW_2000_ENGINEBOARD	Engine Board	1
6	R7_STR_3107_EBshockAbsorber	Engine Board Shock Absorber	1
5	R7_STR_3105_EBmount	Engine Board Mounting Plate	1
4	R7_STR_STD_1_CollarShafffi10	Leveling Ring	8
3	R7_STR_3104_ORANGE-IN	ORANGE-IN	1
1	R7_STR_3104_ORANGE-OUT	ORANGE-OUT	2
2	R7_STR_3102_ROD	ROD	4

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA		
WEIGHT kg		MATERIAL		TITLE Avionics Assembly				
AUTHOR		DATE		NUM R7_STR_3100_Avionics				
DESIGNED BY	AEROSTRUCTURE		11.11.2024		SIZE A3			
DRAWN BY	Karolina Zabczyńska		17.05.2026					
APPROVED BY	Jakub Kozłowski		19.05.2026					
				SCALE 1:2		SHEET 1 of 1		

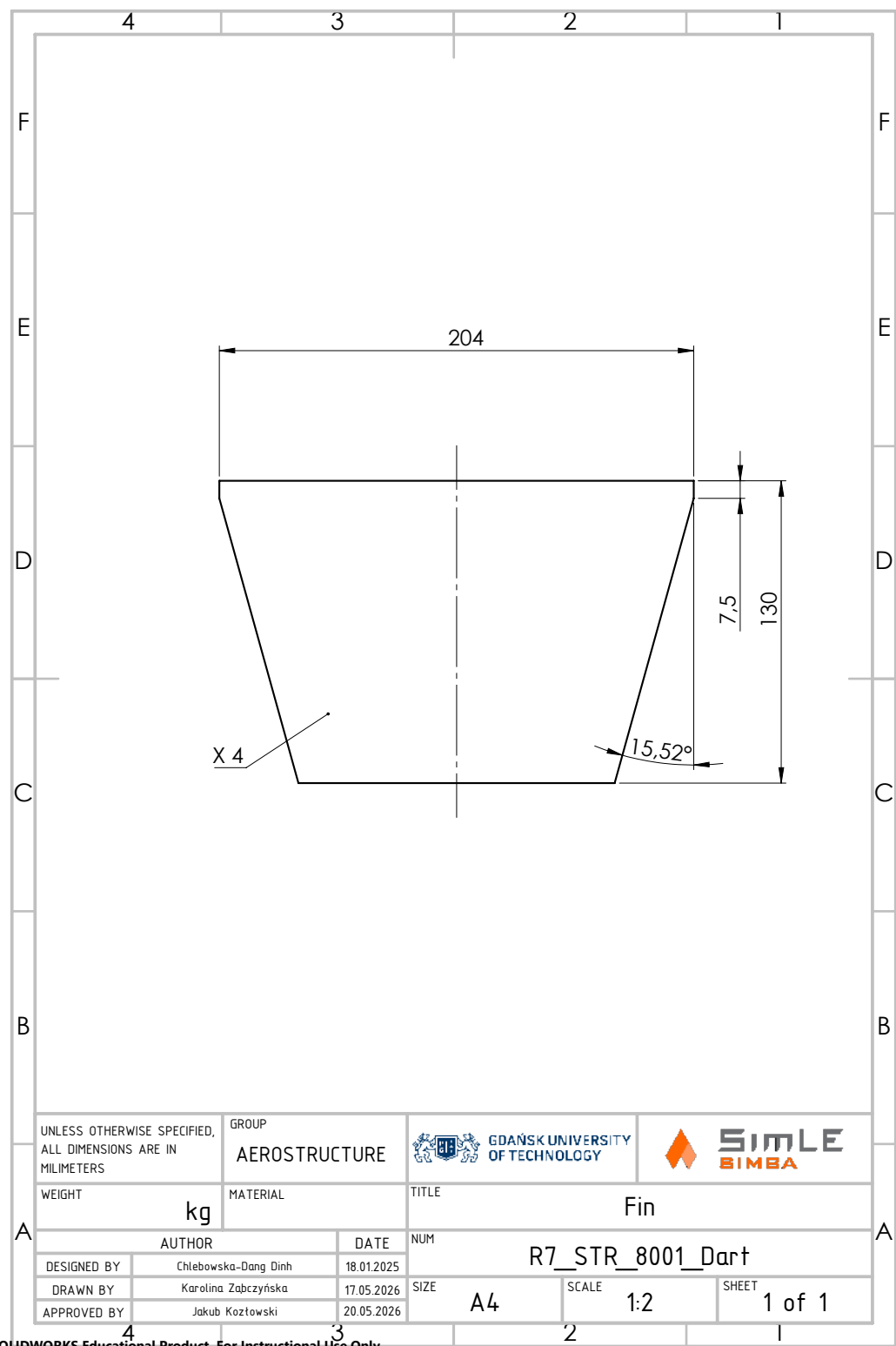




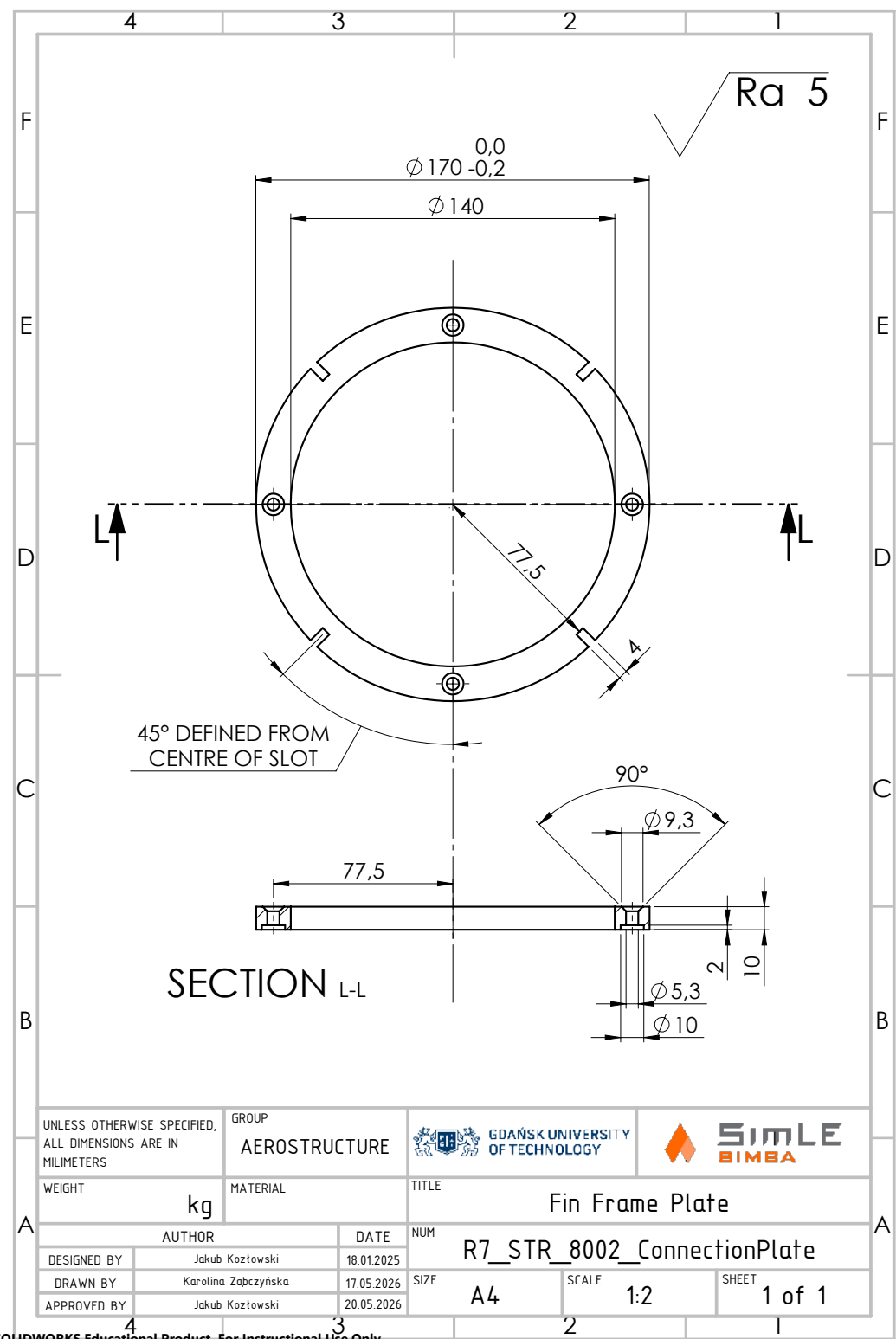


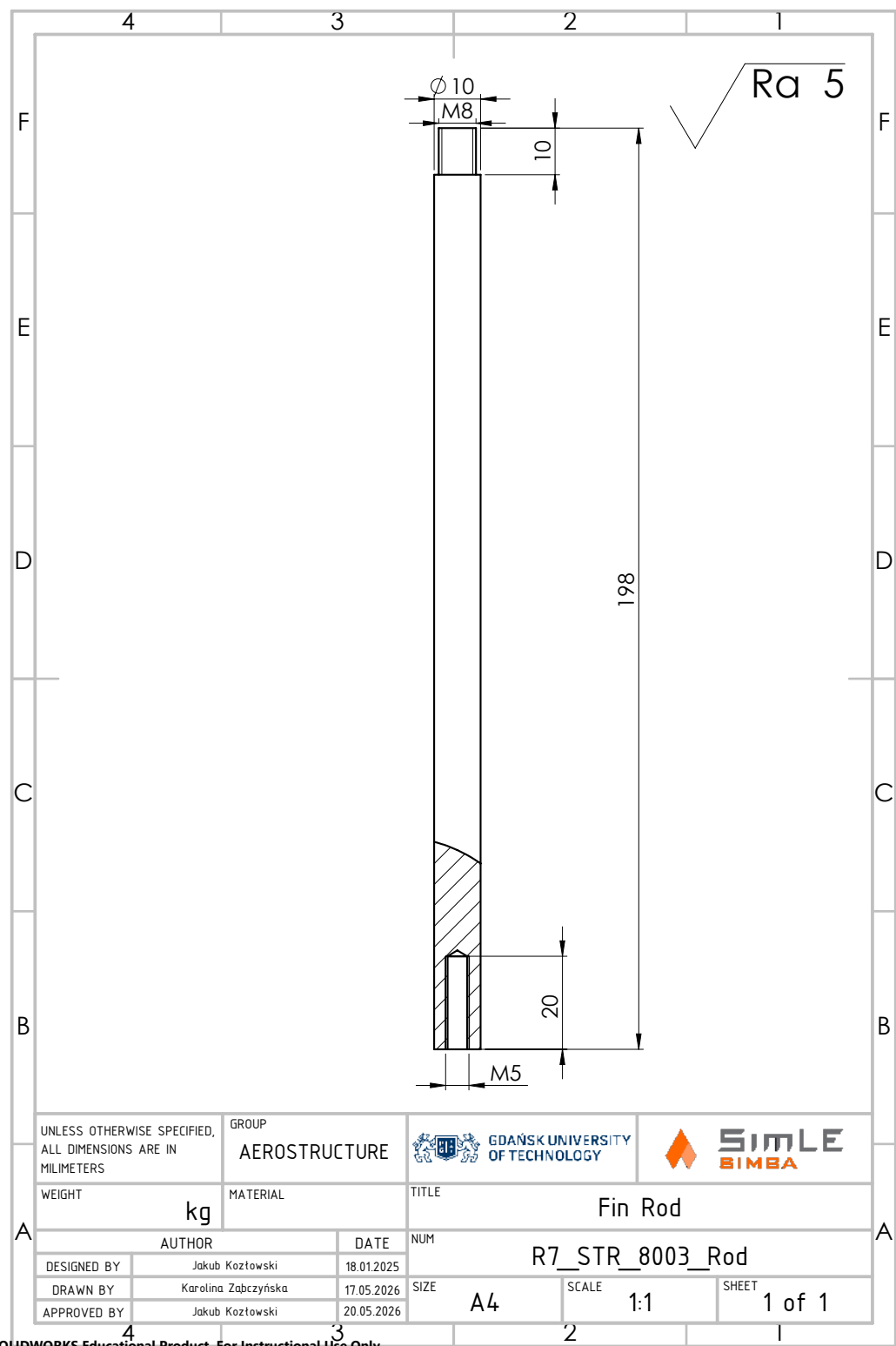
No.	NUMBER	TITLE	QTY.
9	DIN 912 M5 x 30 --- 22N		4
8	DIN 6903-A5.4		8
7	DIN 7991 - M5 x 30 --- 24.8N		16
6	DIN 7991 - M4 x 10 --- 5.6N		48
5	DIN EN ISO 7040 - M5 - N		4
4	R7_STR_6201_RadaxService	Radax 4	1
3	R7_STR_4102_ServiceBody	Service Body	1
2	R7_STR_3200_Avionics	Avionics	1
1	R7_STR_3100_Payload	Payload	1

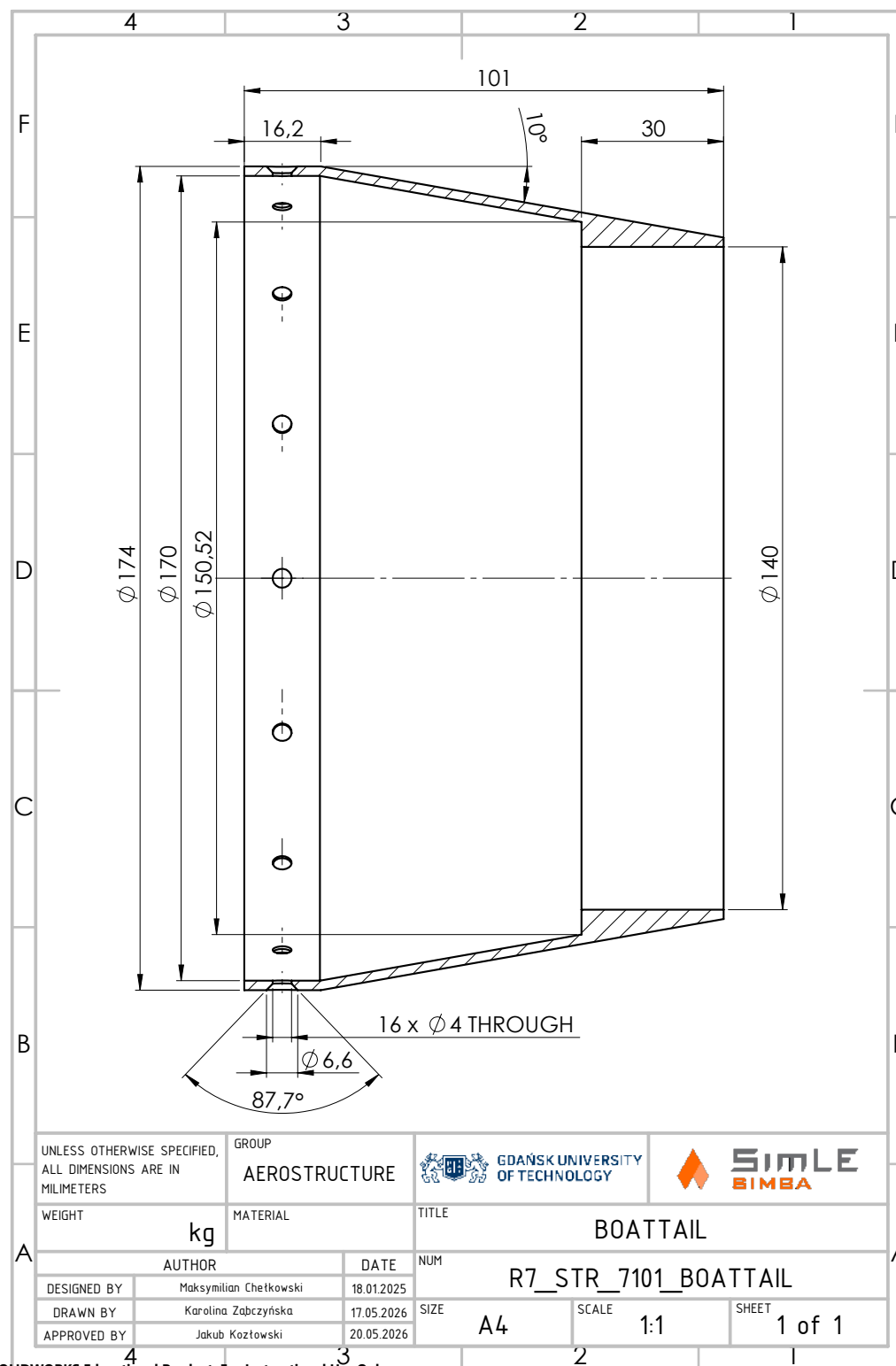
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDANSK UNIVERSITY OF TECHNOLOGY			
		WEIGHT kg		MATERIAL		TITLE Service Body Assembly	
AUTHOR			DATE		NUM		
DESIGNED BY	AEROSTRUCTURE		11.11.2024				
DRAWN BY	Karolina Zabczyńska		17.05.2026		SIZE A3	SCALE 1:5	SHEET 1 of 1
APPROVED BY	Jakub Kozłowski		19.05.2026				



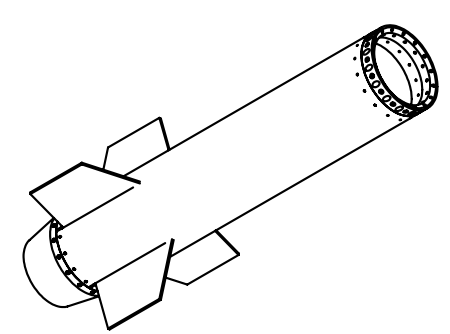
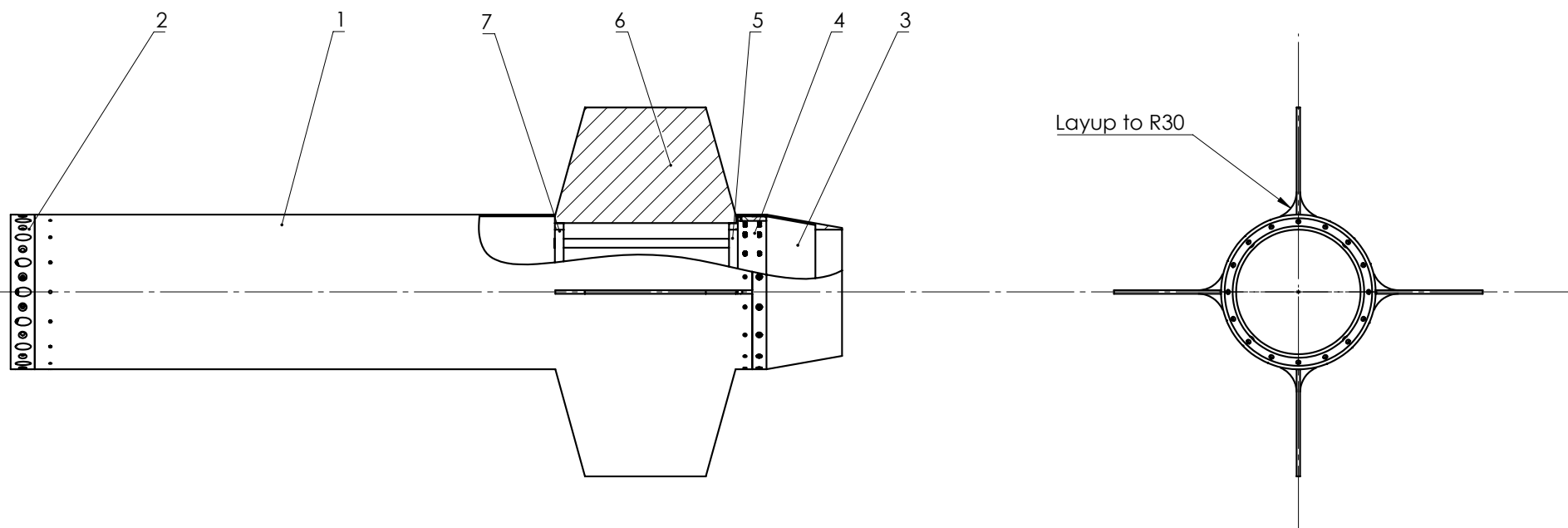
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA	
		MATERIAL		TITLE Fin			
WEIGHT kg				NUM R7_STR_8001_Dart			
AUTHOR		DATE					
DESIGNED BY Chlebowska-Dang Dinh		18.01.2025					
DRAWN BY Karolina Zabczyńska		17.05.2026		SIZE A4		SCALE 1:2	
APPROVED BY Jakub Kozłowski		20.05.2026		SHEET 1 of 1			





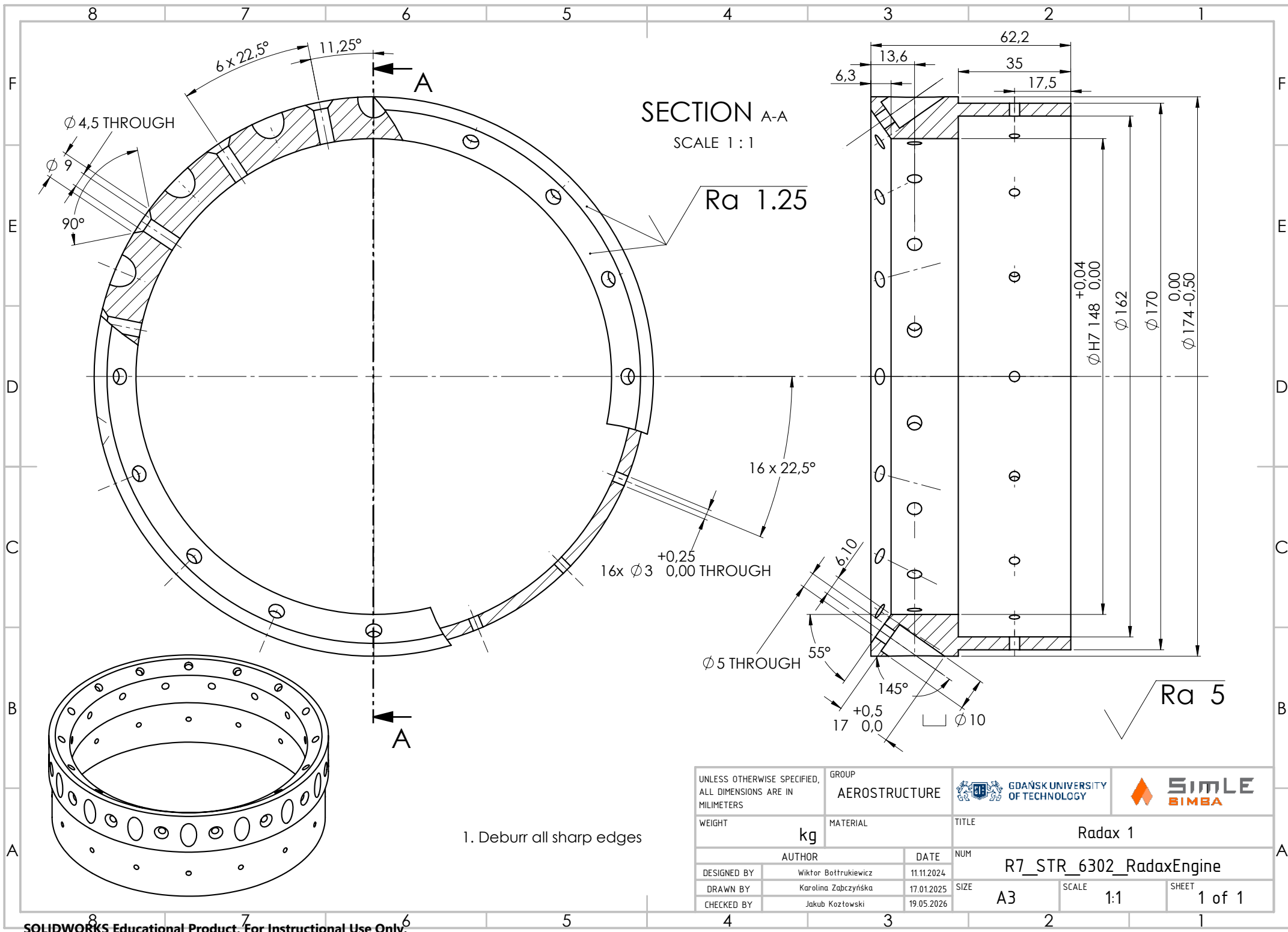


UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA			
		WEIGHT kg		MATERIAL		TITLE BOATTAIL			
AUTHOR				DATE		NUM R7_STR_7101_BOATTAIL			
DESIGNED BY		Maksymilian Chetkowski		18.01.2025		SIZE A4			
DRAWN BY		Karolina Zabczyńska		17.05.2026					
APPROVED BY		Jakub Kozłowski		20.05.2026					
						SCALE 1:1		SHEET 1 of 1	

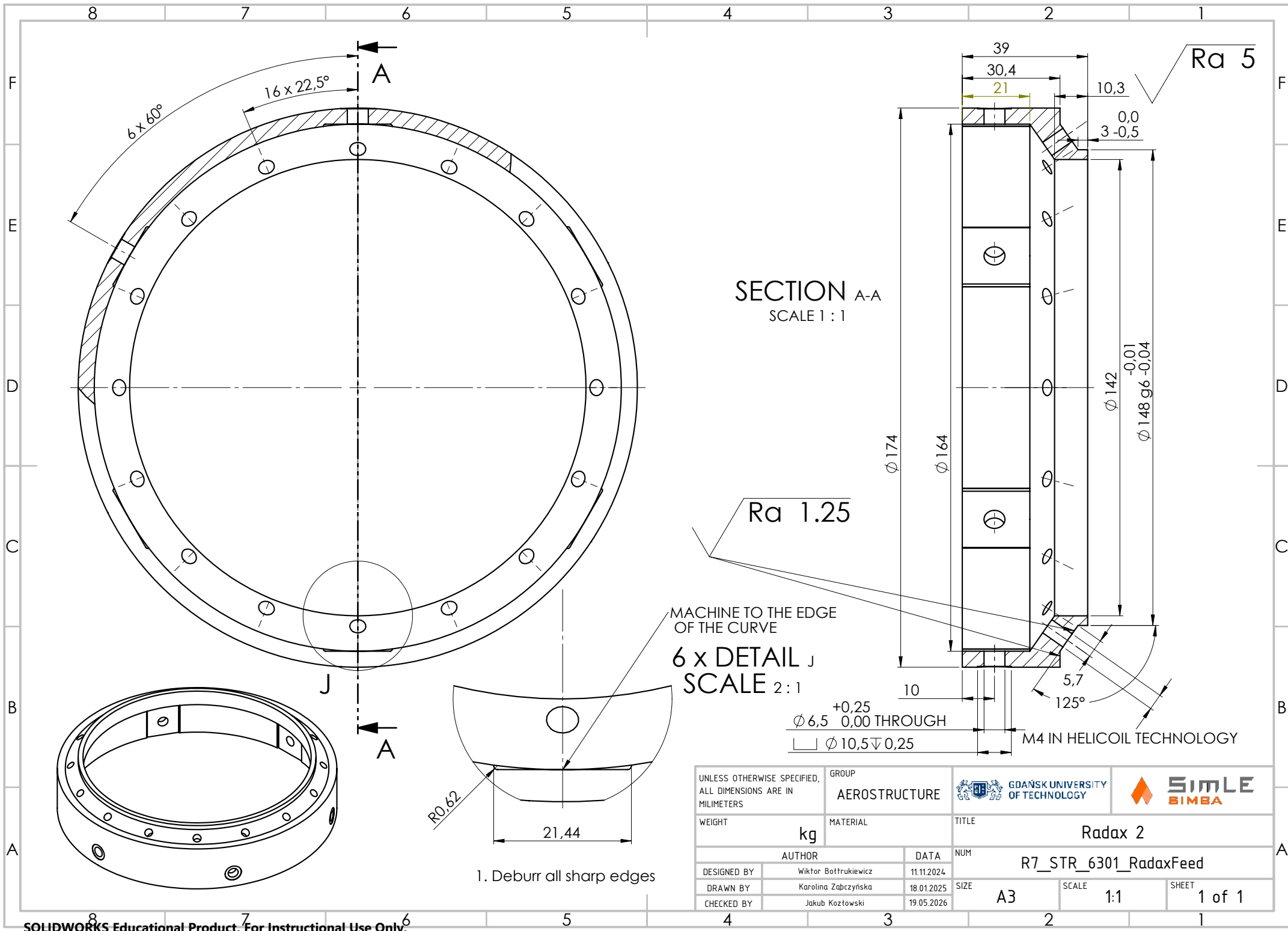


No.	NUMBER	TITLE	QTY.
8	R7_STR_8003_Rod	Fin Rod	4
7	R7_STR_8002_ConnectionPlate	Fin Frame Plate	1
6	R7_STR_8001_Dart	Fin	4
5	R7_STR_7202_Boattail_Plate	Boattail Plate	1
4	R7_STR_7201_Boattail_Ring	Boattail Ring	1
3	R7_STR_7101_Boattail	Boattail	1
2	R7_STR_6302_RadaxEngine	Radax 1	1
1	R7_STR_4103_EngBody	Engine Body	1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE BIMBA	
		WEIGHT kg		MATERIAL		TITLE Engine Body Assembly	
AUTHOR			DATE	NUM			
DESIGNED BY		AREOSTRUCTURE		11.11.2024			
DRAWN BY		Karolina Zabczyńska		17.05.2026			
APPROVED BY		Jakub Kozłowski		19.05.2026			
				SIZE A3		SCALE 1:5	
						SHEET 1 of 1	



UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA	
		WEIGHT kg		MATERIAL		TITLE Radax 1	
AUTHOR			DATE		NUM R7_STR_6302_RadaxEngine		
DESIGNED BY	Wiktor Botrukiewicz		11.11.2024		SIZE A3	SCALE 1:1	SHEET 1 of 1
DRAWN BY	Karolina Ząbczyńska		17.01.2025				
CHECKED BY	Jakub Koztowski		19.05.2026				



SECTION A-A
SCALE 1 : 1

Ra 1.25

MACHINE TO THE EDGE
OF THE CURVE

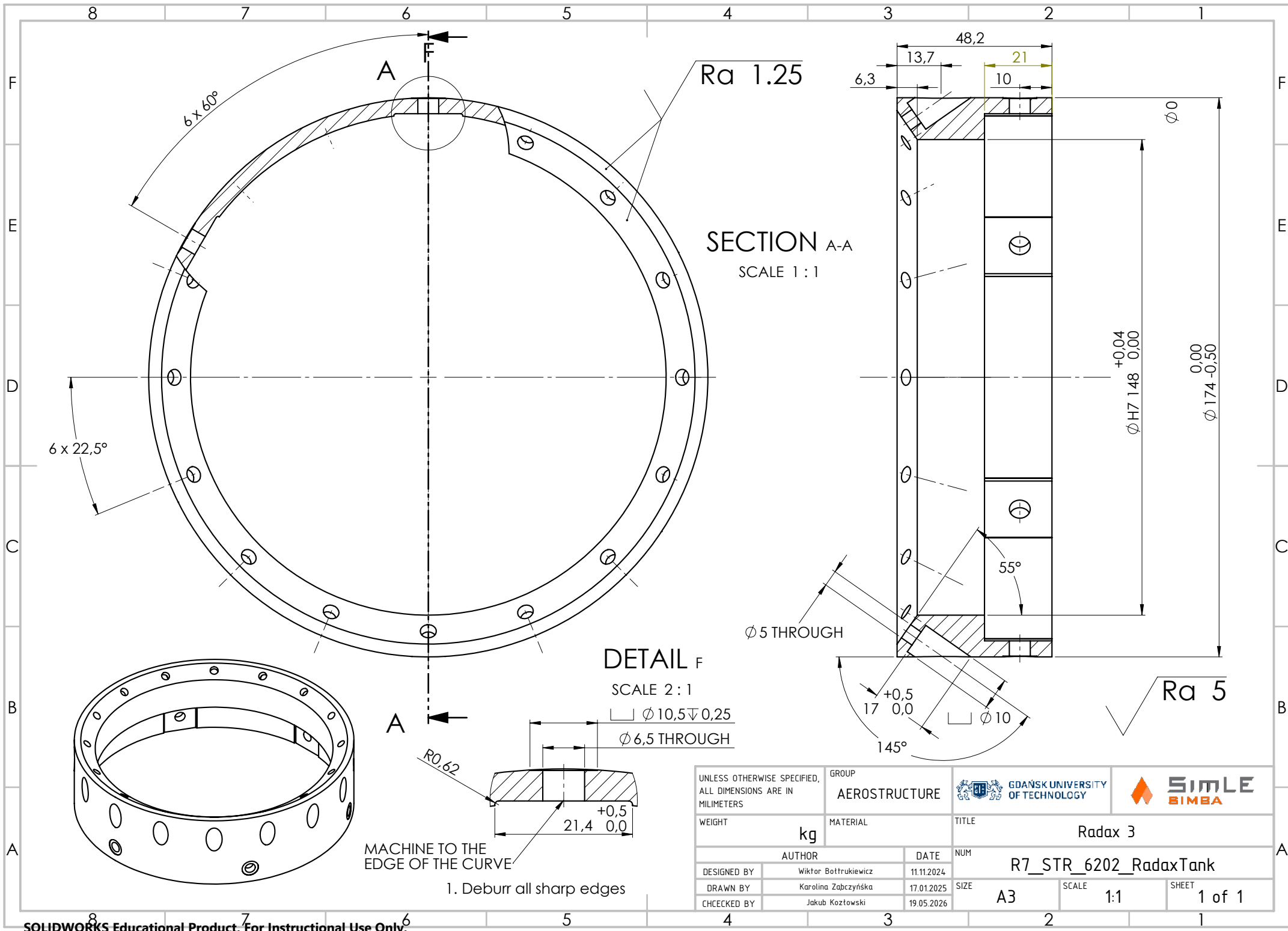
6 x DETAIL J
SCALE 2 : 1

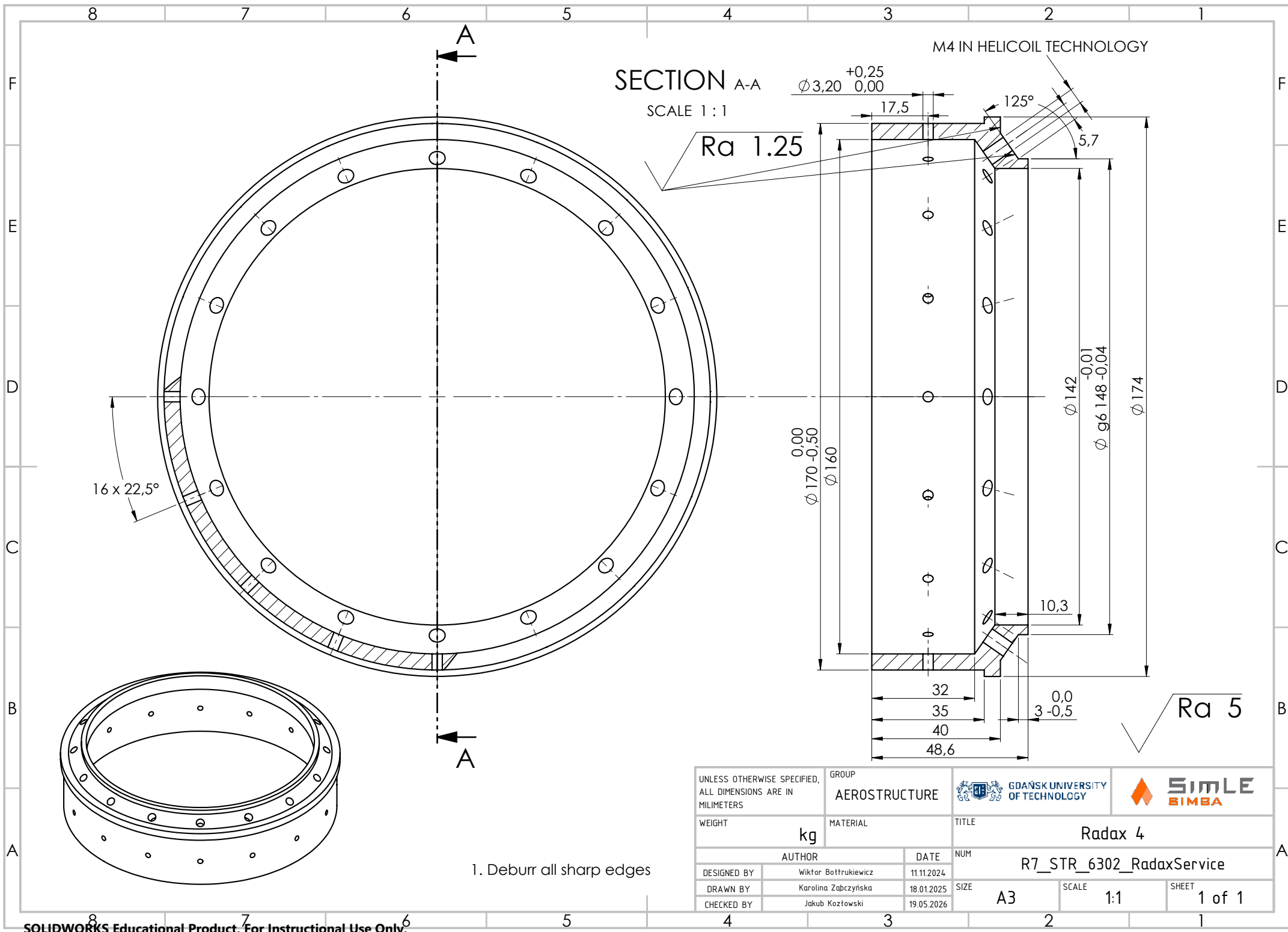
$\phi 6,5^{+0,25}_{0,00}$ THROUGH

$\phi 10,5 \pm 0,25$

M4 IN HELICOIL TECHNOLOGY

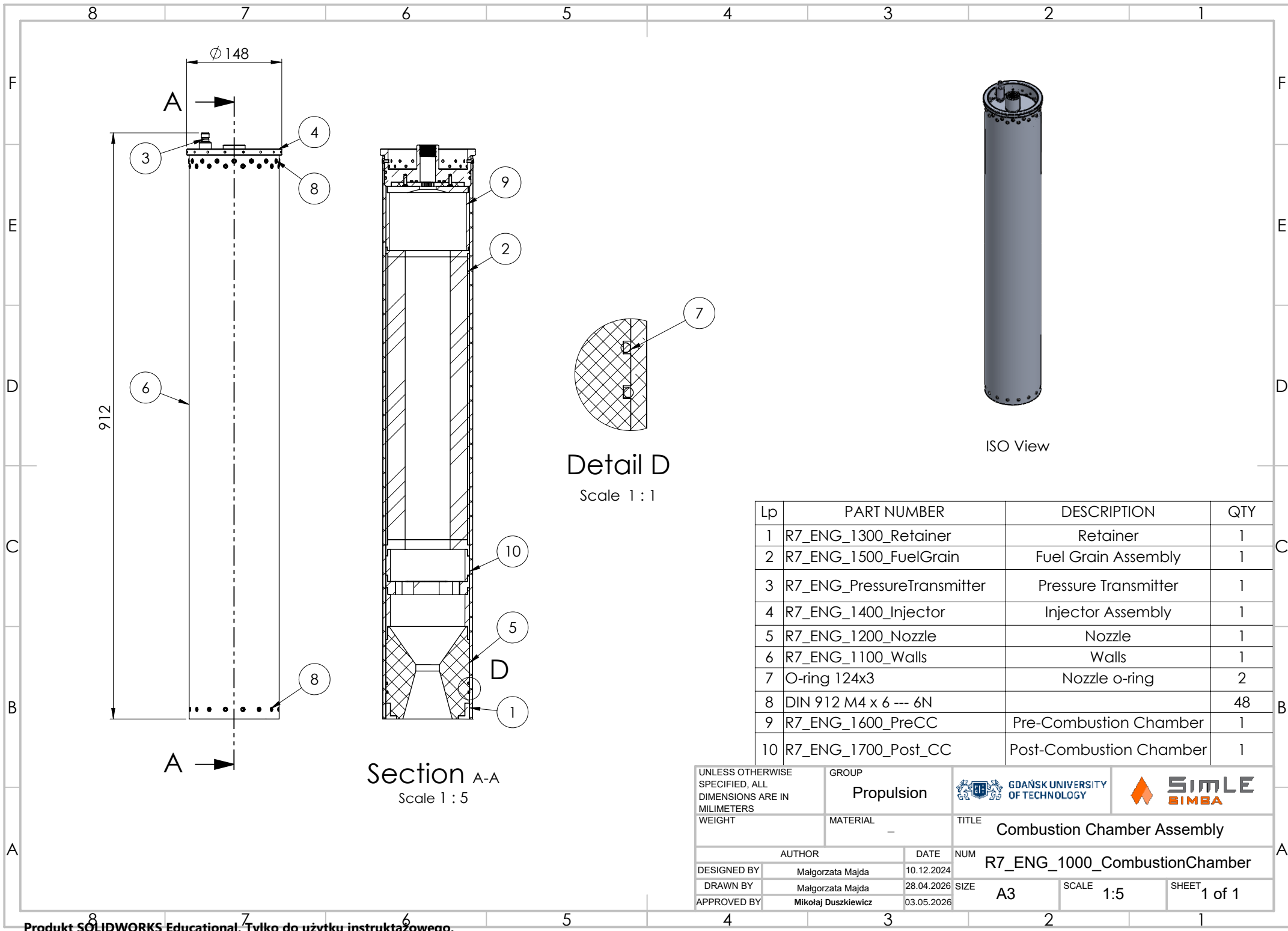
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
		MATERIAL		TITLE Radax 2			
WEIGHT		kg	NUM R7_STR_6301_RadaxFeed				
AUTHOR			DATA				
DESIGNED BY		Wiktor Bottrukiewicz	11.11.2024				
DRAWN BY		Karolina Zabczyńska	18.01.2025				
CHECKED BY		Jakub Kozłowski	A3		SCALE 1:1		SHEET 1 of 1

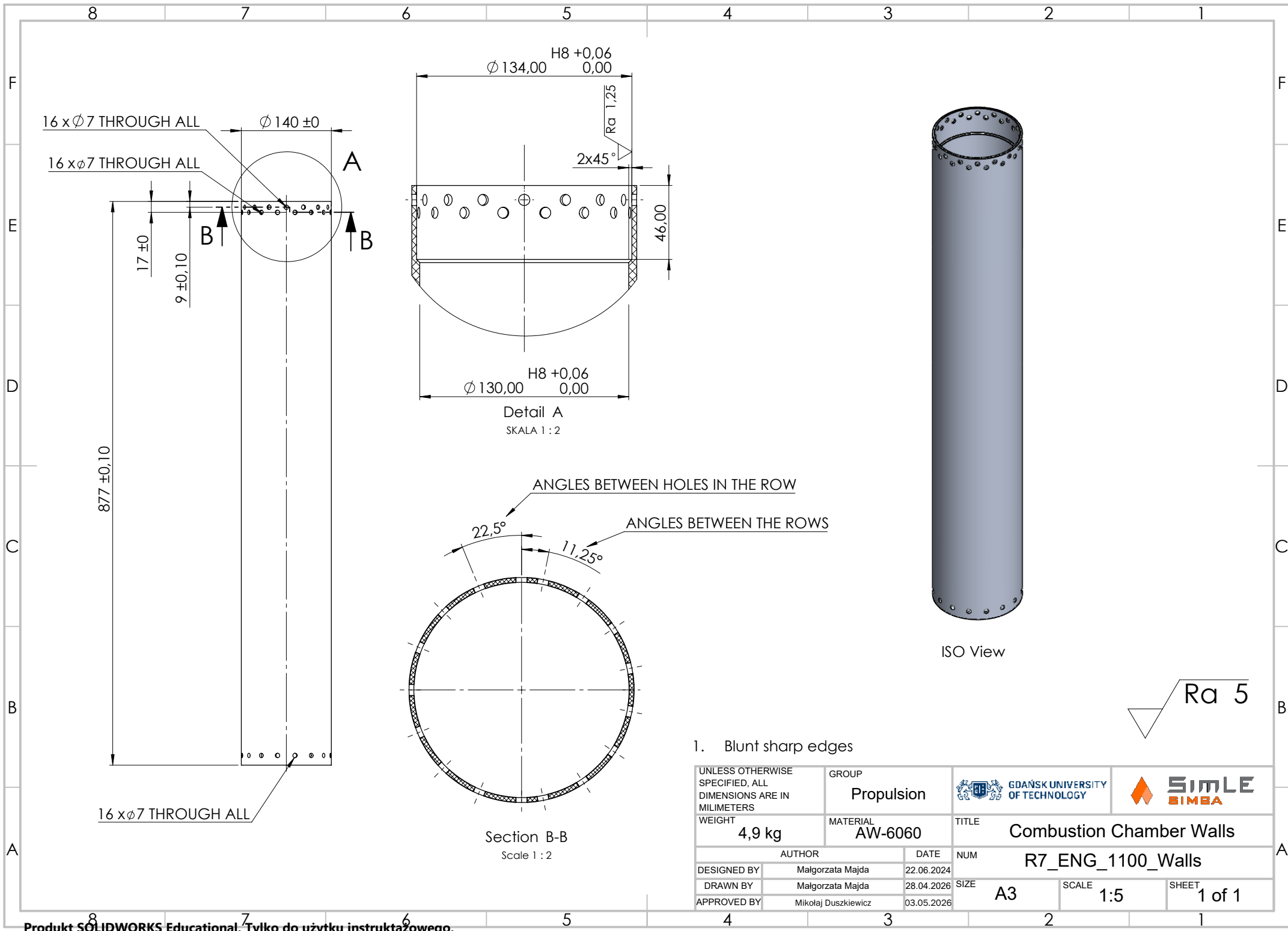


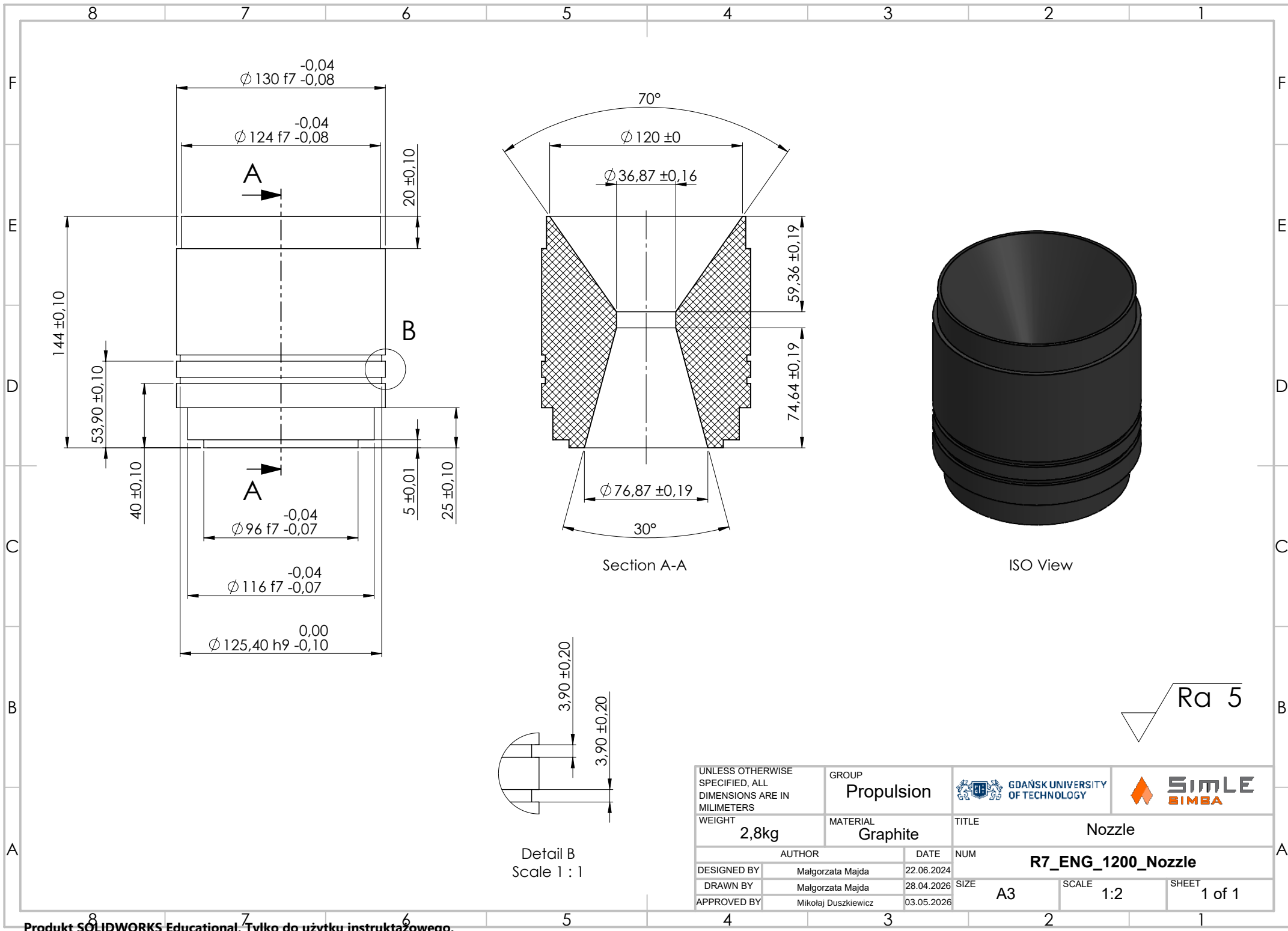


UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP AEROSTRUCTURE	 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT kg		MATERIAL	TITLE Radax 4			
AUTHOR		DATE	NUM R7_STR_6302_RadaxService			
DESIGNED BY	Wiktor Bottrukiewicz	11.11.2024	SIZE A3		SCALE 1:1	SHEET 1 of 1
DRAWN BY	Karolina Zabczyńska	18.01.2025				
CHECKED BY	Jakub Kozłowski	19.05.2026				

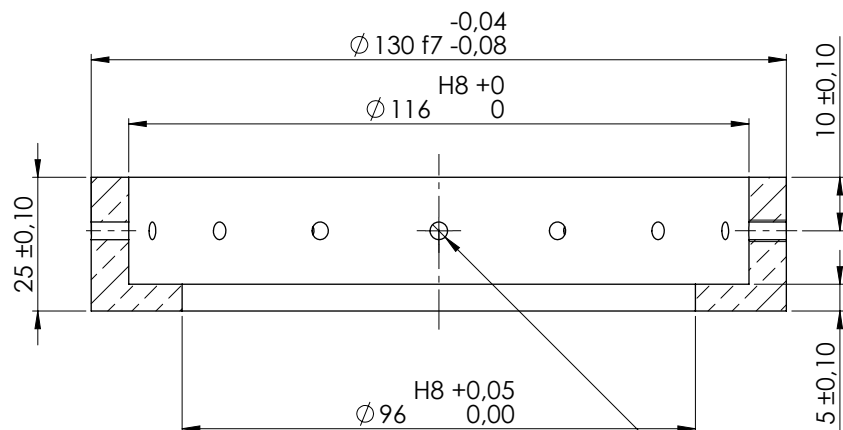
C.2 Propulsion



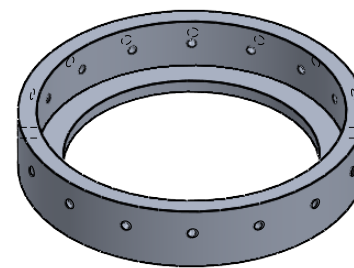




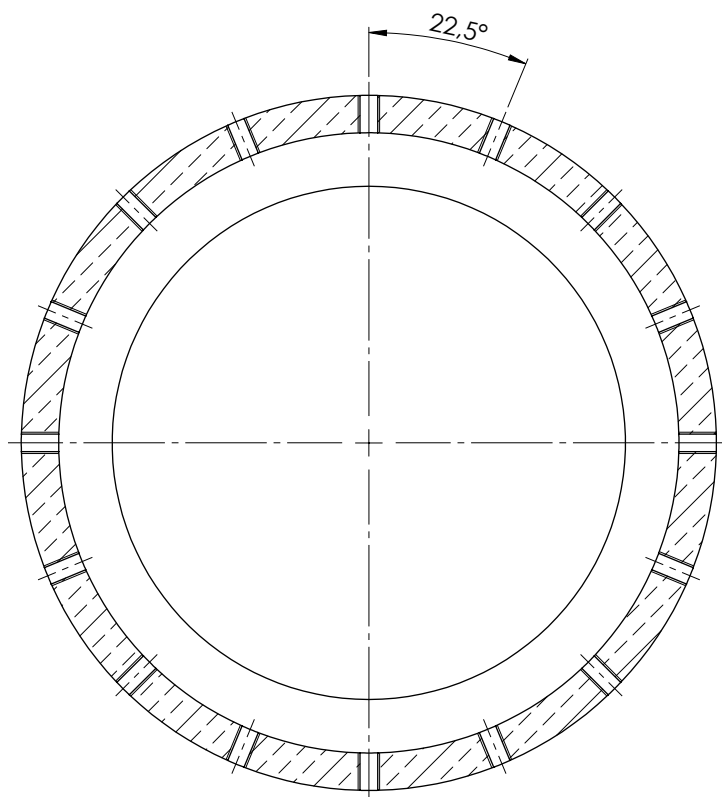
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY					
		WEIGHT 2,8kg		MATERIAL Graphite				TITLE Nozzle	
AUTHOR		DATE		NUM R7_ENG_1200_Nozzle					
DESIGNED BY	Małgorzata Majda	22.06.2024		SIZE A3		SCALE 1:2		SHEET 1 of 1	
DRAWN BY	Małgorzata Majda	28.04.2026							
APPROVED BY	Mikołaj Duszakiewicz	03.05.2026							



16 x $\varnothing 3,30$ THROUGH ALL
M4 - 6H THROUGH ALL



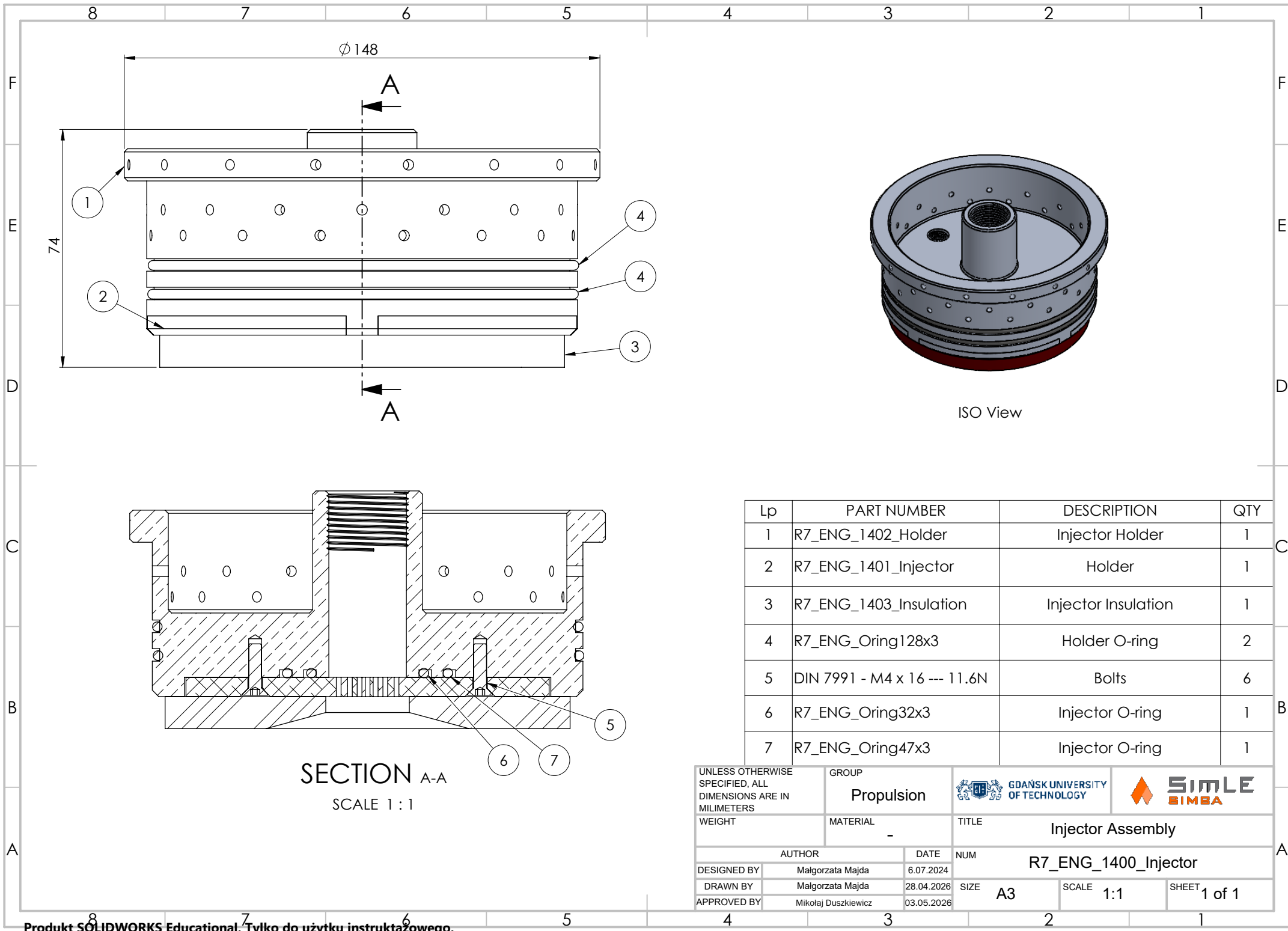
ISO View

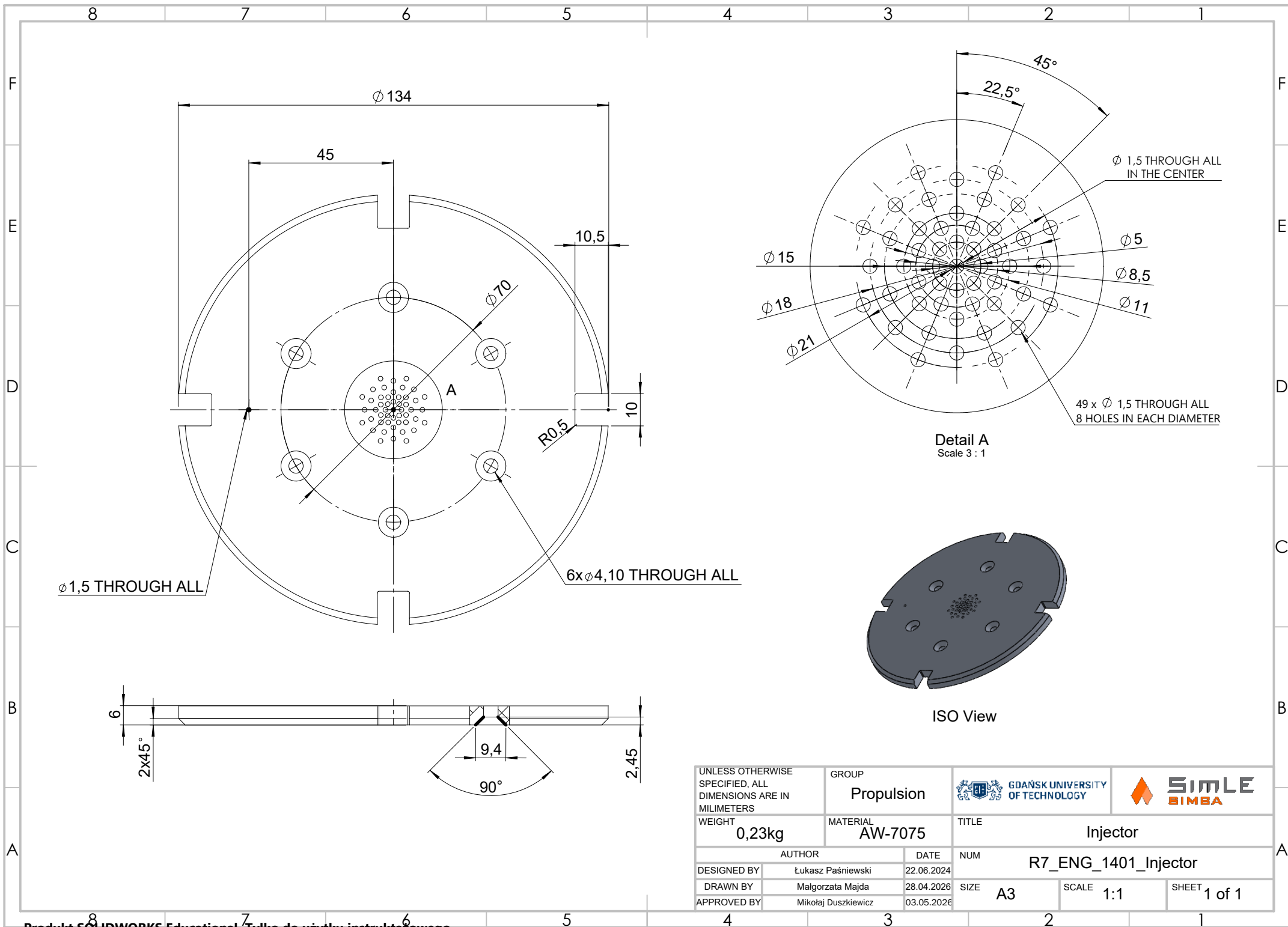


∇ Ra 5

1. Blunt sharp edges.

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDANSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA	
WEIGHT 0,2 kg		MATERIAL AW-2007		TITLE Retainer			
AUTHOR			DATE	NUM R7_ENG_1300_Retainer			
DESIGNED BY	Małgorzata Majda		22.06.2024	SIZE A3			
DRAWN BY	Małgorzata Majda		28.04.2026				
APPROVED BY	Mikołaj Dusziewicz		03.05.2026				
				SCALE 1:2		SHEET 1 of 1	





UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY					
WEIGHT 0,23kg		MATERIAL AW-7075		TITLE Injector					
AUTHOR		DATE		NUM R7_ENG_1401_Injector					
DESIGNED BY	Łukasz Pańniewski	22.06.2024		SIZE A3		SCALE 1:1		SHEET 1 of 1	
DRAWN BY	Małgorzata Majda	28.04.2026							
APPROVED BY	Mikołaj Duszakiewicz	03.05.2026							

8 7 6 5 4 3 2 1

F

E

D

C

B

A

F

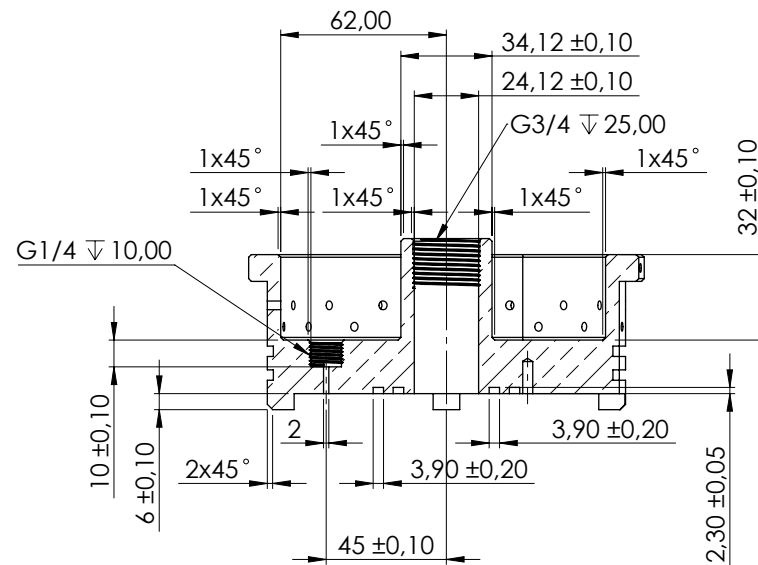
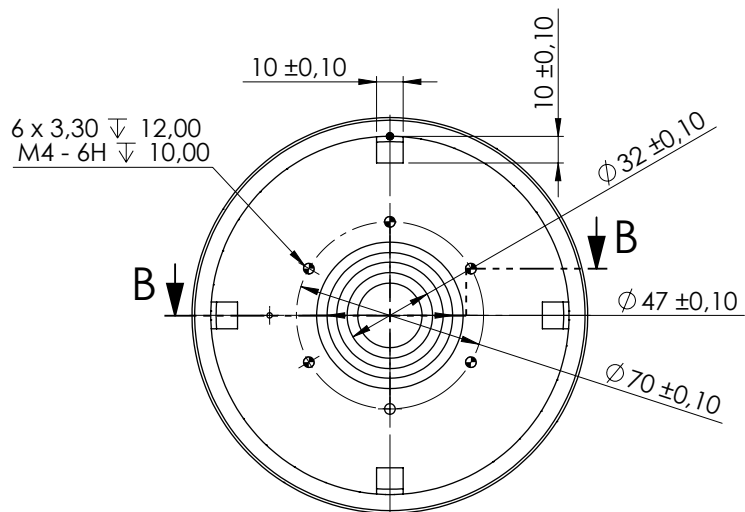
E

D

C

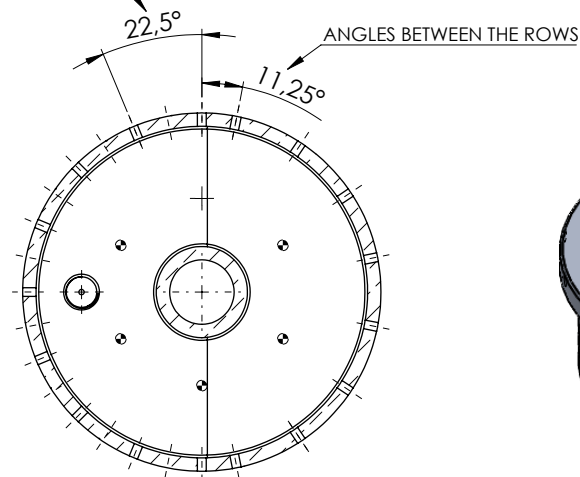
B

A

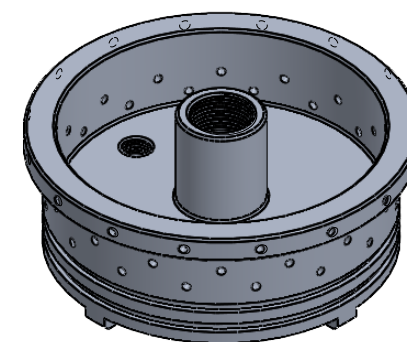


ANGLES BETWEEN HOLES IN THE ROW

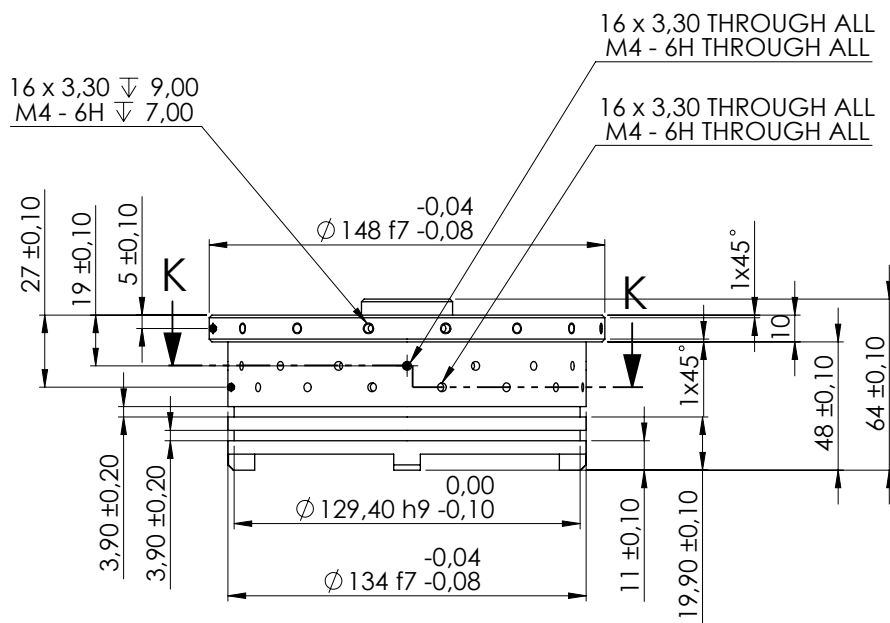
Section B-B



Section K-K

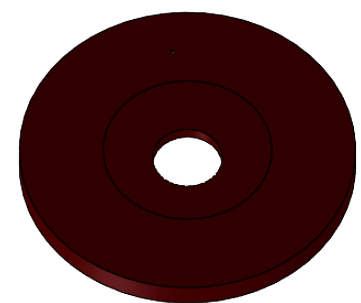
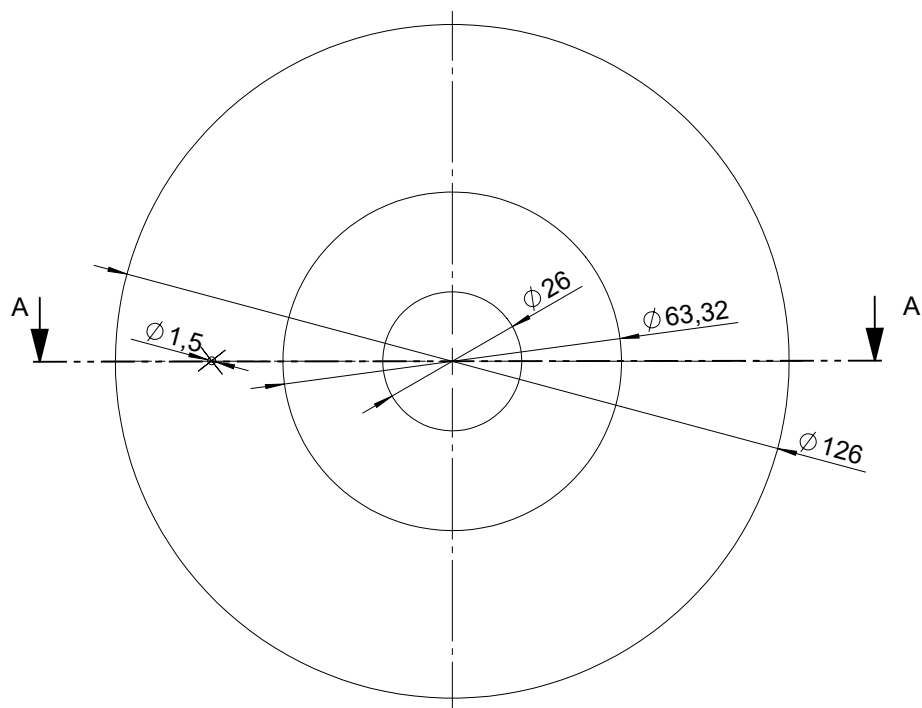


ISO View

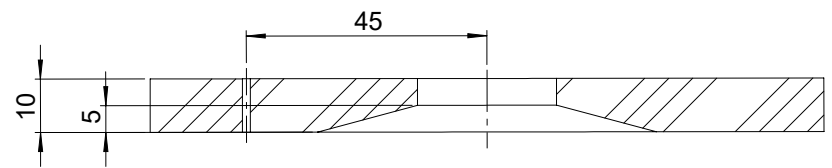


1. Blunt sharp edges

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS	GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY					
	WEIGHT 1,01kg		MATERIAL AW-2007		TITLE Injector Holder			
AUTHOR			DATE			NUM R7_ENG_1402_Holder		
DESIGNED BY			Małgorzata Majda			30.06.2024		
DRAWN BY			Małgorzata Majda			28.04.2026		
APPROVED BY			Mikołaj Duszewicz			03.05.2026		
			SIZE A3			SCALE 1:2		
						SHEET 1 of 1		

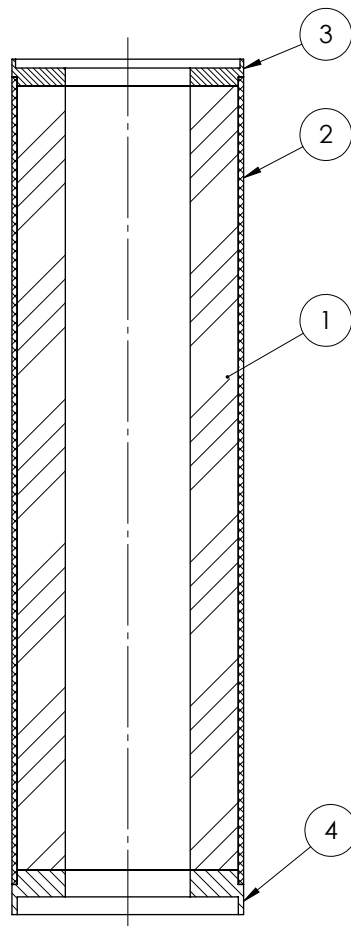
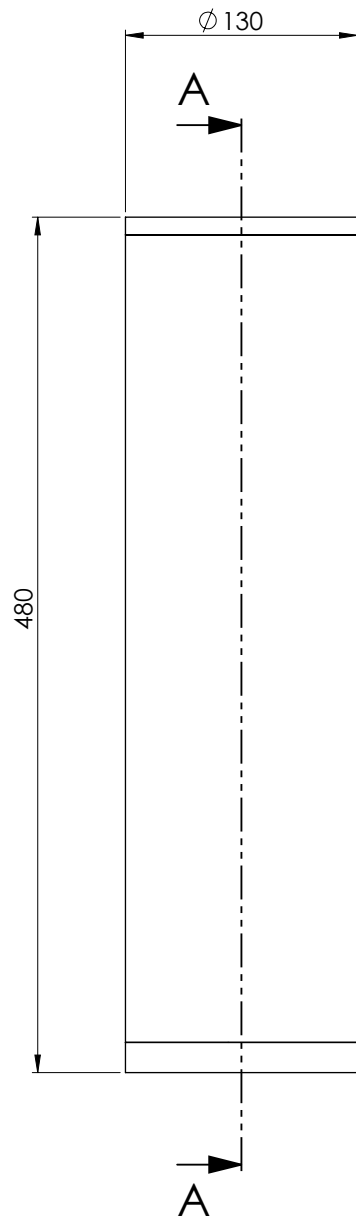


ISO View



Section A-A
Scale 1 : 1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT		MATERIAL Textolite		TITLE Injector Insulation			
AUTHOR			DATE	NUM R7_ENG_1403_Insulation			
DESIGNED BY	Małgorzata Majda		22.06.2024	SIZE A3		SCALE 1:1	SHEET 1 of 1
DRAWN BY	Małgorzata Majda		28.04.2026				
APPROVED BY	Mikołaj Dusziewicz		03.05.2026				



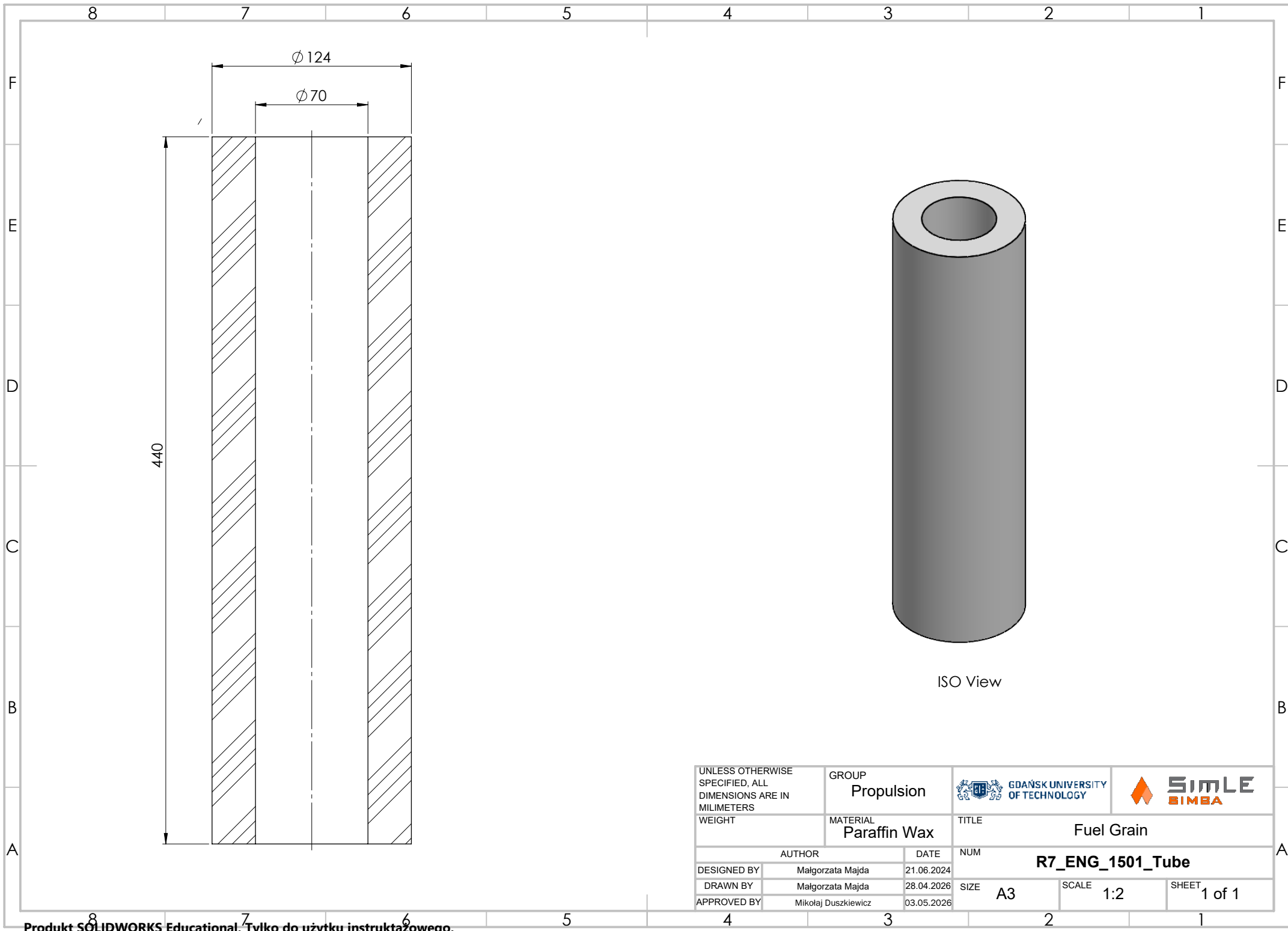
Section A-A
Scale 1 : 3



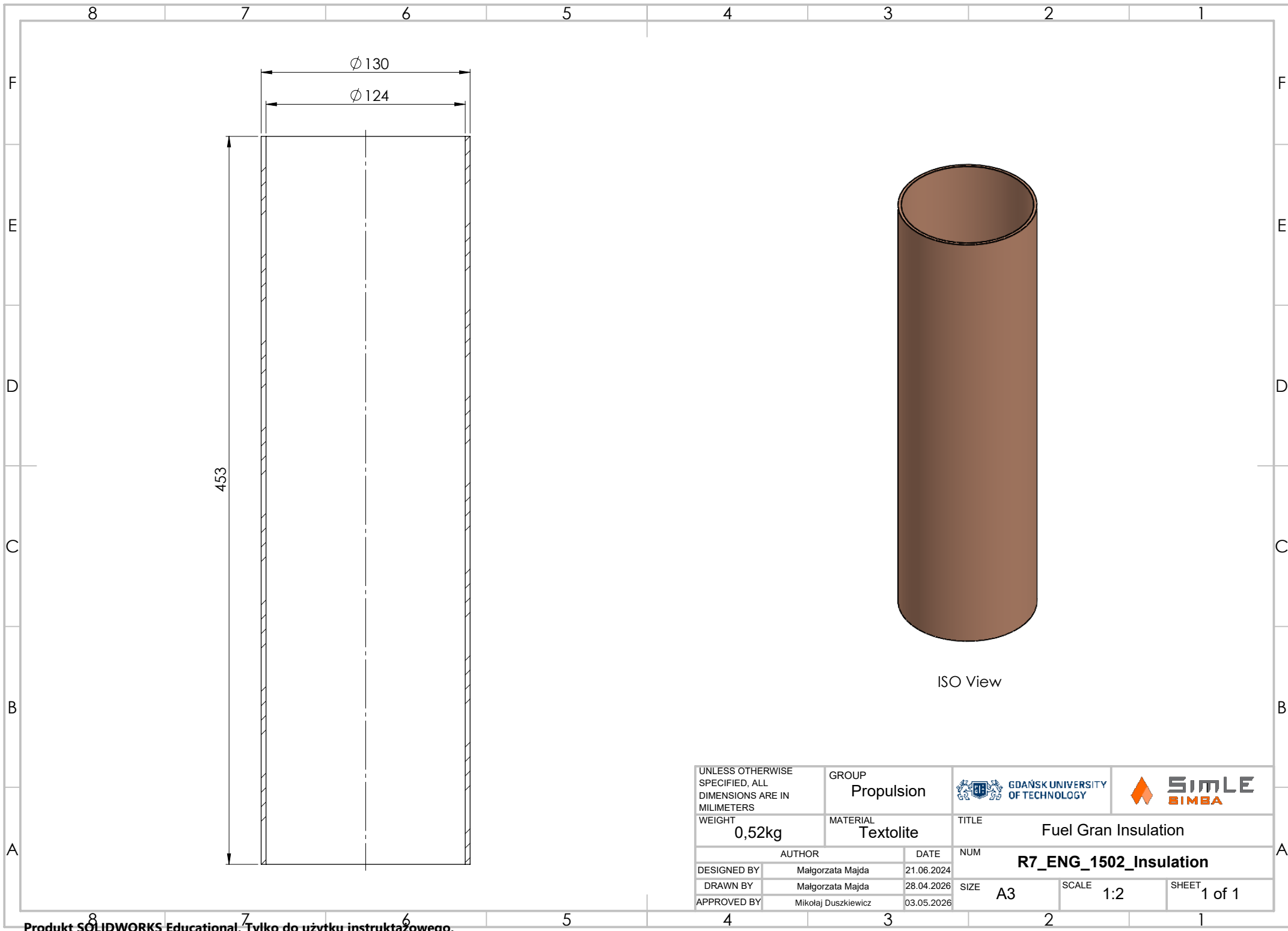
ISO View

Lp	PART NUMBER	DESCRIPTION	QTY
1	R7_ENG_1501_Tube	Fuel Grain	1
2	R7_ENG_1502_Insulation	Fuel Grain Insulation	1
3	R7_ENG_1504_TopWasher	Top Washer	1
4	R7_ENG_1503_BottomWasher	Bottom Washer	1

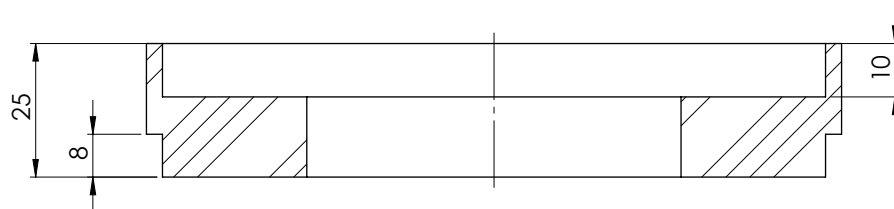
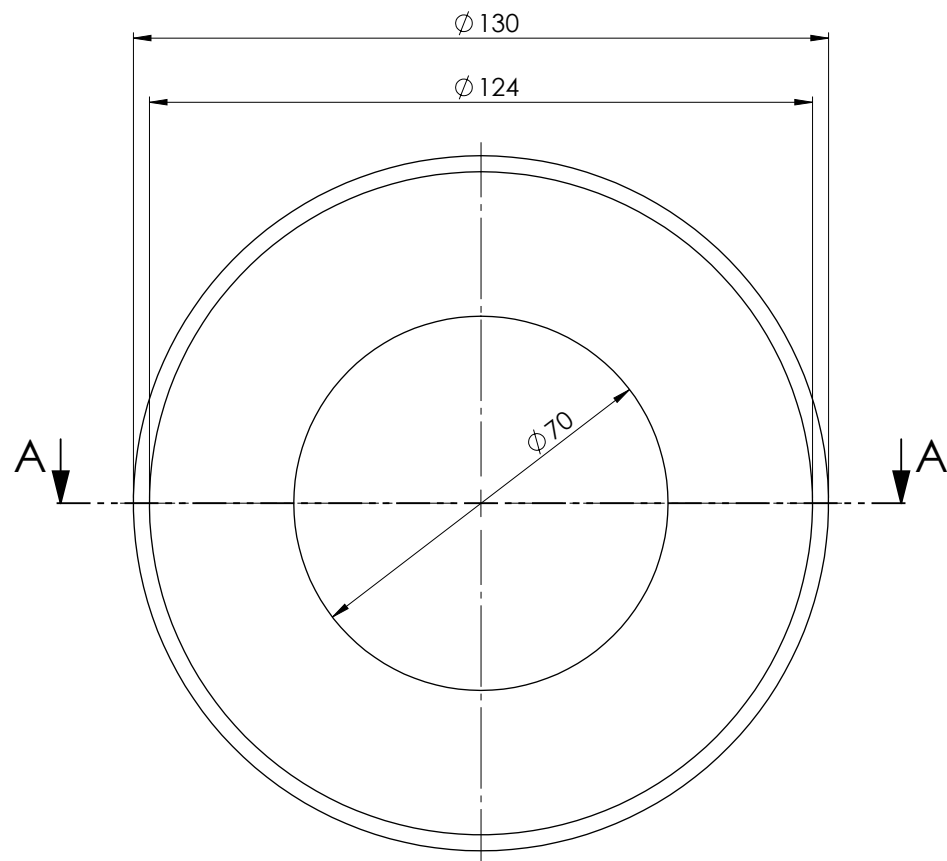
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS WEIGHT	GROUP Propulsion		GDAŃSK UNIVERSITY OF TECHNOLOGY			
	MATERIAL		TITLE Fuel Grain Assembly			
AUTHOR		DATE	NUM R7_ENG_1500_FuelGrain			
DESIGNED BY	Artur Kasiński		01.04.2026		SIZE A3	
DRAWN BY	Małgorzata Majda		28.04.2026			
APPROVED BY	Mikołaj Duszakiewicz		03.05.2026			
				SCALE 1:3		SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE	
		MATERIAL Paraffin Wax		TITLE Fuel Grain			
WEIGHT		AUTHOR		DATE	NUM R7_ENG_1501_Tube		
DESIGNED BY		Małgorzata Majda		21.06.2024	SIZE A3		
DRAWN BY		Małgorzata Majda		28.04.2026			
APPROVED BY		Mikołaj Dusziewicz		03.05.2026	SCALE 1:2		SHEET 1 of 1

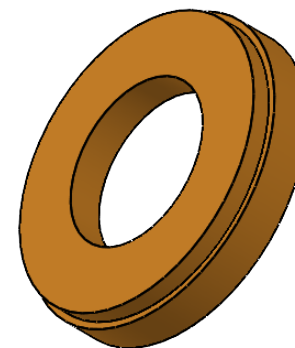


UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE		
		MATERIAL Textolite		TITLE Fuel Gran Insulation				
WEIGHT 0,52kg				NUM R7_ENG_1502_Insulation				
AUTHOR		DATE						
DESIGNED BY	Małgorzata Majda		21.06.2024					
DRAWN BY	Małgorzata Majda		28.04.2026		SIZE A3		SCALE 1:2	
APPROVED BY	Mikołaj Dusziewicz		03.05.2026				SHEET 1 of 1	



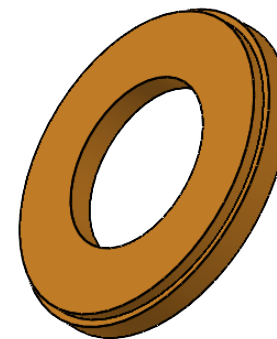
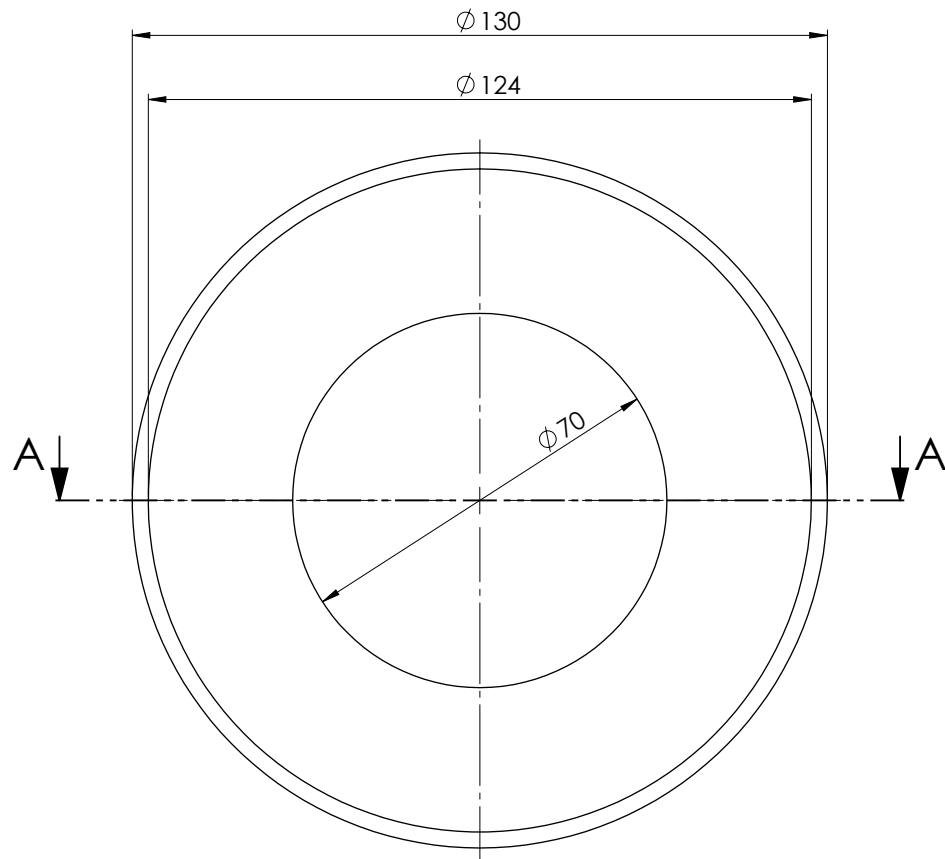
Section A-A

Scale 1 : 1

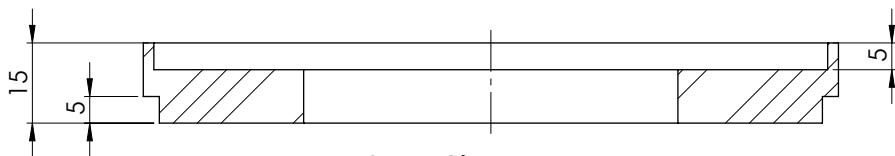


ISO View

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT		MATERIAL Textolite		TITLE Bottom Washer			
AUTHOR			DATE	NUM R7_ENG_1503_BottomWasher			
DESIGNED BY	Małgorzata Majda		5.03.2026	SIZE A3		SCALE 1:1	SHEET 1 of 1
DRAWN BY	Małgorzata Majda		28.04.2026				
APPROVED BY	Mikołaj Duszkievicz		03.05.2026				

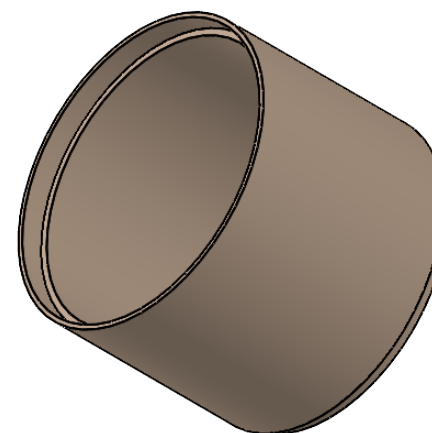
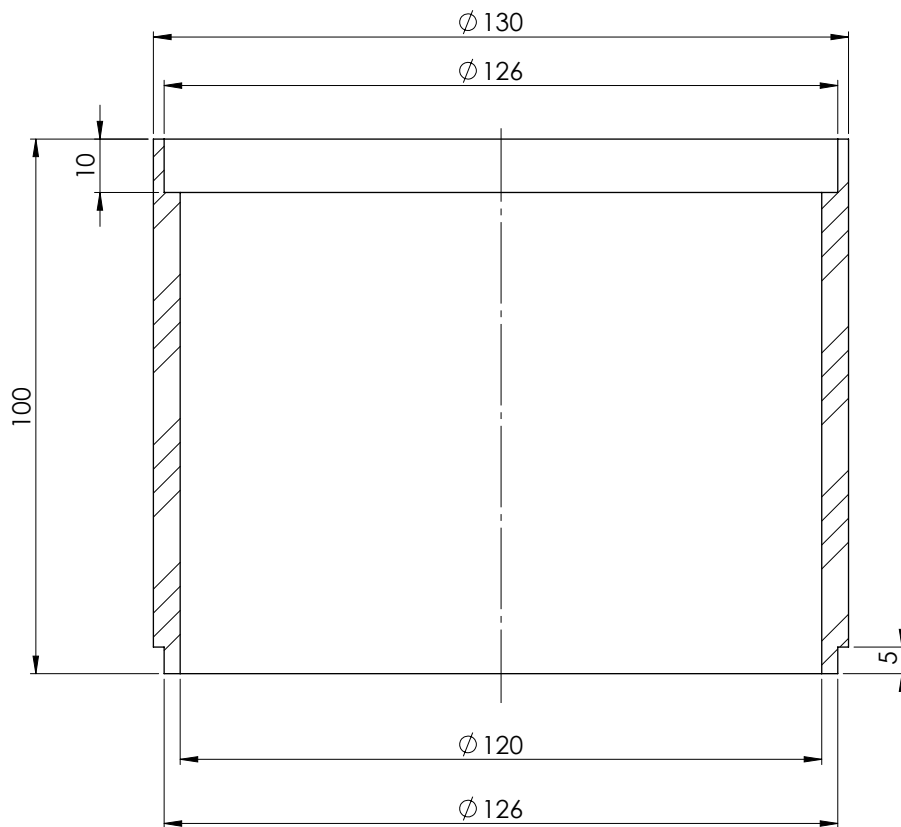


ISO View



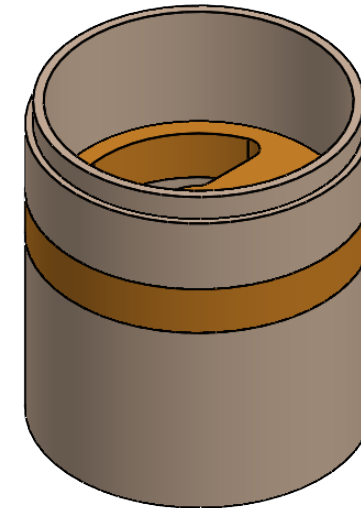
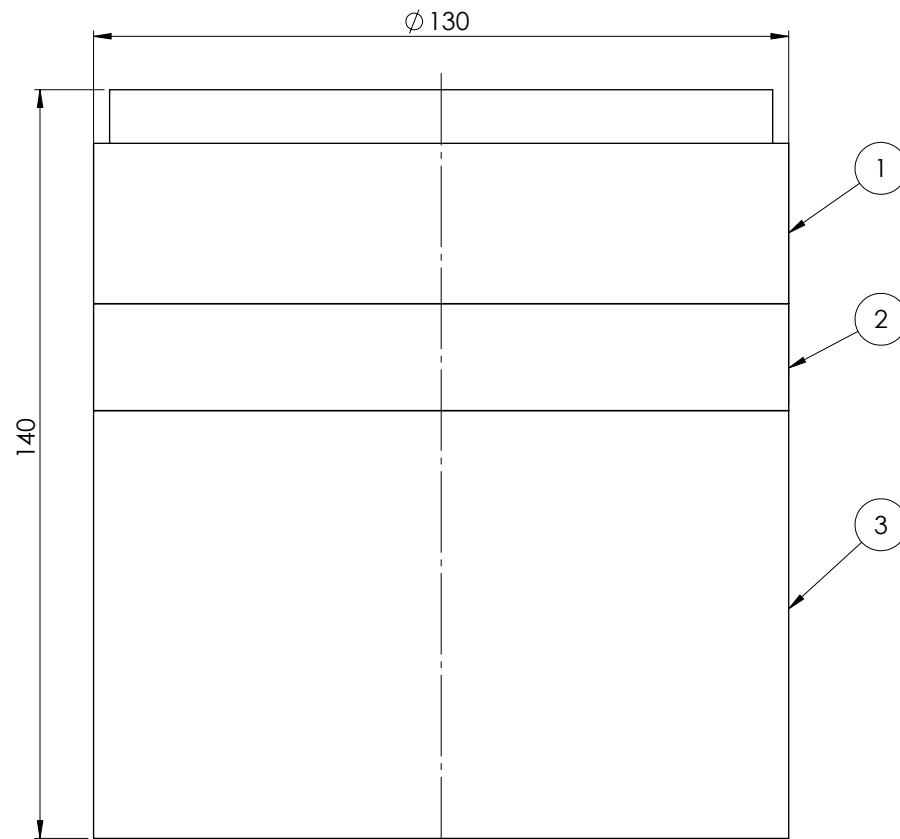
Section A-A
Scale 1 : 1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT		MATERIAL Textolite		TITLE Bottom Washer			
AUTHOR		DATE		NUM R7_ENG_1504_TopWasher			
DESIGNED BY		Małgorzata Majda		5.03.2026			
DRAWN BY		Małgorzata Majda		28.04.2026			
APPROVED BY		Mikołaj Duszkievicz		03.05.2026			
				SIZE A3		SCALE 1:1	
						SHEET 1 of 1	



ISO View

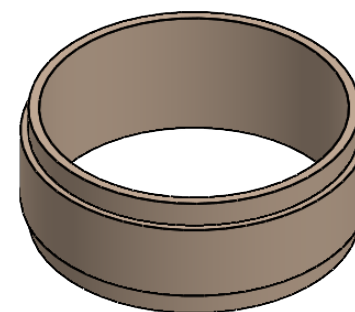
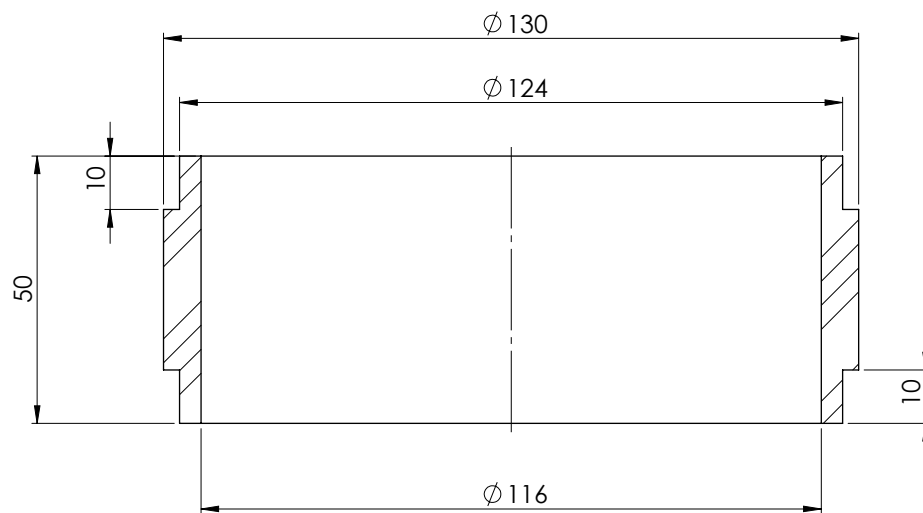
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT		MATERIAL Textolite		TITLE Pre-Combustion Chamber			
AUTHOR		DATE		NUM R7_ENG_1600_PreCC			
DESIGNED BY		Małgorzata Majda		5.03.2026			
DRAWN BY		Małgorzata Majda		28.04.2026			
APPROVED BY		Mikołaj Duszewicz		03.05.2026			
				SIZE A3		SCALE 1:1	
						SHEET 1 of 1	



ISO View

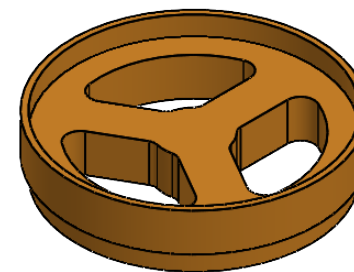
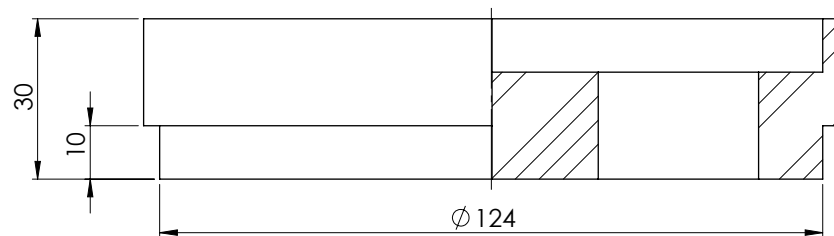
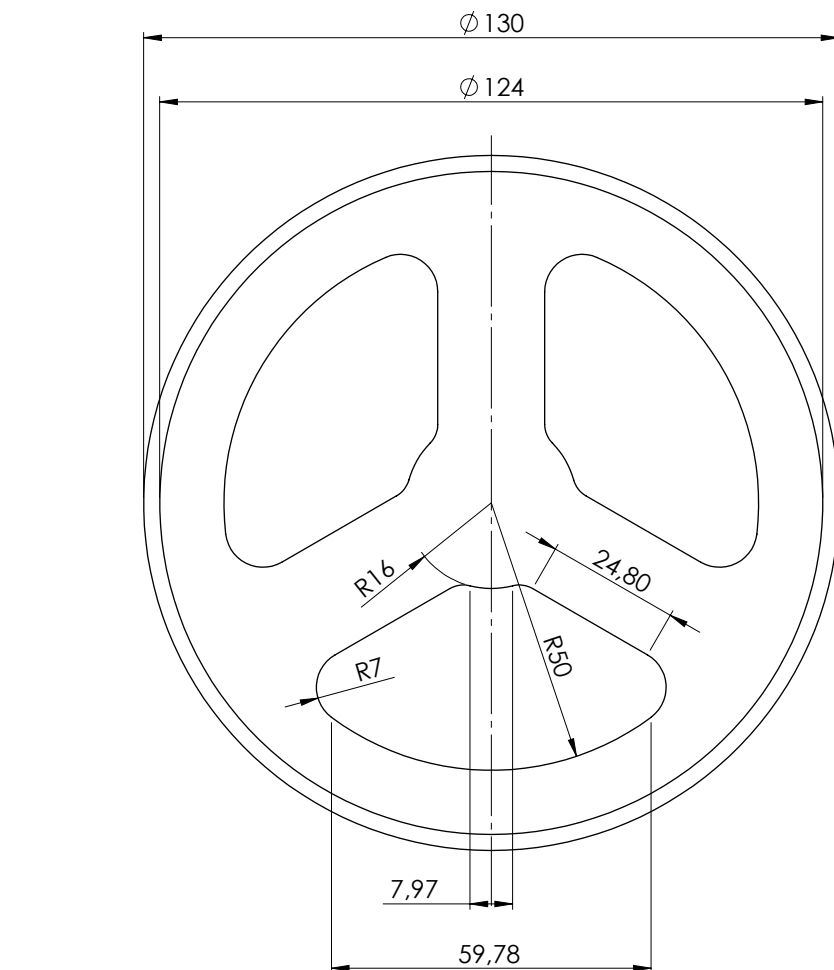
Lp	PART NUMBER	DESCRIPTION		QTY
1	R7_ENG_1701_TopPostCC	Top Post-Combustion Chamber		1
2	R7_ENG_1702_Mixer	Mixer		1
3	R7_ENG_1703_BottomPostCC	Bottom Post-Combustion Chamber		1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion	 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT		MATERIAL Textolite	TITLE Post-Combustion Chamber			
AUTHOR		DATE	NUM R7_ENG_1700_PostCC			
DESIGNED BY	Małgorzata Majda	28.04.2026	SIZE A3			
DRAWN BY	Małgorzata Majda	28.04.2026				
APPROVED BY	Mikołaj Duszkievicz	03.05.2026				
			SCALE 1:1		SHEET 1 of 1	



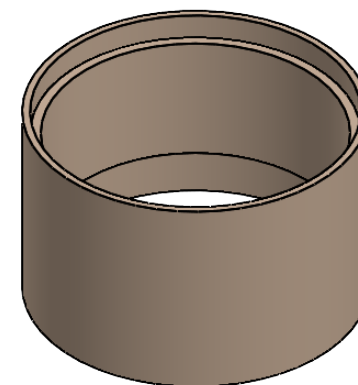
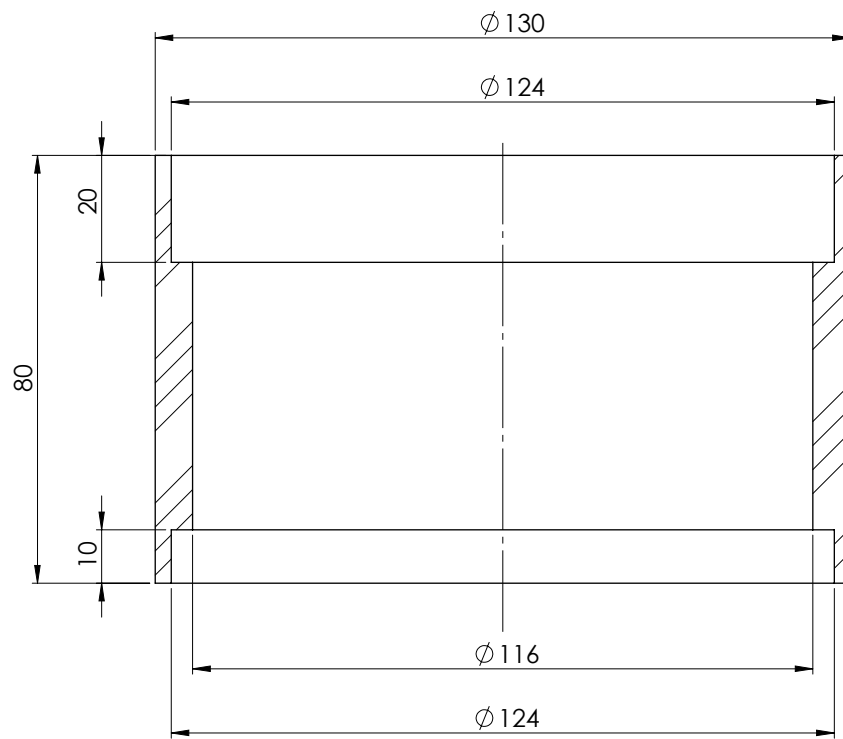
ISO View

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA		
WEIGHT		MATERIAL Textolite		TITLE Top Post-Combustion Chamber				
AUTHOR		DATE		NUM R7_ENG_1701_TopPostCC				
DESIGNED BY	Małgorzata Majda		5.03.2026		SIZE A3		SCALE 1:1	
DRAWN BY	Małgorzata Majda		28.04.2026		SHEET 1 of 1			
APPROVED BY	Mikołaj Duszewicz		03.05.2026					



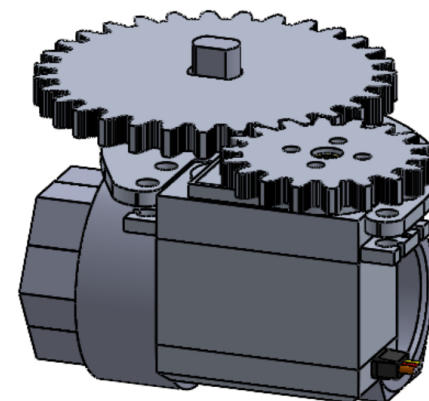
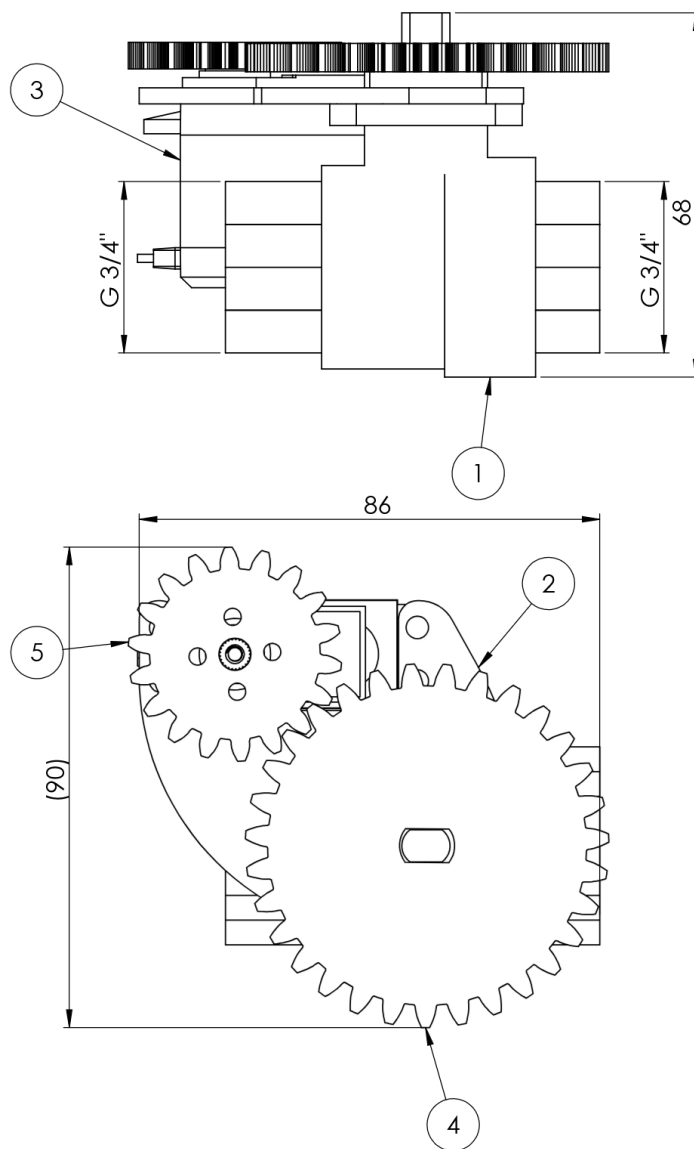
ISO View

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY							
WEIGHT		MATERIAL Textolite		TITLE Mixer							
AUTHOR			DATE	NUM R7_ENG_1702_Mixer							
DESIGNED BY	Małgorzata Majda		8.03.2026	SIZE A3				SCALE 1:1		SHEET 1 of 1	
DRAWN BY	Małgorzata Majda		28.04.2026								
APPROVED BY	Mikołaj Dusziewicz		03.05.2026								



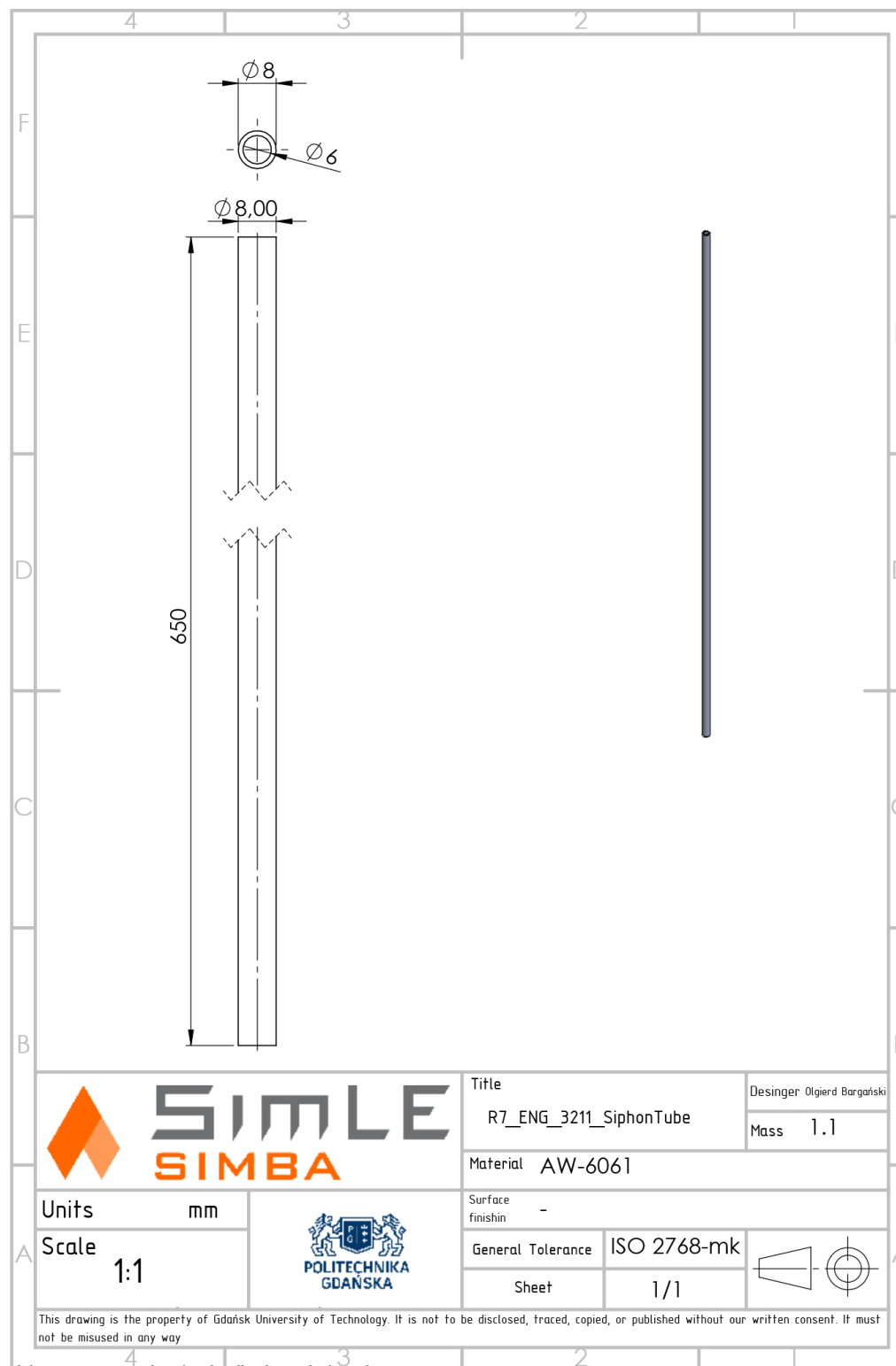
ISO View

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY		 SIMLE SIMBA	
WEIGHT		MATERIAL Textolite		TITLE Bottom Post-Combustion Chamber			
AUTHOR				DATE	NUM R7_ENG_1703_BottomPostCC		
DESIGNED BY		Małgorzata Majda		5.03.2026			
DRAWN BY		Małgorzata Majda		28.04.2026	SIZE	A4	SCALE
APPROVED BY		Mikołaj Duszakiewicz		03.05.2026		1:1	SHEET 1 of 1



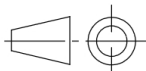
No.	Part Number	Description	Qty
1	R7_ENG_3202_Main_Valve	Main Valve 3/4"	1
2	R7_ENG_3209_Servo_Plate	Servo Plate	1
3	R7_ENG_3206_Servo_Motor	Servo Motor 70 kg	1
4	R7_ENG_3208_Valve_Gear	Valve Gear	1
5	R7_ENG_3207_Servo_Gear	Servo Gear	1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT kg		MATERIAL -		TITLE Main Valve			
AUTHOR		DATE		NUM R7_ENG_32001_Main_Valve			
DESIGNED BY Olgiard Bargański		07.04.2026		SIZE A3			
DRAWN BY Mikołaj Duszkiewicz		20.05.2026					
APPROVED BY				SCALE 1:3		SHEET 1/5	

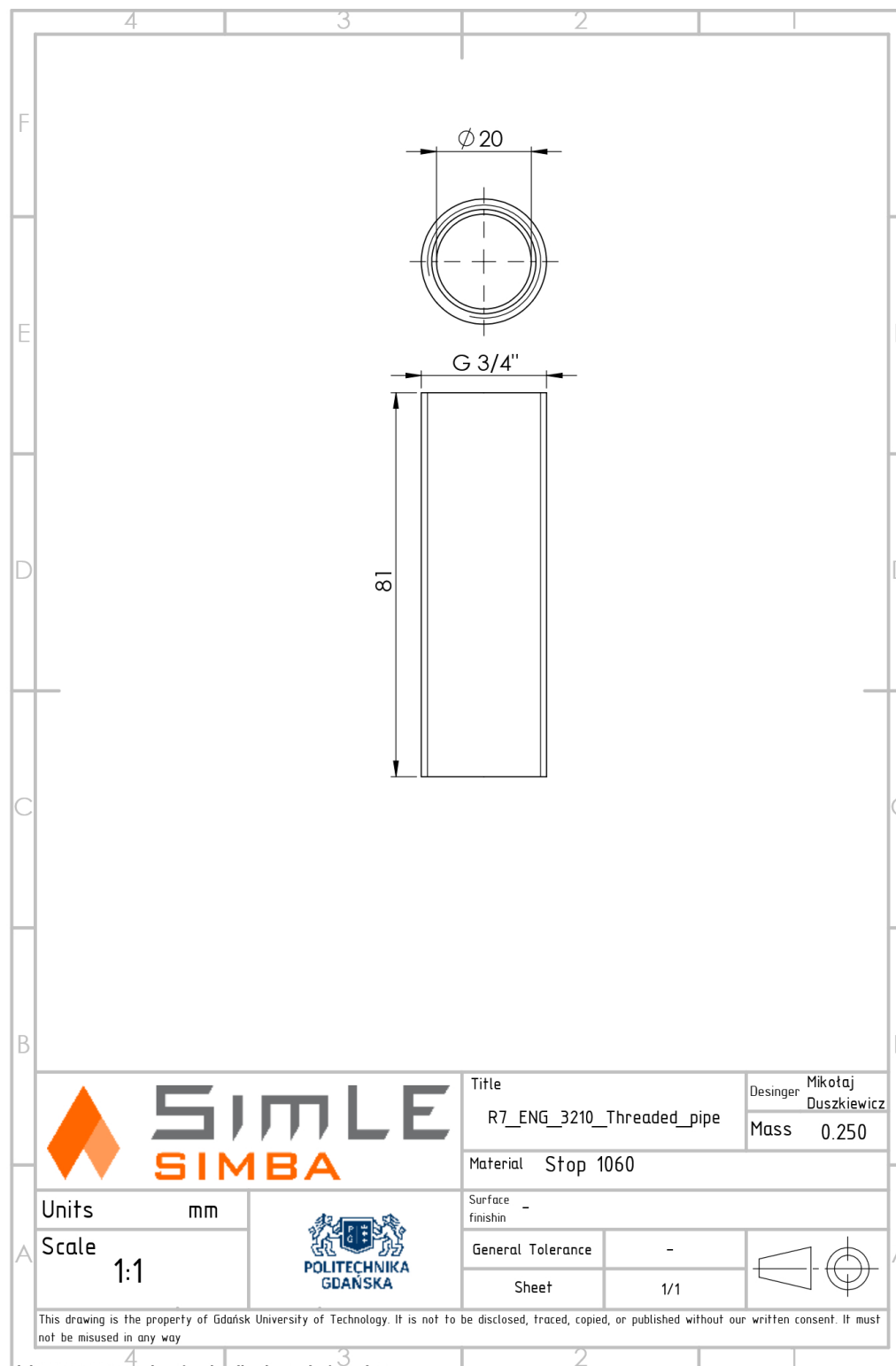


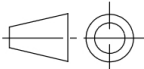
Units mm
Scale 1:1



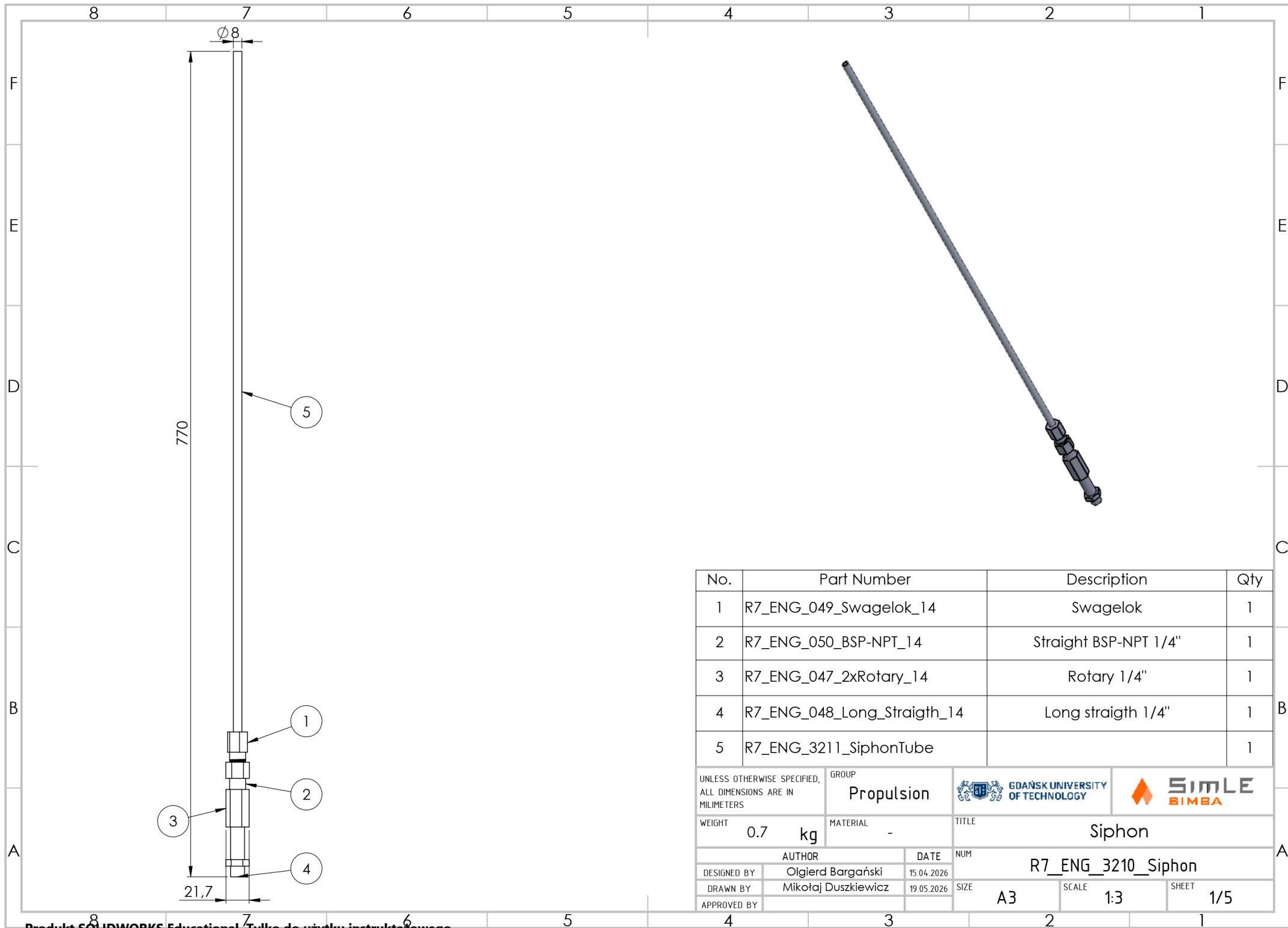
Title		Desinger Olgierd Bargański	
R7_ENG_3211_SiphonTube		Mass	1.1
Material AW-6061			
Surface finishin -			
General Tolerance	ISO 2768-mk		
Sheet	1/1		

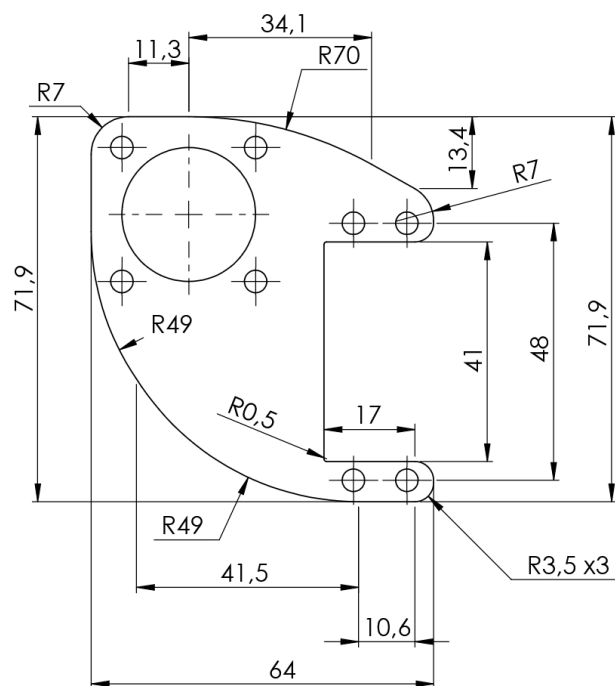
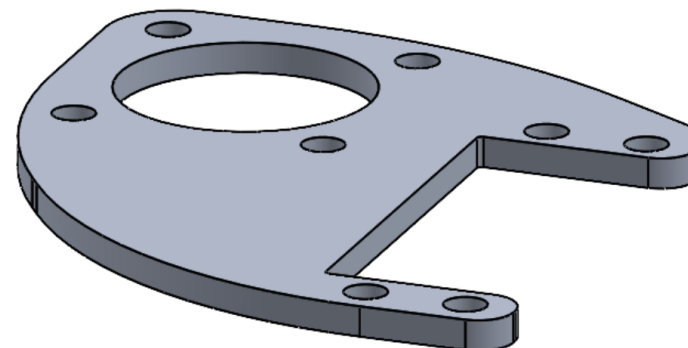
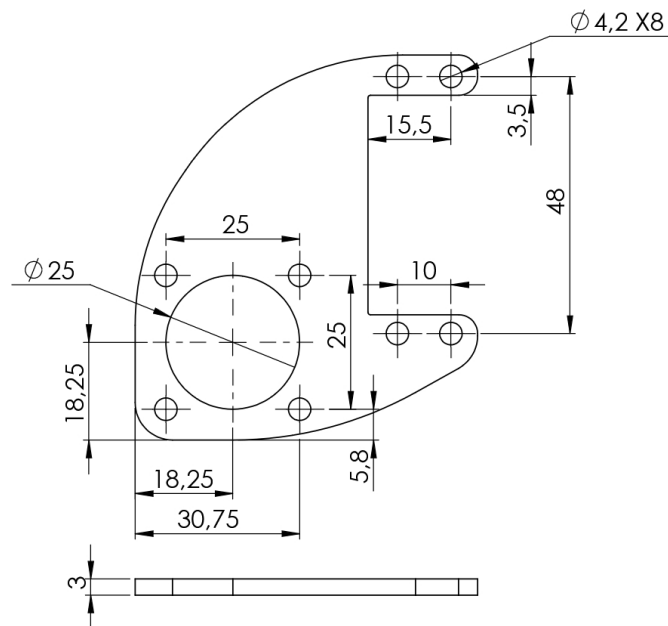
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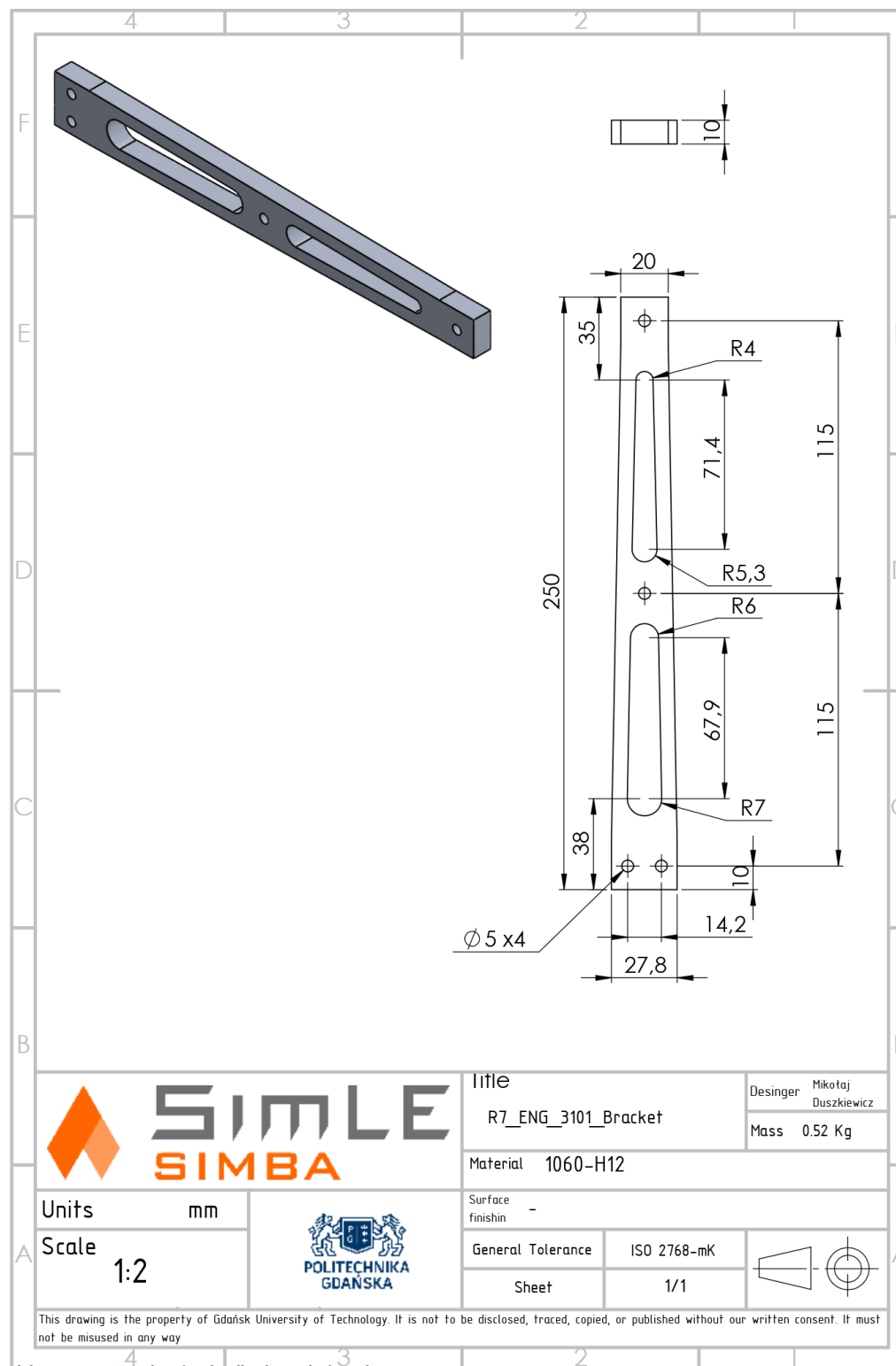
		Title R7_ENG_3210_Threaded_pipe		Desinger Mikołaj Duszkievich
		Material Stop 1060		Mass 0.250
Units mm		Surface finishin -		
Scale 1:1		General Tolerance	-	
		Sheet	1/1	

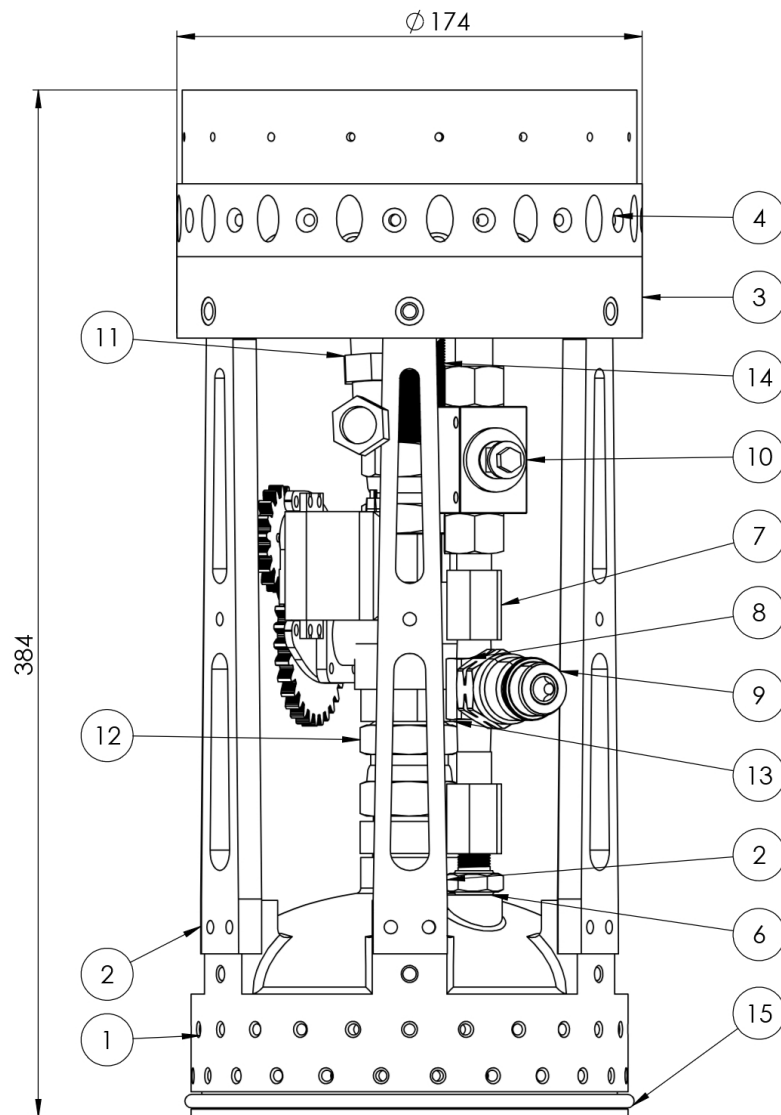
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UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP Propulsion		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT 0.02 kg		MATERIAL 6061 Alloy		TITLE Servo Plate			
AUTHOR		DATE		NUM R7_ENG_3209_Servo_Plate			
DESIGNED BY Olgiard Bargański		11.04.2025					
DRAWN BY Mikołaj Duszkiewicz		20.05.2026		SIZE A3		SCALE 1:3	
APPROVED BY						SHEET 1/5	





No	Part Number	Description	Qty
1	R7_ENG_2300_LowerEndCap	Lower End Cap	1
2	R7_ENG_3101_Bracket	Bracket	6
3	R7_STR_6301_RadaxFeed	Radax Feed	1
4	R7_STR_6302_RadaxEngine	Radax Engine	1
5	R7_ENG_Straight_Fitting_34	Straight Fitting 3/4"	1
6	R7_ENG_046 Straight 14	Straight Fitting 1/4"	1
7	R7_ENG_045_Rotary_14	Rotary	2
8	R7_ENG_051_Threeway_14	Threeway 1/4"	1
9	R7_ENG_052_Quickconnect_14	Quickconnect 1/4"	1
10	R7_ENG_044_Valve_14	Valve 1/4"	1
11	R7_ENG_054_90deg_14	Elbow 90 degree - 1/4"	3
12	R7_ENG_041_Rotary_34	Rotary 3/4"	2
13	R7_ENG_32001_Main_Valve	Main Valve 3/4"	1
14	R7_ENG_3210_Threaded_pipe	Threaded pipe 3/4"	1
15	O-ring 152x5	Seal	1

UNLESS OTHERWISE SPECIFIED,
ALL DIMENSIONS ARE IN
MILLIMETERS

GROUP

Propulsion



GAŃSK UNIVERSITY
OF TECHNOLOGY



SIMLE
BIMBA

WEIGHT

3.2 kg

MATERIAL

-

TITLE

Bottom Feed Assembly

DESIGNED BY

Olgiard Bargański

DATE

11.04.2025

DRAWN BY

Mikołaj Duszkiewicz

APPROVED BY

NUM

R7_ENG_3000_BottomFeed

SIZE

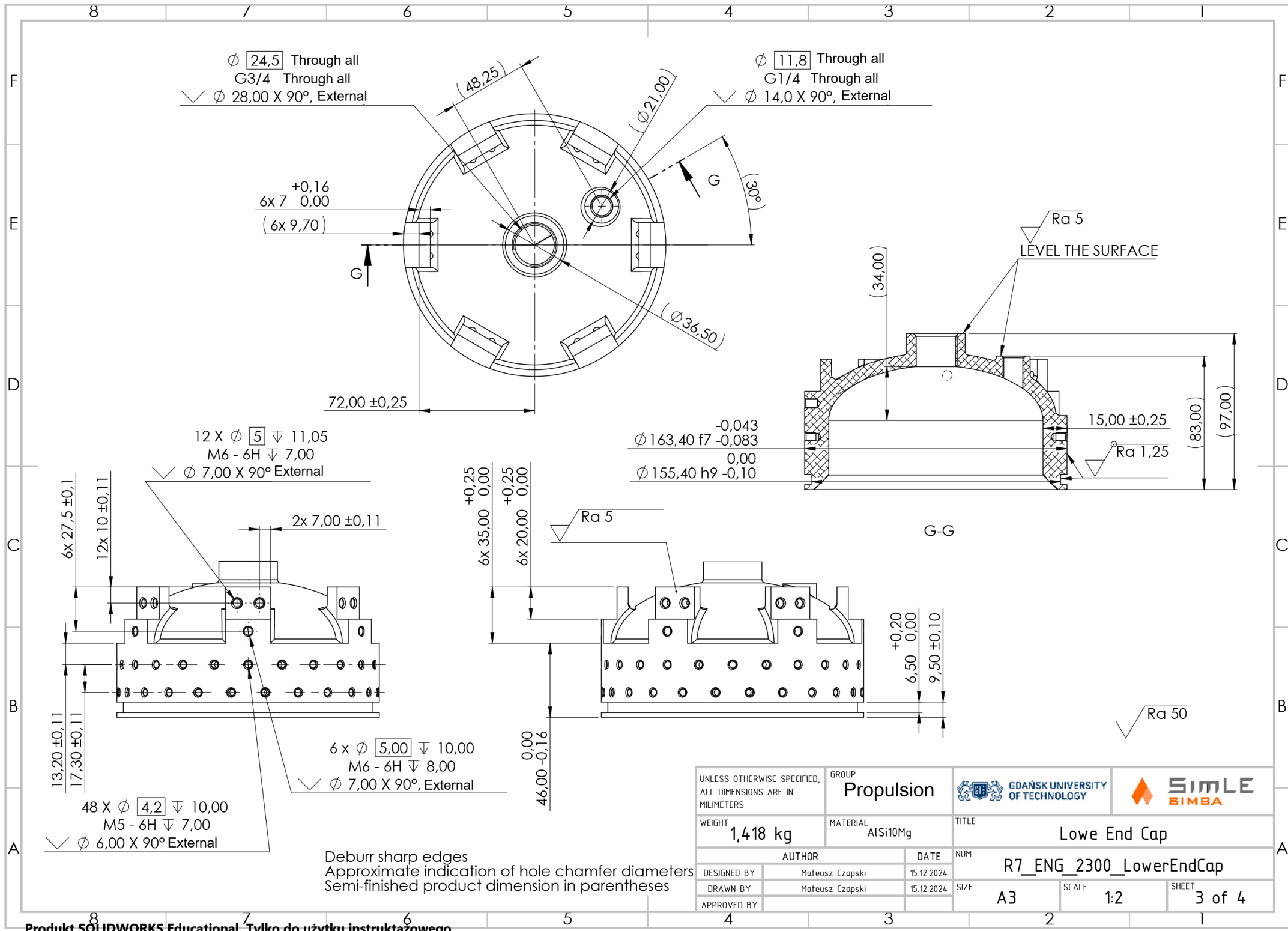
A3

SCALE

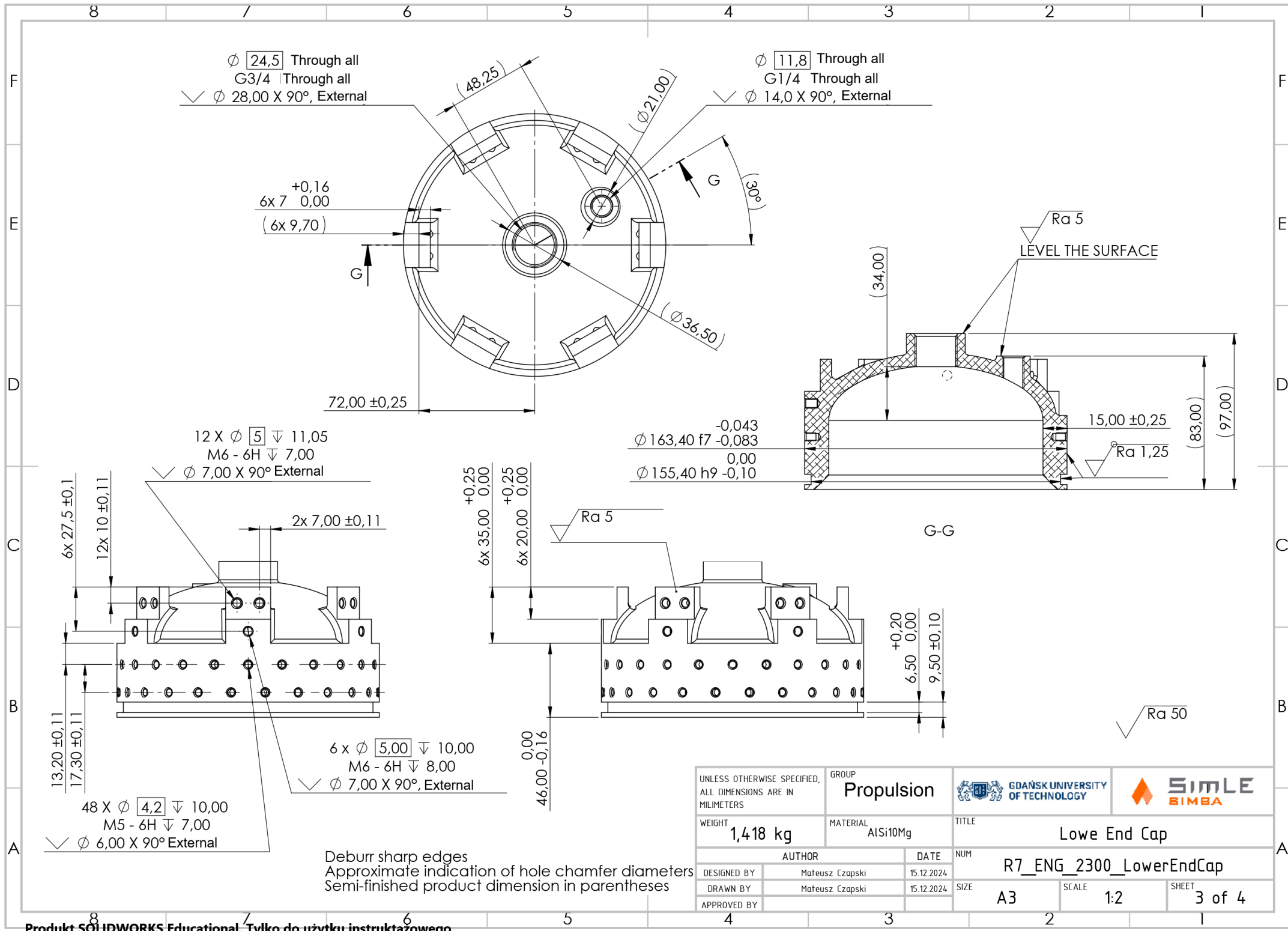
1:3

SHEET

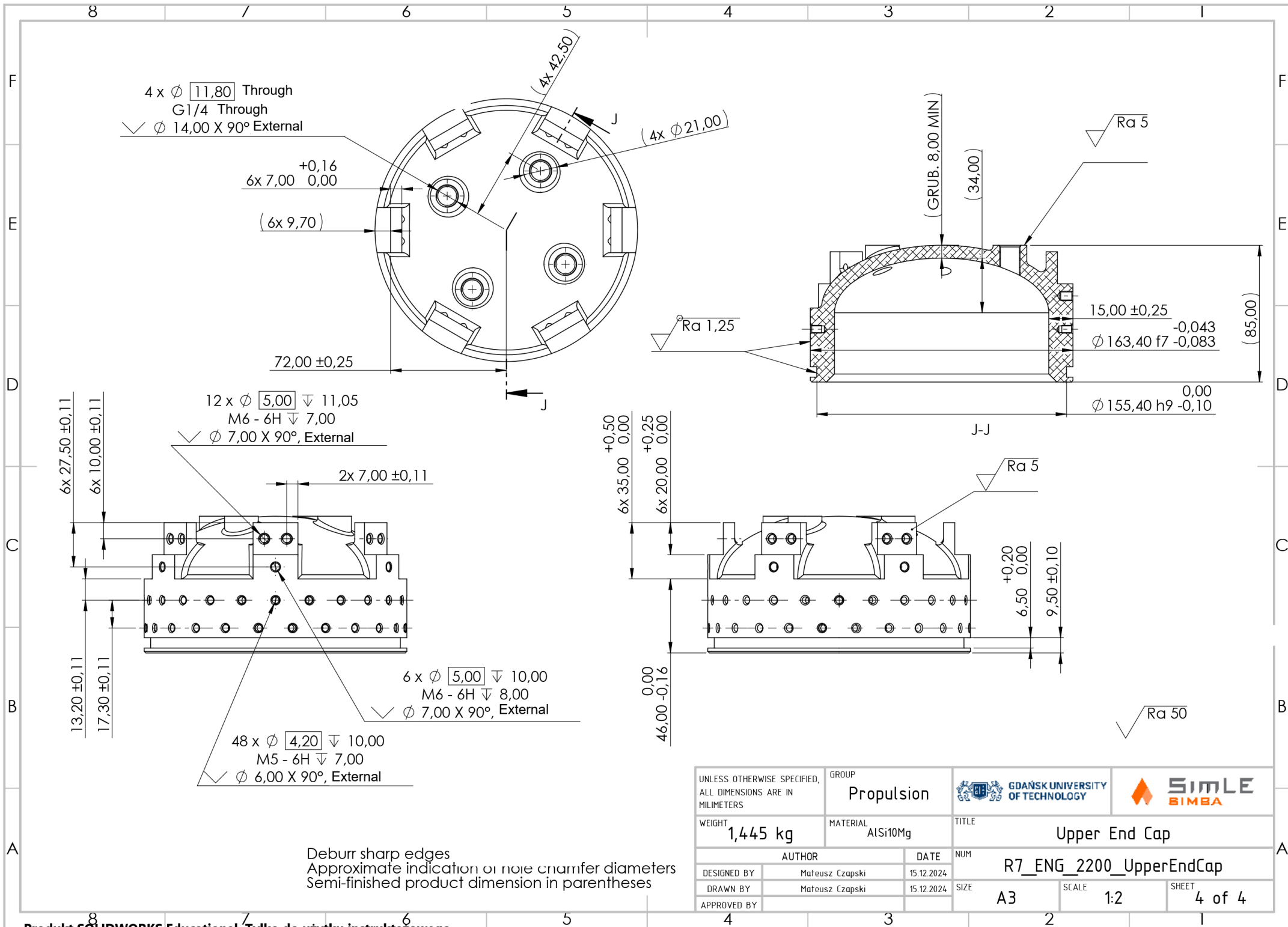
1/5



UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP Propulsion	 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT 1,418 kg		MATERIAL AlSi10Mg	TITLE Lowe End Cap			
AUTHOR		DATE	NUM R7_ENG_2300_LowerEndCap			
DESIGNED BY	Mateusz Czapski	15.12.2024	SIZE A3			
DRAWN BY	Mateusz Czapski	15.12.2024				
APPROVED BY			SCALE 1:2		SHEET 3 of 4	

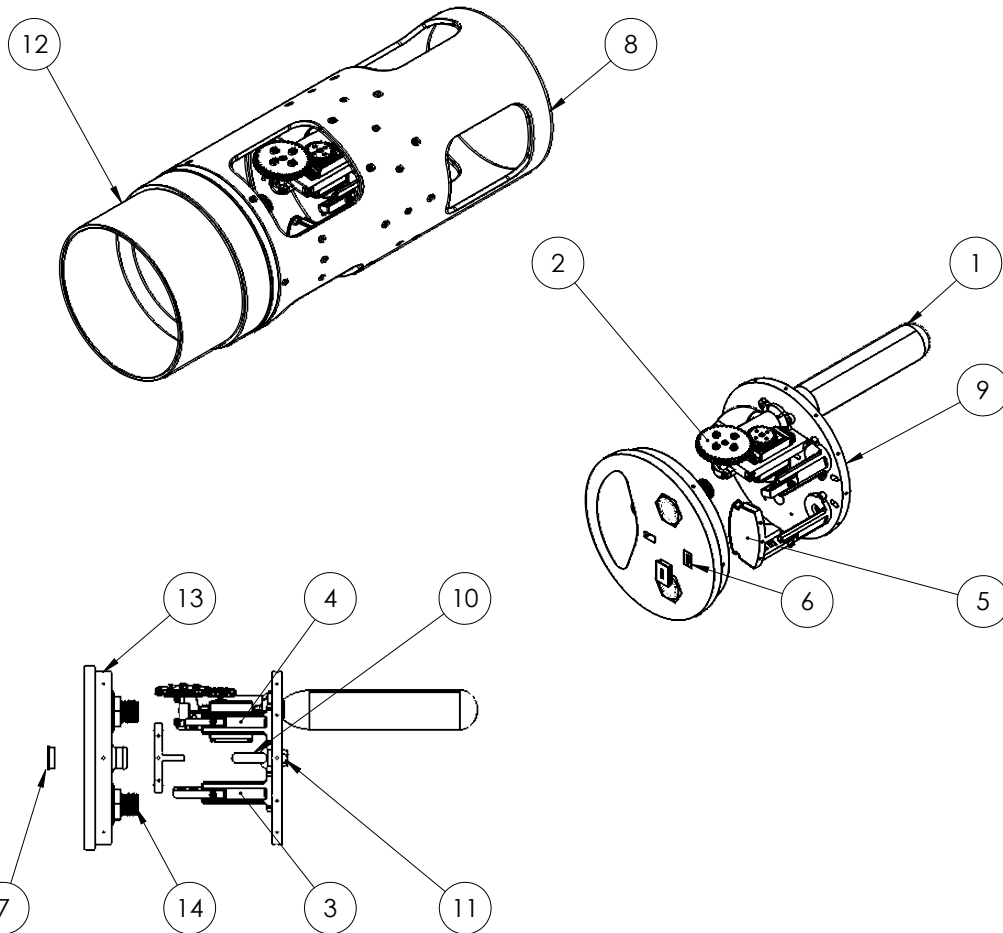
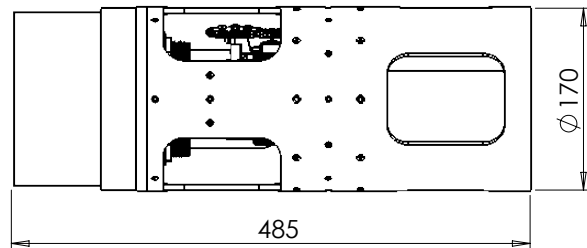


UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP Propulsion	 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT 1,418 kg		MATERIAL AlSi10Mg	TITLE Lowe End Cap			
AUTHOR		DATE	NUM R7_ENG_2300_LowerEndCap			
DESIGNED BY	Mateusz Czapski	15.12.2024	SIZE A3			
DRAWN BY	Mateusz Czapski	15.12.2024				
APPROVED BY			SCALE 1:2		SHEET 3 of 4	



UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP Propulsion	 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT 1,445 kg		MATERIAL AlSi10Mg	TITLE Upper End Cap			
AUTHOR		DATE	NUM R7_ENG_2200_UpperEndCap			
DESIGNED BY	Mateusz Czapski	15.12.2024				
DRAWN BY	Mateusz Czapski	15.12.2024				
APPROVED BY			A3		SCALE 1:2	SHEET 4 of 4

C.3 Recovery

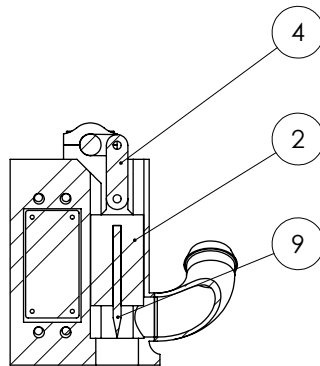
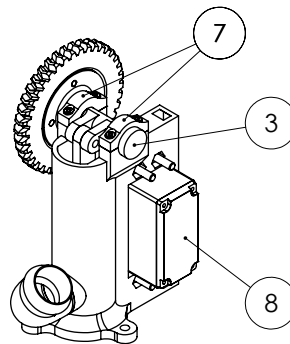
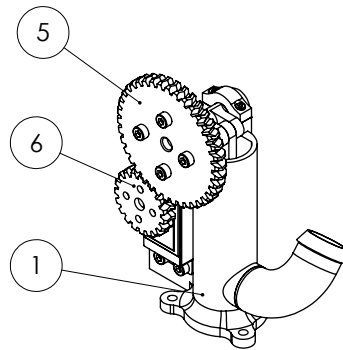
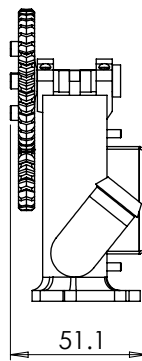
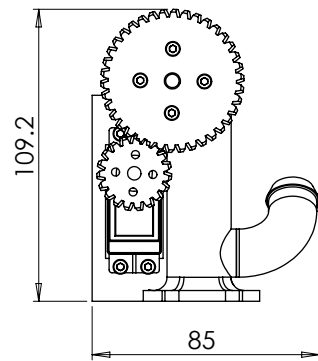


Remarks

1. Drawings of all elements are for demonstration, only bulk dimensions are given
2. Remove supports from all printed elements
3. Deburr all edges

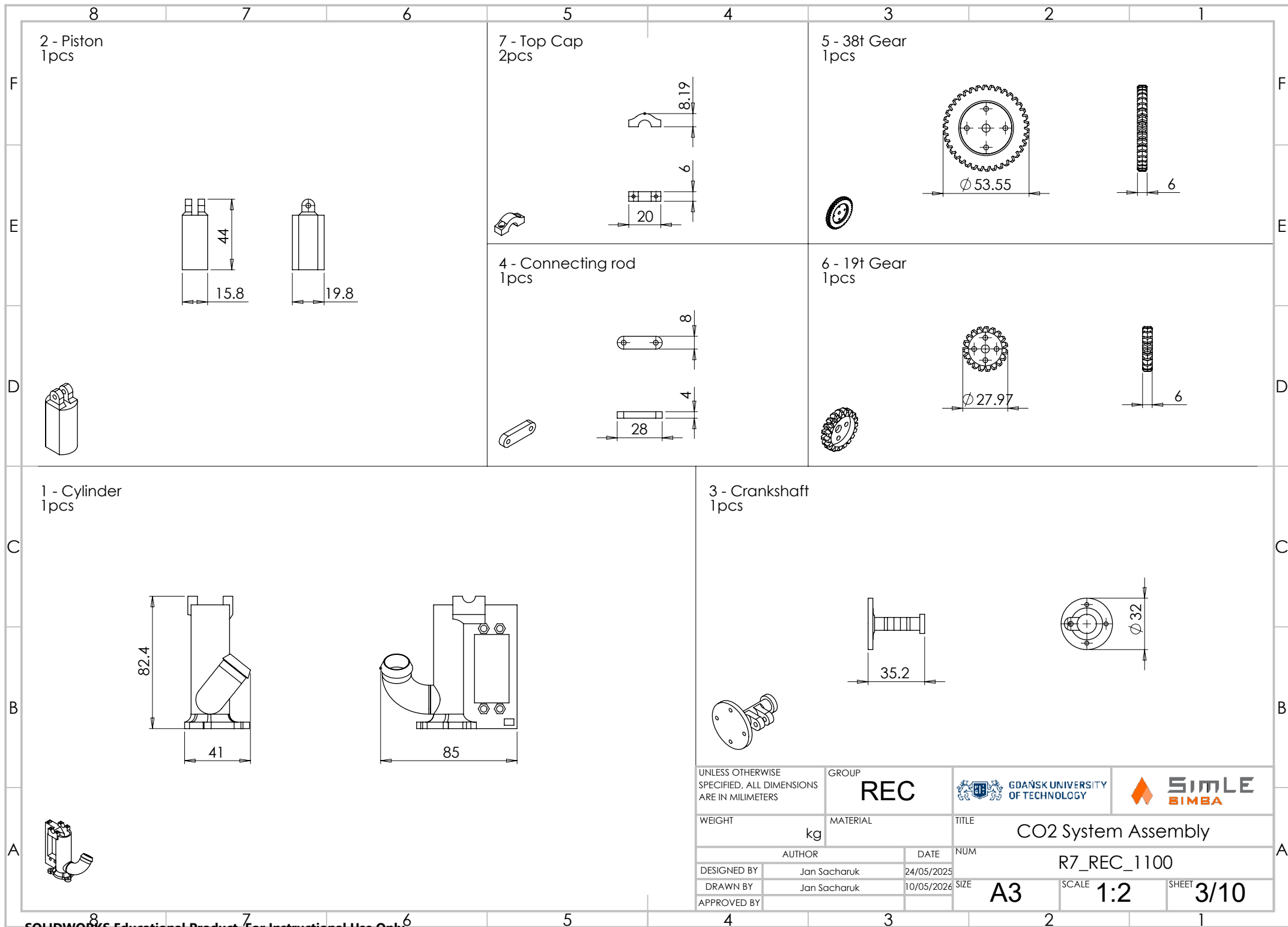
ITEM NO.	PART NUMBER	QTY.
1	88g CO2 Cartridge	1
2	R7_REC_1100_SingleCO2SYS	1
3	R7_REC_1200_LineCutterLeft	1
4	R7_REC_1200_LineCutterRight	1
5	R7_REC_1203_Tension Plate	1
6	R7_REC_1204_Lower Seal	1
7	R7_REC_1205_Upper Seal	1
8	R7_REC_1301_Coupler	1
9	R7_REC_1302_Baseplate	1
10	M8 Eyebolt	1
11	DIN EN ISO 7042 - M8 - N	1
12	R7_REC_1304_Pushtube	1
13	R7_REC_1303_SingleRing2xBP	1
14	R7_REC_1600_ChargeAssem	2

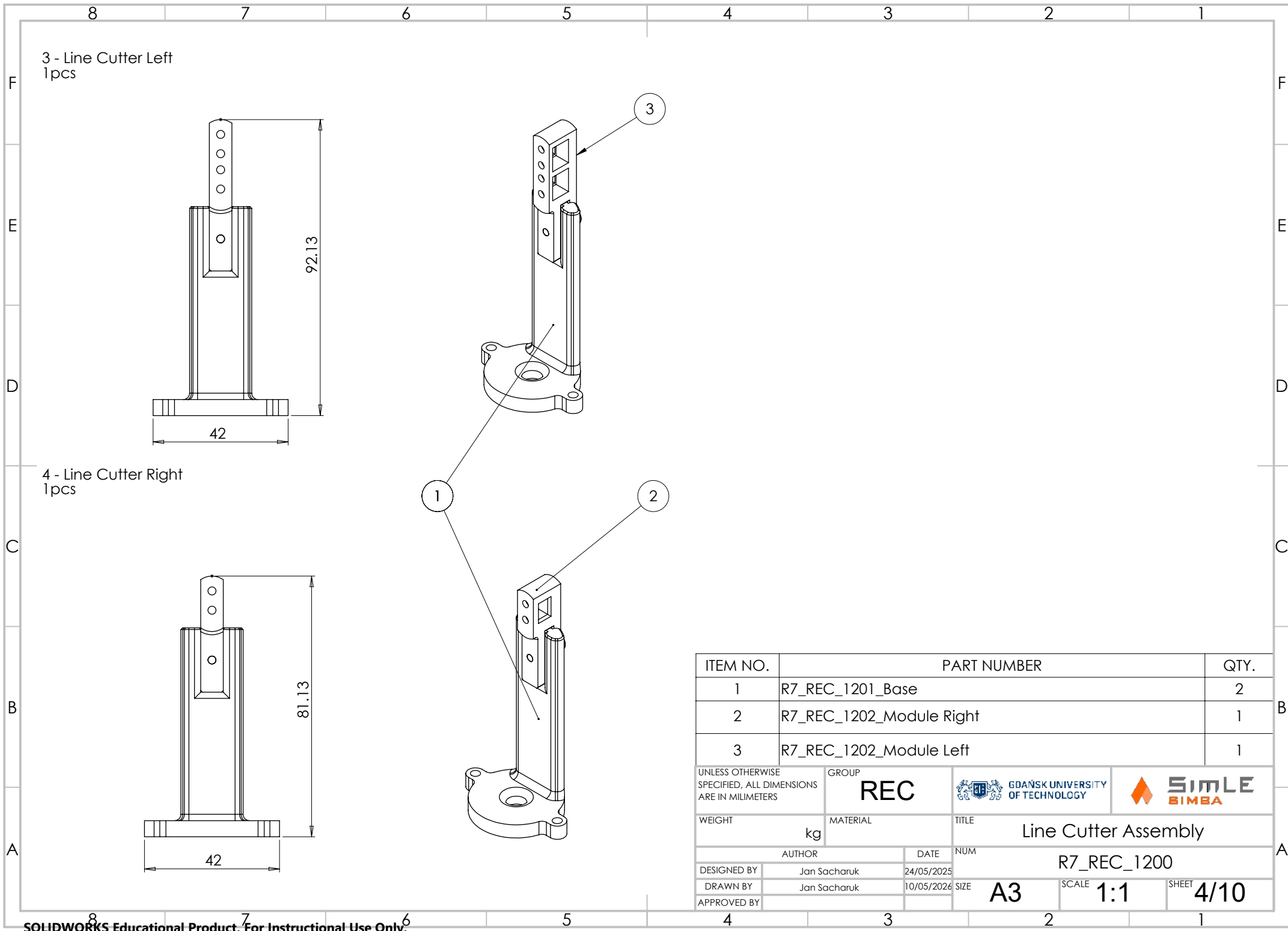
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP REC	GDANSK UNIVERSITY OF TECHNOLOGY	SIMLE BIMBA
WEIGHT N/A kg	MATERIAL N/A	TITLE Recovery System		
AUTHOR		DATE	NUM	R7_REC_0000
DESIGNED BY	Jan Sacharuk	27/11/2025	SIZE	A3
DRAWN BY	Jan Sacharuk	10/05/2026	SCALE	1:5
APPROVED BY			SHEET	1/10

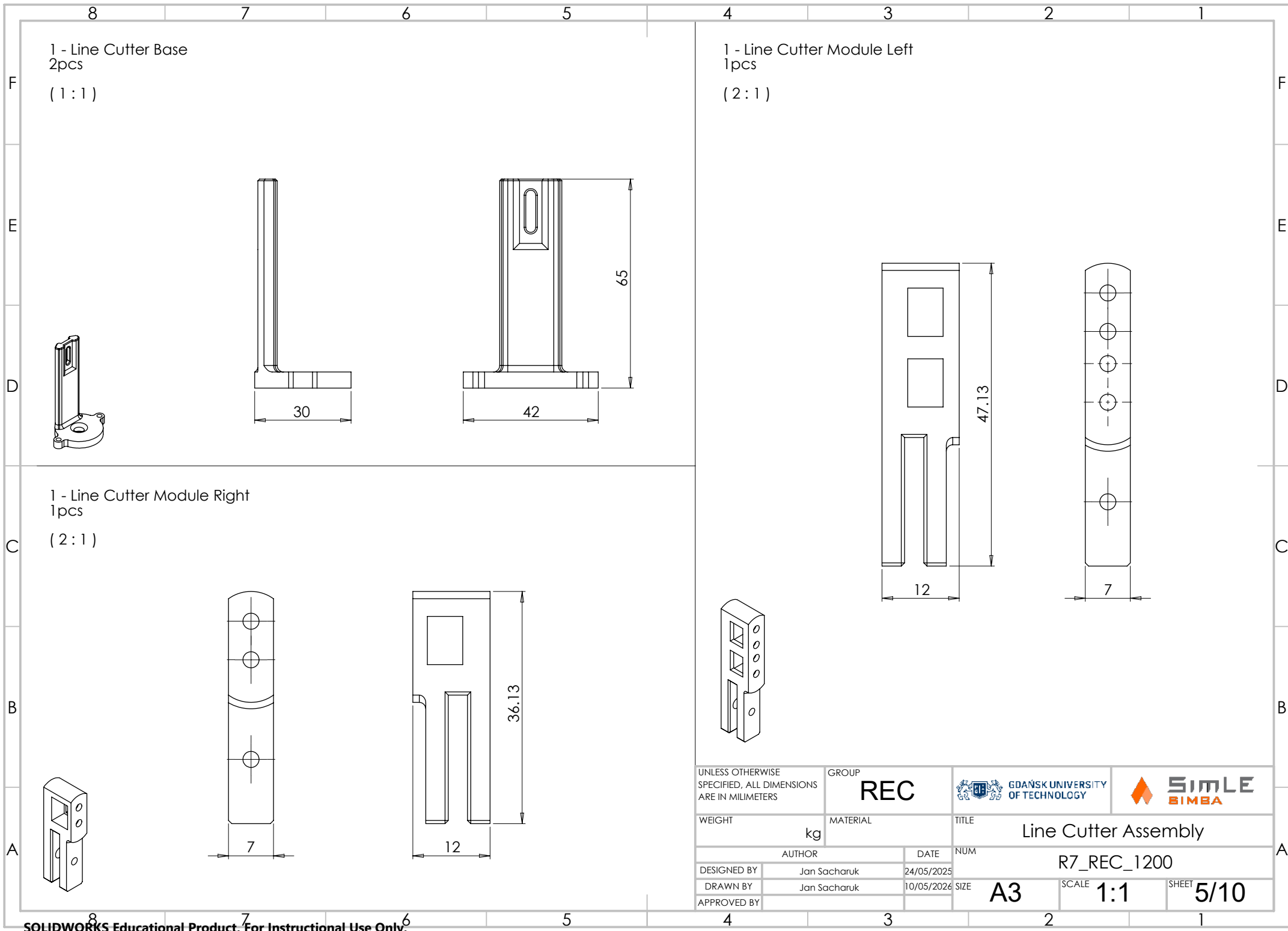


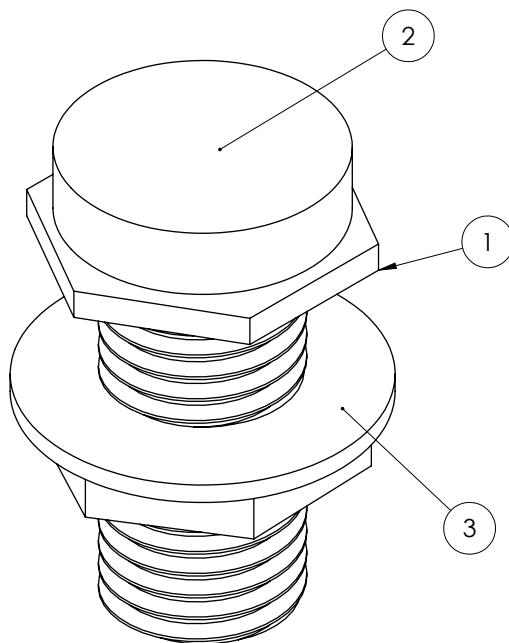
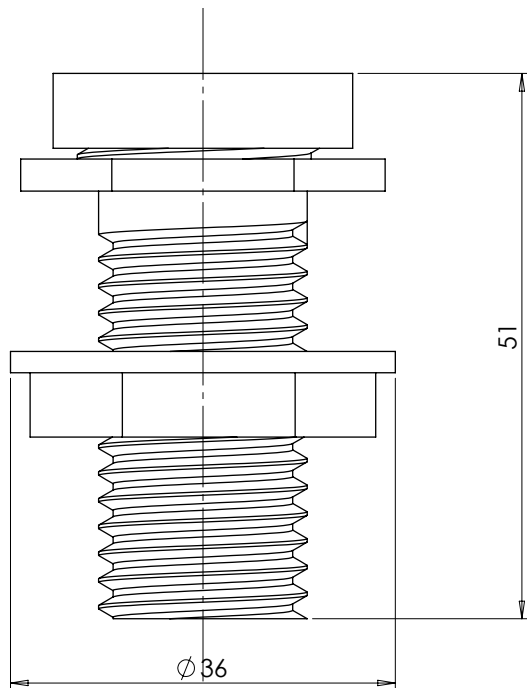
ITEM NO.	PART NUMBER	QTY.
1	R7_REC_1101_Cylinder	1
2	R7_REC_1102_Piston	1
3	R7_REC_1103_Crankshaft	1
4	R7_REC_1104_Connecting rod	1
5	R7_REC_1105_38tGear	1
6	R7_REC_1106_19tGear	1
7	R7_REC_1107_TopCap	2
8	R7_REC_1114_StandardServo	1
9	Needle	1

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILIMETERS		GROUP REC	GDANSK UNIVERSITY OF TECHNOLOGY	SIMLE BIMBA
WEIGHT kg	MATERIAL	TITLE CO2 System Assembly		
AUTHOR	DATE	NUM	R7_REC_1100	
DESIGNED BY Jan Sacharuk	24/05/2025	SIZE	A3	SHEET 2/10
DRAWN BY Jan Sacharuk	10/05/2026	SCALE	1:2	
APPROVED BY				

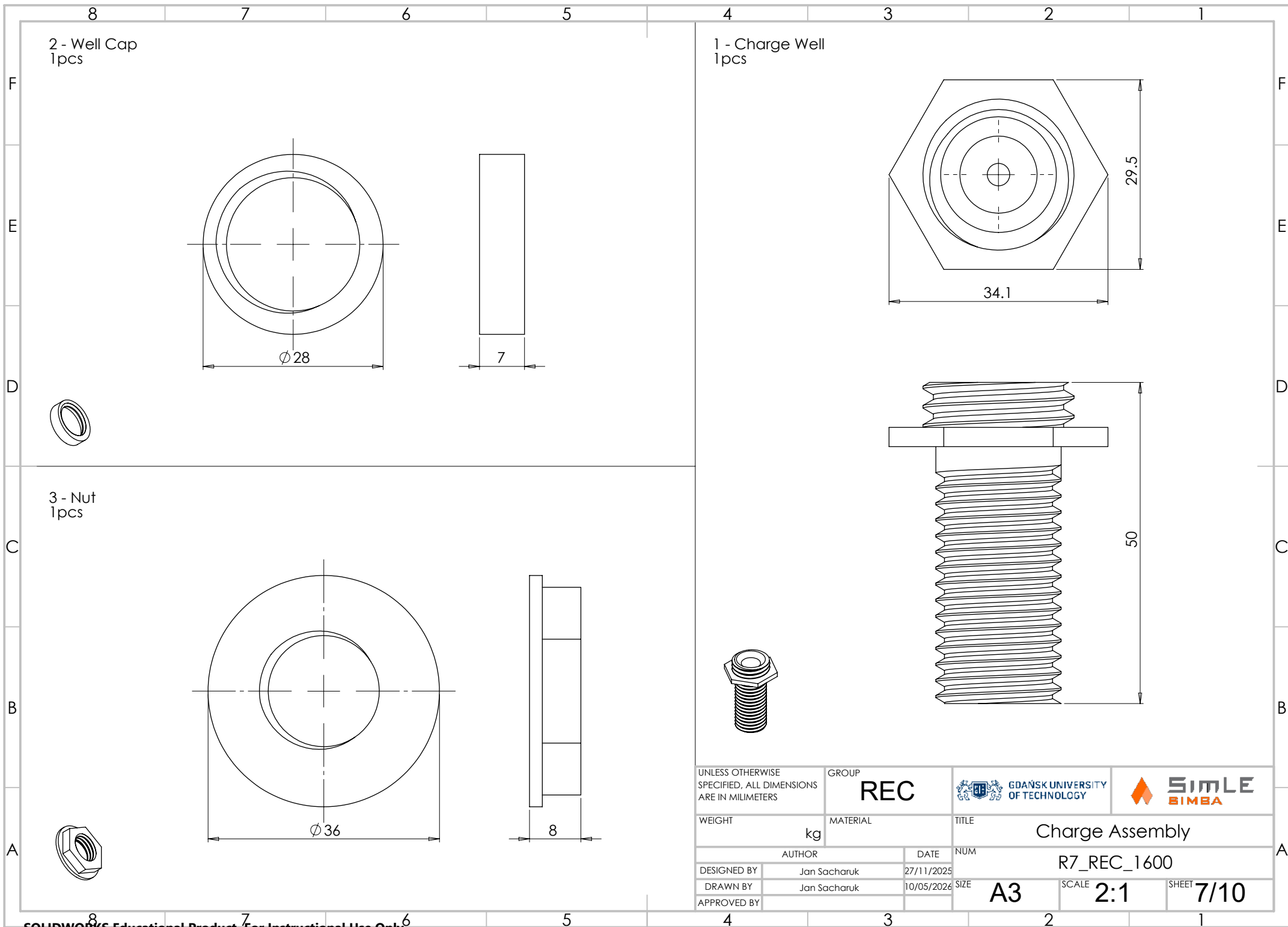


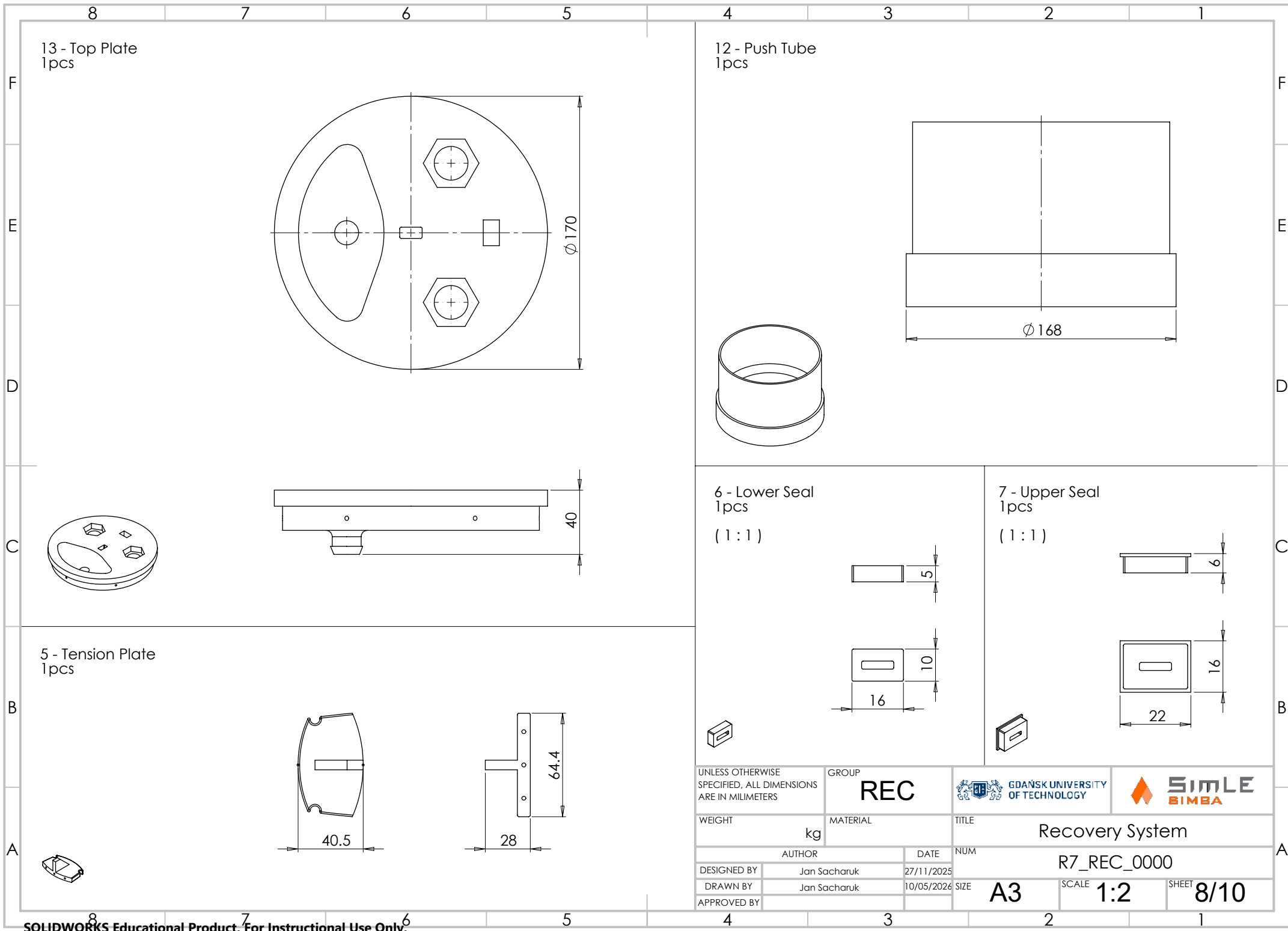




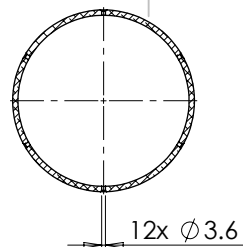
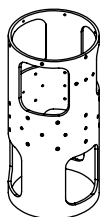
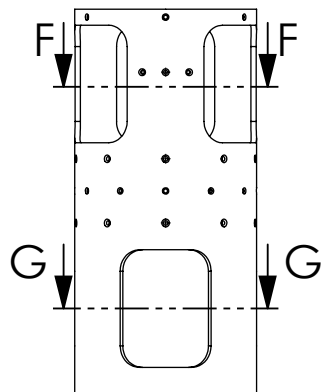
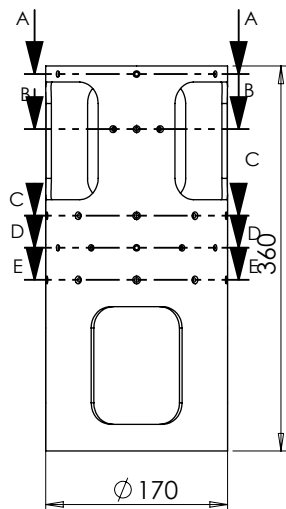


ITEM NO.	PART NUMBER		QTY.
1	R7_REC_1601_ChargeWell		1
2	R7_REC_1602_WellCap		1
3	R7_REC_1603_Nut		1
UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP REC	 GDAŃSK UNIVERSITY OF TECHNOLOGY 
WEIGHT kg		MATERIAL	TITLE Charge Assembly
AUTHOR		DATE	NUM R7_REC_1600
DESIGNED BY	Jan Sacharuk	27/11/2025	SIZE A3
DRAWN BY	Jan Sacharuk	10/05/2026	
APPROVED BY			SCALE 2:1
			SHEET 6/10

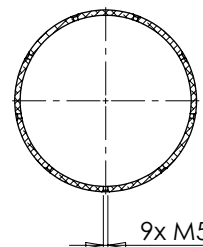




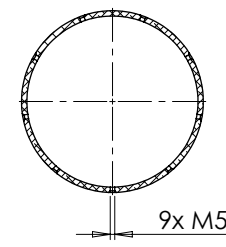
8 - Coupler
1 pcs



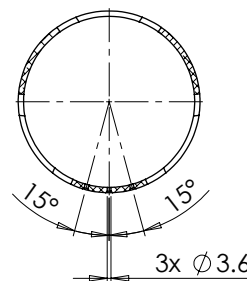
SECTION A-A



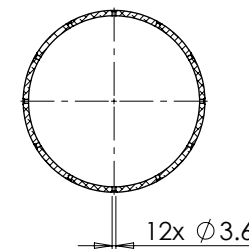
SECTION C-C



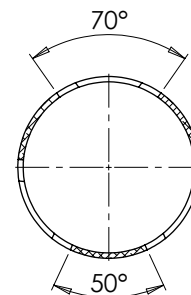
SECTION E-E



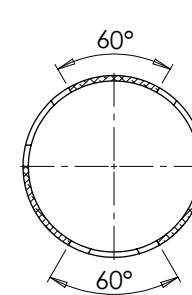
SECTION B-B



SECTION D-D



SECTION F-F

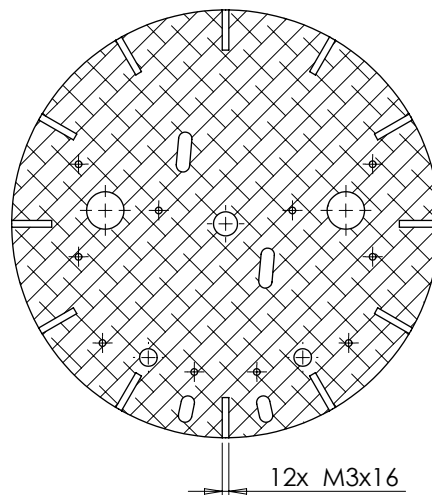


SECTION G-G

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP REC		 GDAŃSK UNIVERSITY OF TECHNOLOGY			
WEIGHT kg		MATERIAL		TITLE Recovery System			
AUTHOR		DATE		NUM R7_REC_0000			
DESIGNED BY Jan Sacharuk		24/04/2025		SIZE A3			
DRAWN BY Jan Sacharuk		10/05/2026					
APPROVED BY				SCALE 1:5		SHEET 9/10	

Technical drawing of a circular mechanical part, likely a flange or end plate, showing dimensions and features:

- Overall diameter: $\varnothing 115.5$
- Inner diameter: $\varnothing 40.00$
- Outer diameter of the central hole: $\varnothing 90.55$
- Central hole diameter: $\varnothing 40.00$
- Two large circular holes (for bolts) with diameter $\varnothing 40.00$.
- Two smaller circular holes (for bolts) with diameter $\varnothing 16.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 10.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 8.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 6.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 5.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 4.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 3.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 2.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 1.50$.
- Two small circular holes (for bolts) with diameter $\varnothing 1.00$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.50$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.25$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.125$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.0625$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.03125$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.015625$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.0078125$.
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- Two small circular holes (for bolts) with diameter $\varnothing 0.00006103515625$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.000030517578125$.
- Two small circular holes (for bolts) with diameter $\varnothing 0.0000152587890625$.
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- Two small circular holes (for bolts) with diameter $\varnothing 0.000000000000000000108420217248550435588245280086994171142578$



UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS		GROUP REC		 GDANSK UNIVERSITY OF TECHNOLOGY		 SIMLE BIMBA	
WEIGHT kg		MATERIAL		TITLE Recovery System			
AUTHOR		DATE		NUM R7_REC_0000			
DESIGNED BY	Jan Sacharuk	24/04/2025					
DRAWN BY	Jan Sacharuk	10/05/2026		SIZE A3		SCALE 1:2	SHEET 10/10
APPROVED BY							

D Checklists



SIMLE

SIMBA

CHECKLIST - R7 - Engine Cleaning Propellant Tanks

12.05.2026, VERSION 1

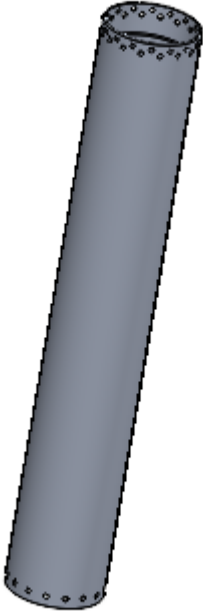
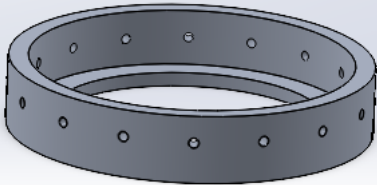
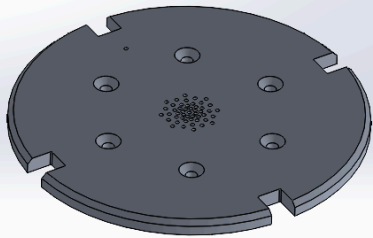
1. Tools list
2. Custom parts list
3. Cleaning instructions
4. Help

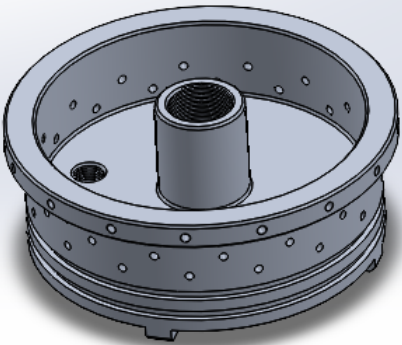
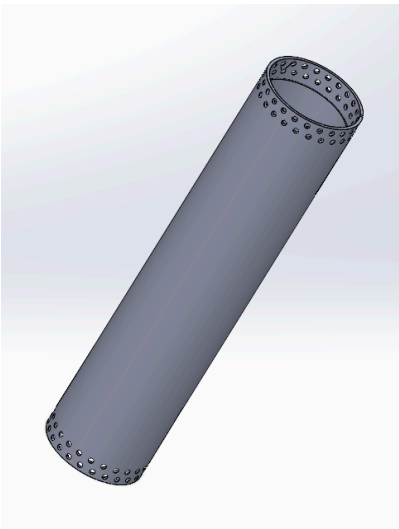
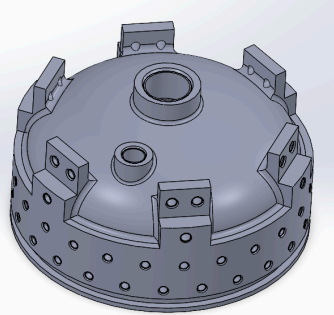
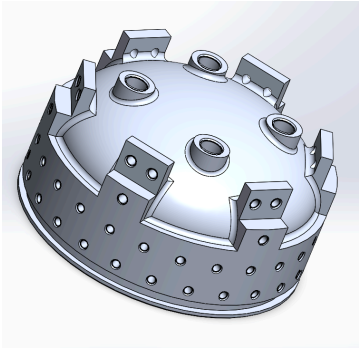
1. Tools List

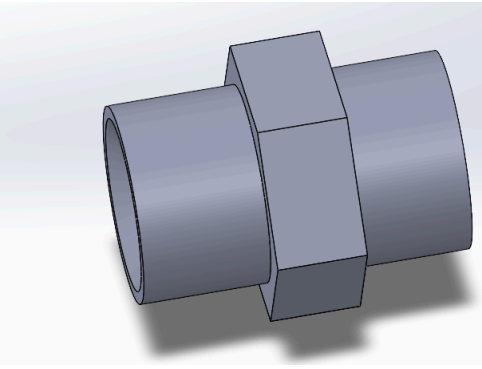
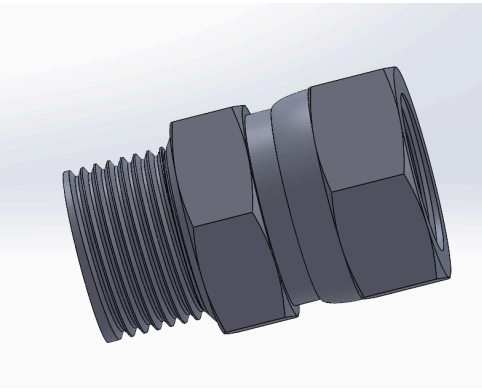
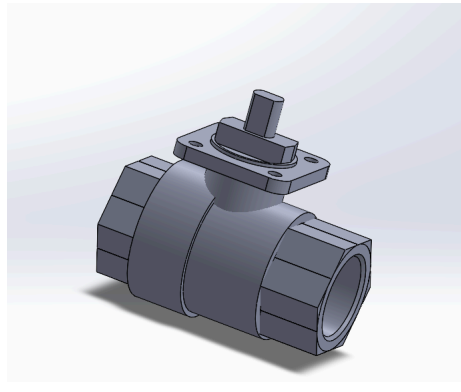
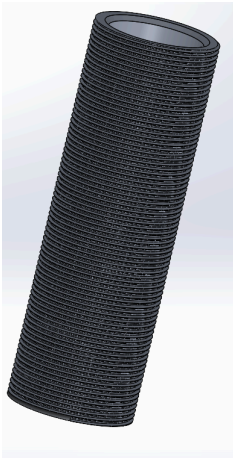
Name	Status
Isopropyl alcohol degreaser IPA	
Distilled water	
Cleaning cloth	
Nitrile gloves	
Paper towels	
Soapy water	

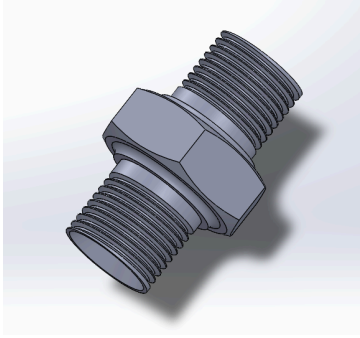
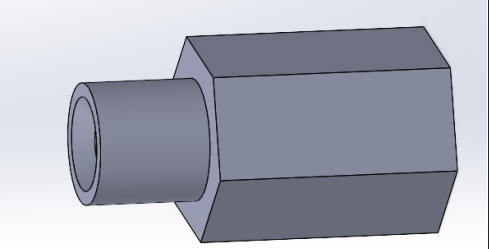
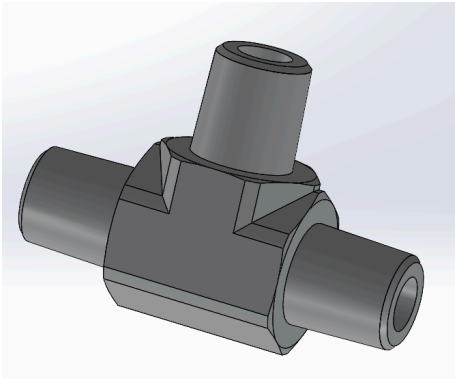
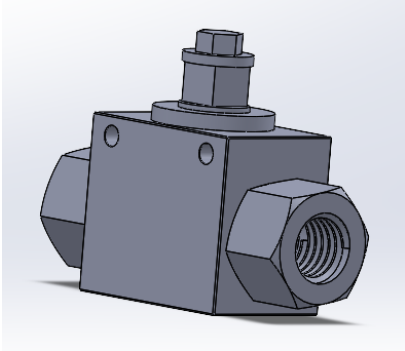
2. Custom parts list

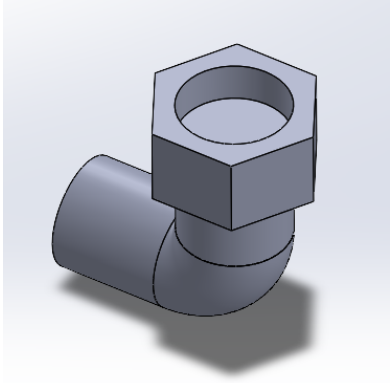
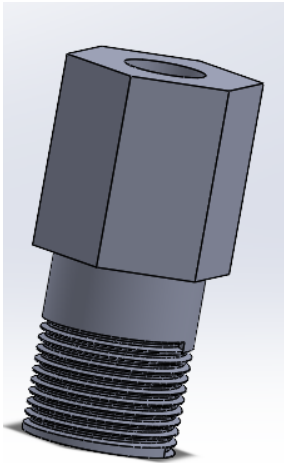
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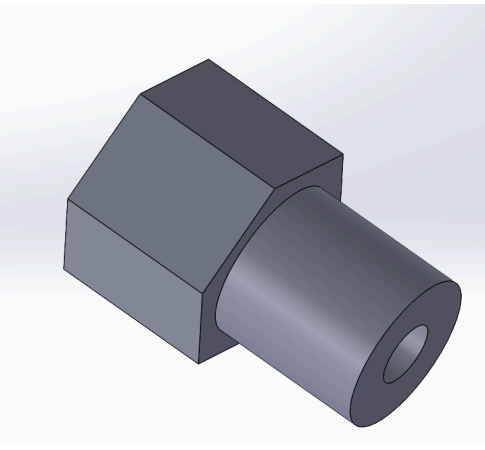
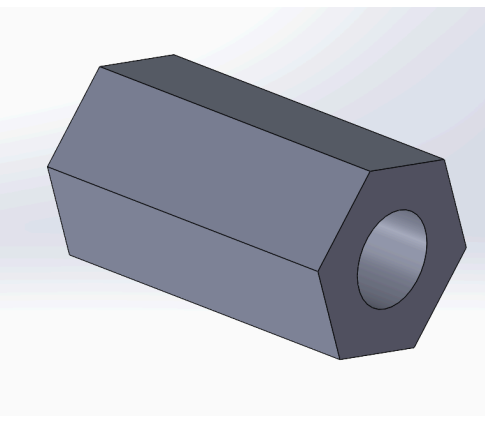
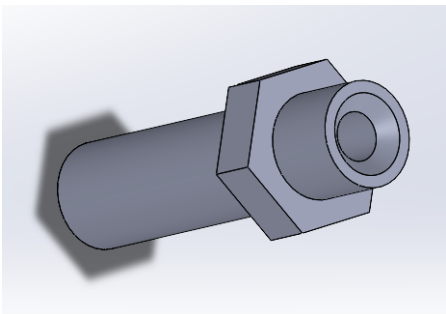
	ntity		
R7_ENG_1100_Walls	1		
R7_ENG_1300_Retainer	1		
R7_ENG_1401_InjectorPlate	1		

R7_ENG_1402_Holder	1		
R7_ENG_2100_Walls	1		
R7_ENG_2200_UpperEndCap	1		
R7_ENG_2300_LowerEndCap	1		

R7_ENG_Straight_Fitting_34	1		
R7_ENG_041_Rotary_34	2		
R7_ENG_3202_Main_Valve	1		
R7_ENG_3210_Threaded_pipe	1		

R7_ENG_046_Straight_14	1		
R7_ENG_045_Rotary_14	3		
R7_ENG_051_Threeway_14	1		
R7_ENG_044_Valve_14	2		

R7_ENG_054_90deg_14	3		
R7_ENG_3211_SiphonTube	1		
R7_ENG_049_Swagelok_14	1		

R7_ENG_050_BSP-NPT_14	1		
R7_ENG_047_2xRotary_14	1		
R7_ENG_048_Long_Straight_14	1		

3. Cleaning instructions

All activities involving the use of IPA and surface cleaning should be performed while wearing nitrile gloves. When using canned compressed air, make sure it does not leave any residue on the cleaned surfaces. Due to the harsh desert conditions, all components must be protected against sand and dust. After the use of IPA or water, all components should be dried thoroughly.

Holder preparation:

Clean the holder from dirt and soot using soapy water, IPA, and paper towels. A lot of contamination collects between the injector plate and the holder.

Remove the remaining silicone from the bottom side, using IPA and paper towels. There must not be even the smallest amount of silicone left.

Degrease the entire holder using IPA, before applying Krytox and installing the O-rings. Every surface of the holder located inside the combustion chamber must be cleaned. Pay attention to the O-ring grooves, which should also be blown out with compressed air.

Blow out the threaded hole with compressed air in order to remove any possible contaminants.

Preparation of the injector plate:

Clean the injector plate of silicone residue, contamination, and soot using soapy water, paper towels, and IPA.

Blow out the holes with compressed air. Ensure that there is no contamination present in any of the holes and that none of the holes are obstructed or blocked.

Degrease the entire injector plate thoroughly, paying particular attention to cleanliness, as silicone will be applied to one of the surfaces

Oxidizer tank and combustion chamber:

The bolt holes should be blown out with compressed air in order to remove any contaminants from inside the holes. The edges of the holes should also be deburred using a deburring tool. Hydraulic components should be kept separated from sand and dust. If sand gets into the hydraulic components, they should be cleaned with compressed air.

4. Help

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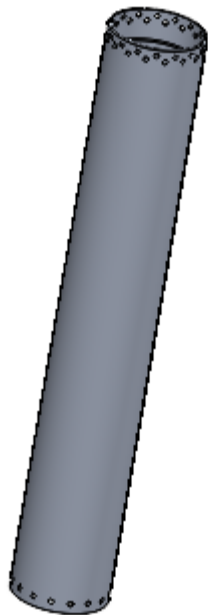
**CHECKLIST - R7 - Engine
Combustion Chamber**
12.05.2026, VERSION 1

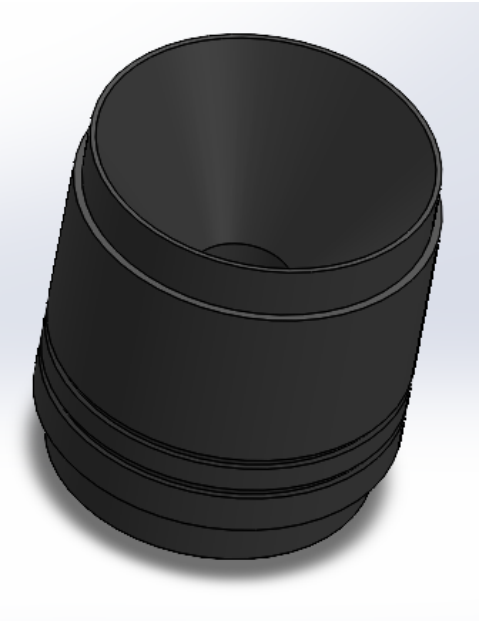
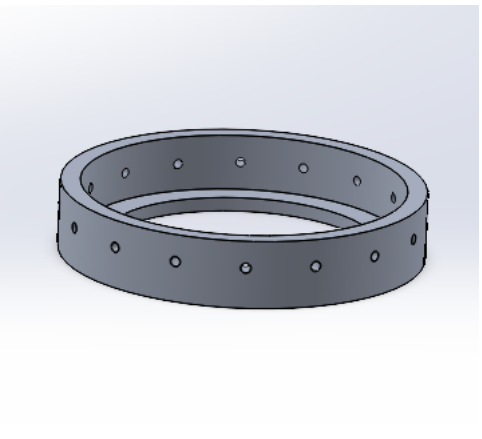
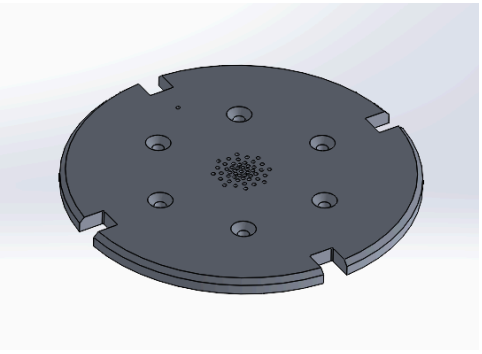
1. Tools list
2. Custom parts list
3. Ready parts list
4. Assembly instructions
 - 4.1 Injector assembly
 - 4.2 Fuel grain assembly
 - 4.3 Combustion chamber assembly
5. Help

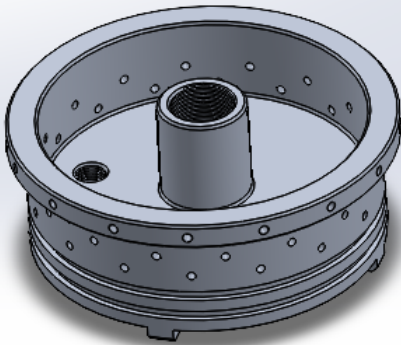
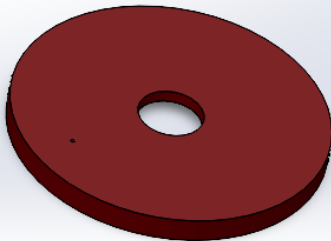
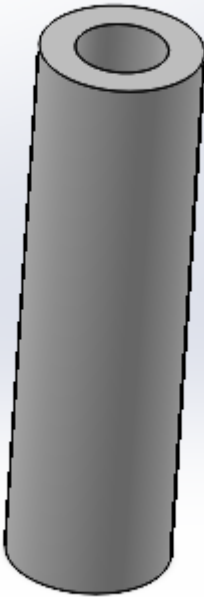
1. Tools List

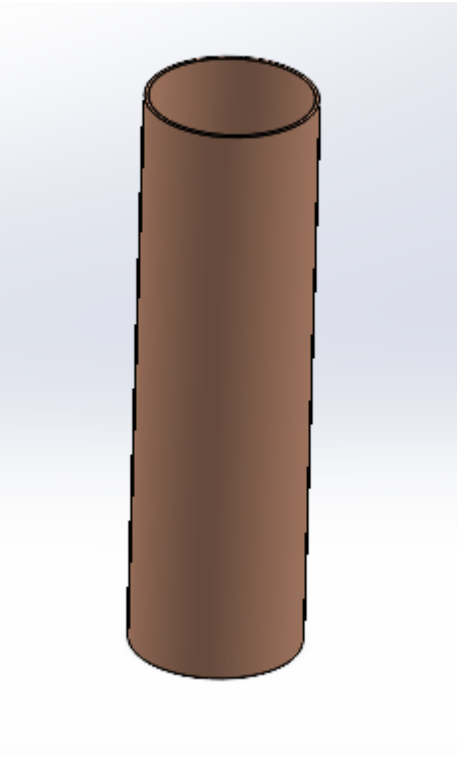
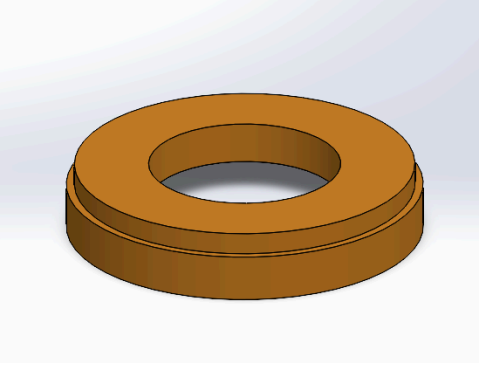
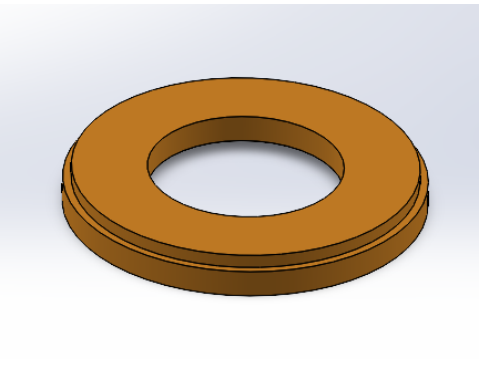
Name	Status
PTFE tape	
High temperature red silicone	
krytox	
IPA	
Disposable nitrile gloves	
Soupy water	
Flat plate used for pressing down the assembly	
Painting tape	
Allen key 7mm	
Torque wrench + Allen key adapter 7mm	
Ratchet wrench 19mm	

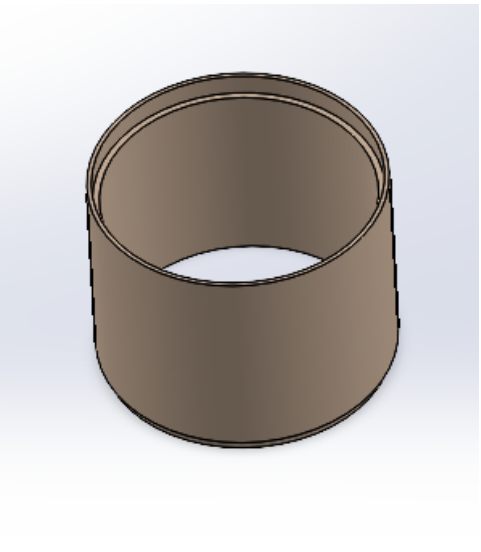
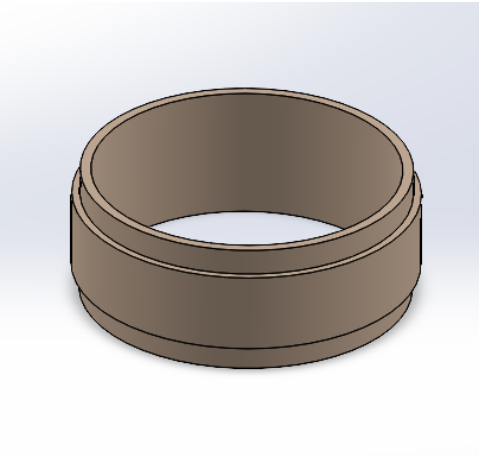
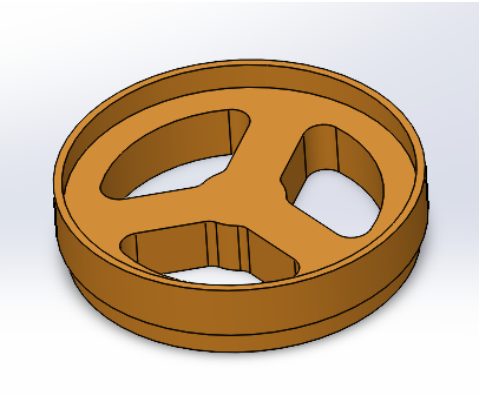
2. Custom parts list

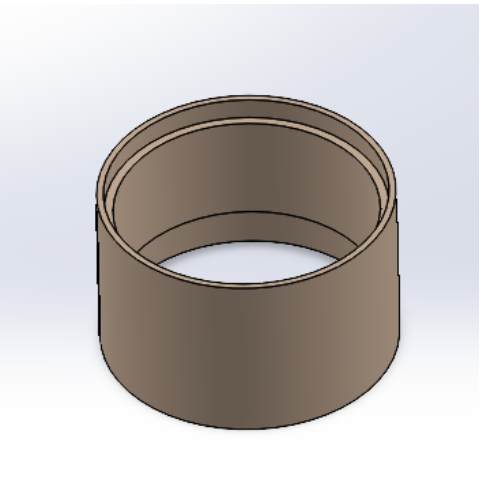
Name	Quantity	Photo	Status
R7_ENG_1100_Walls	1		

R7_ENG_1200_Nozzle	1		
R7_ENG_1300_Retainer	1		
R7_ENG_1401_InjectorPlate	1		

R7_ENG_1402_Holder	1		
R7_ENG_1403_Insulation	1		
R7_ENG_1501_Tube	1		

R7_ENG_1502_Insulation	1		
R7_ENG_1503_BottomWasher	1		
R7_ENG_1504_TopWasher	1		

R7_ENG_1600_PreCC	1		
R7_ENG_1701_TopPostCC	1		
R7_ENG_1702_Mixer	1		

R7_ENG_1703_BottomPostCC	1		
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3. Ready parts list

Name	Qty	Status
Pressure Transmitter	1	
O-ring 128x3	2	
O-ring 124x3	2	
O-ring 47x3	1	
O-ring 32x3	1	
Screw M4x6	48	
Socket countersunk head screw M4x14	6	
dowty seal G1/4	1	
Male/Female adapter G1/4	1	
Igniters	3	
Flares	3	

4. Assembly instructions

No	INJECTOR ASSEMBLY	Status
1	Check o-ring for damage	
2	Apply krytox to O-ring 47x3 and O-ring 32x3	
3	Mount both O-rings to R7_ENG_1402_Holder	
4	Establish the correct orientation of R7_ENG_1401_Injector relative to R7_ENG_1402_Holder, use injectors through hole as reference (turn the injector plate until the through hole aligns with the hole on the holders surface), and start screwing both parts together with 6 M4x14 socket countersunk head screws	
5	Thoroughly clean the injector plate with IPA and cover all screw heads and injector holes with previously cut out tape	
6	Apply silicone in-between the tape and spread it on the injector plate	
7	Establish the correct orientation of R7_ENG_1403_Insulation and mount it to R7_ENG_1401_Injector, use injectors through hole as reference (turn the injector plate until the through hole aligns with the hole on the insulation plate)	
8	Take off the tape covering the holes of the injector with small tweezers	

No	FUEL ASSEMBLY	Status
1	Thoroughly clean the parts using pressurized air and visually inspect for possible damage or debris build up, before performing any installation	
2	Mask off R7_ENG_1200_Nozzle and R7_ENG_1703_BottomPostCC with the tape and prepare the surface for the application of silicone	
3	Apply the silicone on the stepped joint of R7_ENG_1200_Nozzle and mount the R7_ENG_1703_BottomPostCC to it. After connecting both parts, press it down with a flat plate	
4	Leave the silicone to cure (in the meantime proceed with other	

	parts	
5	Mask off R7_ENG_1701_TopPostCC and R7_ENG_1702_Mixer with tape and prepare the surface for the application of silicone	
6	Apply the silicone on the stepped joint of R7_ENG_1702_Mixer and mount the R7_ENG_1701_TopPostCC to it. After connecting both parts, press it down with a flat plate	
7	Apply the silicone in a circular manner to the mating surface of inner diameter of the R7_ENG_1701_TopPostCC and R7_ENG_1702_Mixer, after application drag your finger, dipped in the soupy watter, through the silicone to make a fillet	
8	Leave the silicone to cure (in the meantime proceed with other parts)	
9	Apply the silicone to the stepped joint of the R7_ENG_1702_Mixer in a circular manner, then mount the Mixer+TopPostCC assembly to the R7_ENG_1703_BottomPostCC	
10	Press the assembly down with a flat plate and leave it to cure	
11	Mask the R7_ENG_1503_BottomWasher off with painting tape and prepare it thoroughly for silicone application	
12	Apply the silicone to the stepped joint of R7_ENG_1503_BottomWasher and the flat, mating surface between the fuel grain and the bottom washer	
13	Mount R7_ENG_1503_BottomWasher to R7_ENG_1500_FuelGrain assembly, put something soft under the grain. Afterwards gently press it down with a flat plate, inspect for possible misalignment and wait until the silicone will cure.	
14	Mask both R7_ENG_1701_TopPostCC and R7_ENG_1503_BottomWasher off with painting tape	
15	Apply silicone in-between R7_ENG_1701_TopPostCC and R7_ENG_1503_BottomWasher, press the whole thing down with the flat plate and wait for the silicone to cure. Remember to always put something soft under the surface that is in contact with the floor.	
16	Repeat the process for masking off and silicone application for R7_ENG_1504_TopWasher and the whole assembly. Press it down gently.	

17	Apply silicone to the R7_ENG_1600_PreCC and connect it with the preassembled Top Washer	
18	Take the tape off from every surface it was sticking to	

No	COMBUSTION CHAMBER ASSEMBLY	Status
1	Check 124x4 o-rings for damage, if not damaged cover them with krytox and apply them to the nozzle.	
2	Slide the assembled parts into the R7_ENG_1100_Walls and insert the R7_ENG_1300_Retainer from the bottom.	
3	Establish the correct position by R7_ENG_1300_Retainer relative to the combustion chamber walls by aligning marked lines engraved on the surfaces of both parts . Afterwards, screw in 16 M4x6 bolts with 7mm allen key. Check each bolt with torque wrench, allen key adapter, size 7.	
4	Connect the flares to the igniters using high temperature red silicone, let it cure before use.	
5	Feed the assembled igniters through the port, going from R7_ENG_1200_Nozzle up to R7_ENG_1600_PreCC.	
6	Apply silicone blobs to the R7_ENG_1600_PreCC at halfway of its height (45mm). Nextly, embed the igniters into the silicone blobs, in order to secure their position apply painting tape over them. After the silicone will cure, take the tape off and apply new silicone layer covering the igniters.	
7	Secure the wires of igniters so that they do not protrude outside the nozzle using painting tape	
8	Check 128x3 o-rings for damage, if not damaged - cover them with krytox and apply them to the holder.	
9	Mount the holder assembly so that it braces against R7_ENG_1600_PreCC, align the markings on both holder and R7_ENG_1100_Walls. If correct, screw the M4x6 screws in with allen key of 7mm size. Lastly, verify each screwed bolt with a torque wrench.	

5. Help

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CHECKLIST - R7 - Engine Fill and Vent Procedures

12.05.2026, VERSION 1

1. Instructions
 - 1.1 Filling stage
 - 1.2 If Hold is not required
 - 1.3 If Hold is required
2. Lines diagram
3. Help

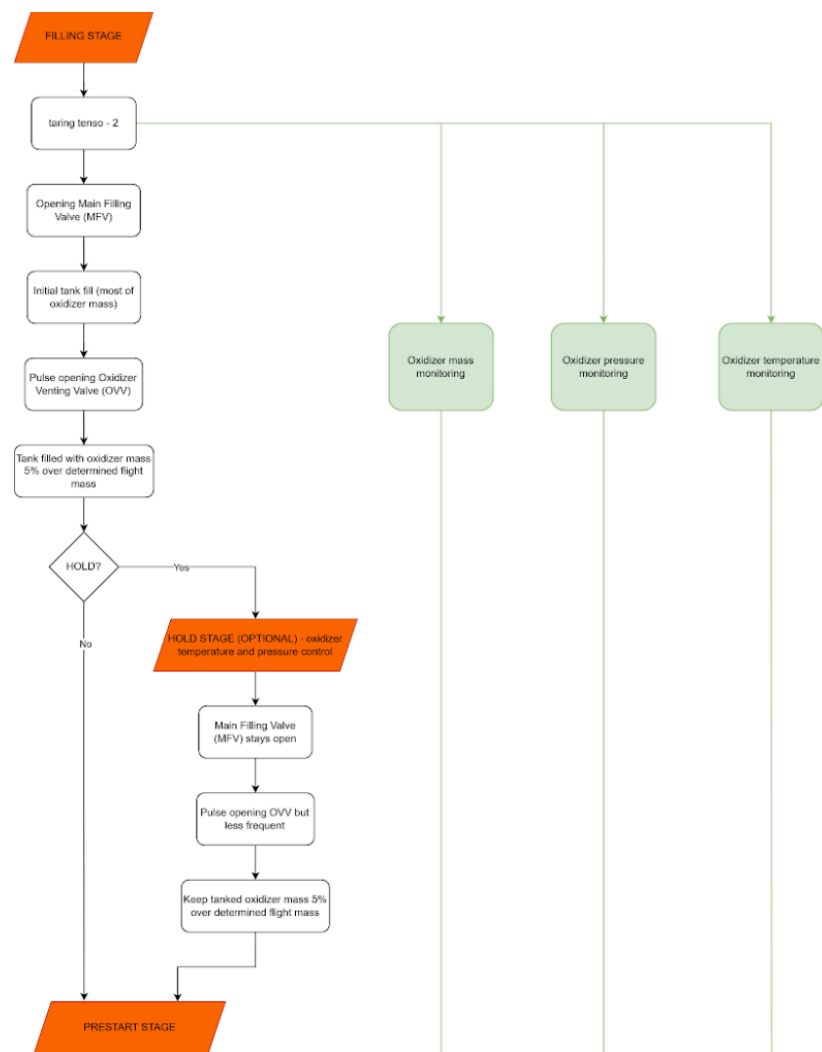
1. Instructions

No	FILLING STAGE	Status
1	Tare Tenso-2.	
2	Open the Main Filling Valve (MFV).	
3	Perform the initial tank fill, filling most of the oxidizer mass.	
4	Begin pulse-opening the Oxidizer Venting Valve (OVV).	
5	Continue filling until the tank contains oxidizer mass equal to 5% above the determined flight mass.	
6	Check whether HOLD is required.	

No	IF <u>HOLD</u> IS NOT REQUIRED	Status
1	Proceed directly to PRESTART STAGE.	

No	IF HOLD IS REQUIRED	Status
1	Enter HOLD STAGE - optional oxidizer temperature and pressure control.	
2	Keep the Main Filling Valve (MFV) open.	
3	Continue pulse-opening the OVV, but less frequently.	
4	Maintain the tanked oxidizer mass at 5% above the determined flight mass.	
5	After HOLD is complete, proceed to PRESTART STAGE.	

2. Diagram



3. Help

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CHECKLIST - R7 - Engine

Final Assembly

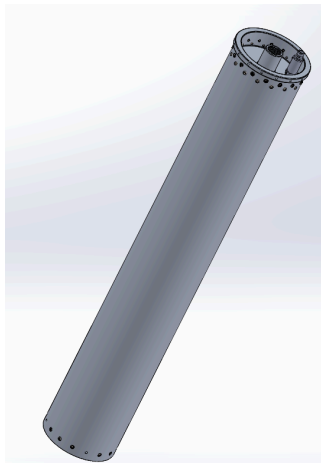
12.05.2026, VERSION 1

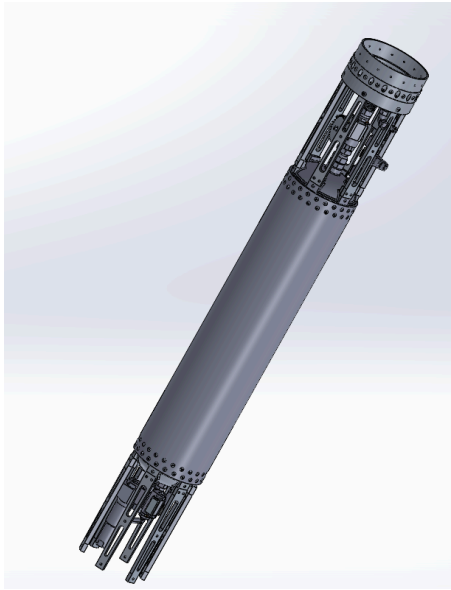
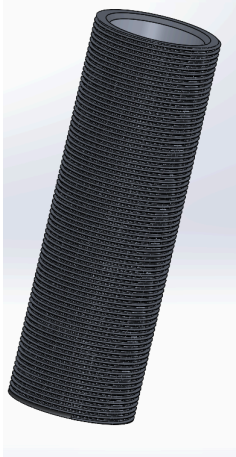
1. Tools list
2. Custom parts list
3. Ready parts list
4. Assembly instructions
5. Lines diagram
5.1 P&ID
6. Help

1. Tools List

Name	Status
Allen key 10mm	

2. Custom parts list

Name	Quantity	Photo	Status
R7_ENG_1000_CombustionChamber	1		

R7_ENG_2001_FeedOxTank	1		
R7_ENG_3210_Threaded_pipe			

3. Ready parts list

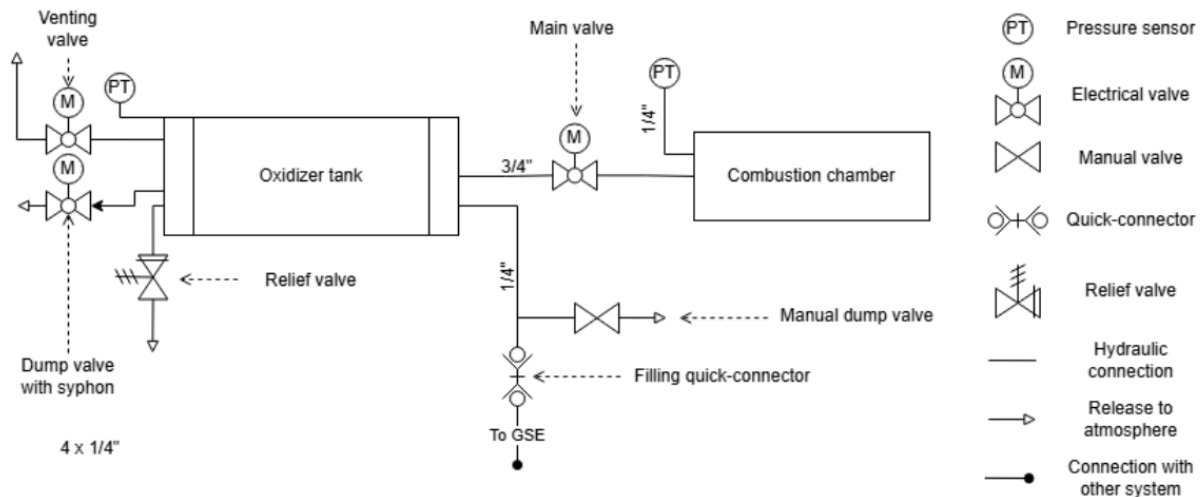
Name	Status
R7_ENG_060_M6x10_Screw - 36	

4. Assembly instructions

1	Assemble the combustion chamber in compliance with CHECKLIST - R7 - ENG - Combustion Chamber	
2	Assemble the oxidizer tank in compliance with CHECKLIST - R7 - ENG - Oxidizer Tank & Hydraulics	
3	Connect R7_ENG_3210_Threaded_pipe to R7_ENG_1402_Holder, then tighten the connection securely.	
4	Bolt R7_ENG_1000_CombustionChamber together with R7_ENG_2001_FeedOxTank. Be careful during tightening to avoid damaging the hydraulic components and ensure that the entire assembly is properly centered.	
5	Tighten the remaining R7_ENG_3101_Brackets using R7_ENG_060_M6x10_Screws.	

4. Lines diagram

4.1 P&ID



6. Help

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CHECKLIST - R7 - Engine Oxidizer Tank & Hydraulics

Last modified: 15.05.2026, Olgierd Bargański

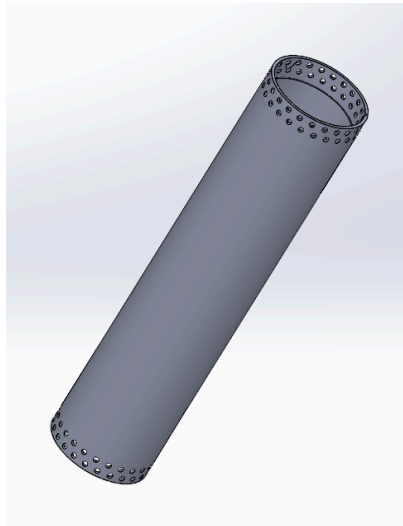
1. Tools list
2. Custom parts list
3. Ready parts list
4. Assembly
5. Help

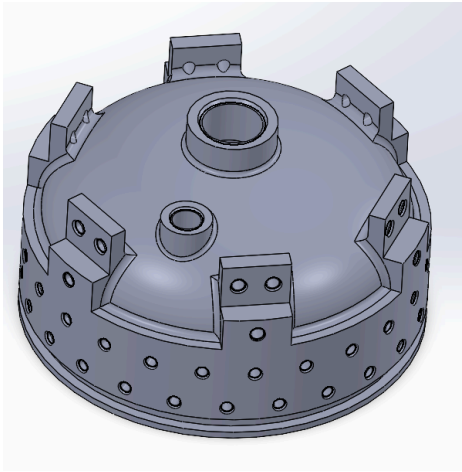
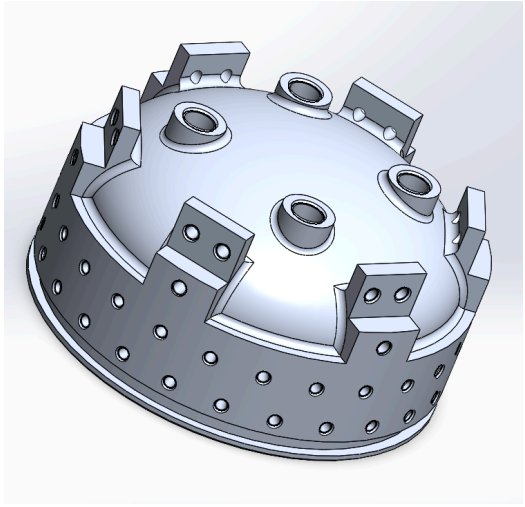
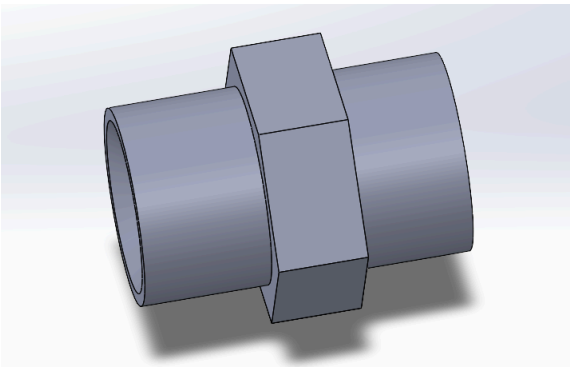
1. Tools List

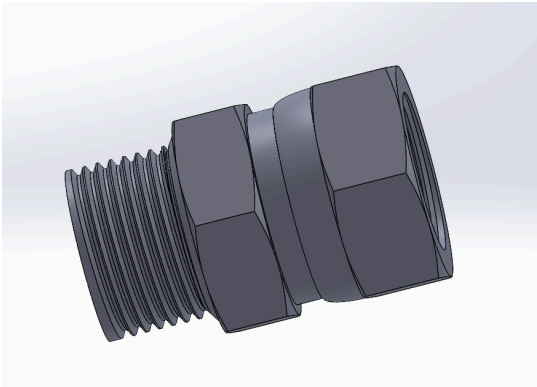
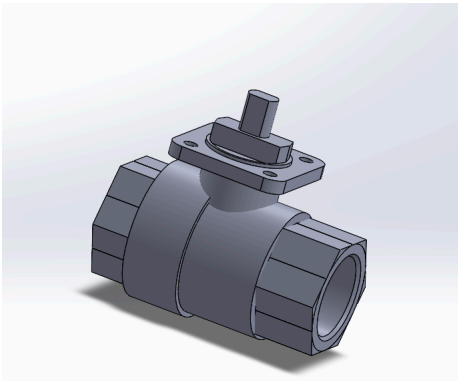
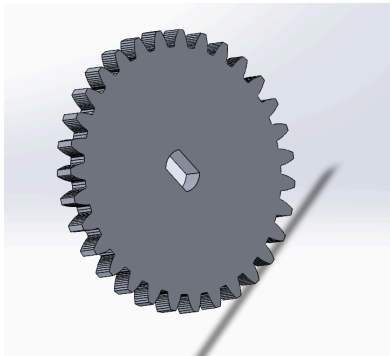
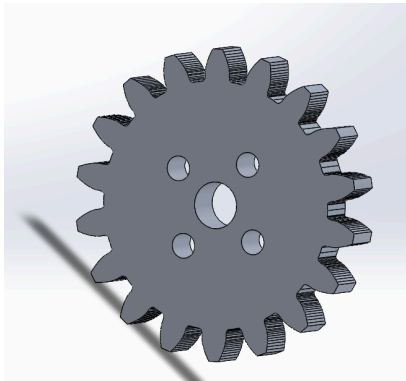
Name	Status
PTFE tape	
Krytox	
IPA	
Distilled water	
Plastic cups	
Disposable nitrile gloves	
Allen key 10mm	
Torque wrench + Allen key adapter 10mm	
Wrench 32mm x2	
Wrench 22mm	

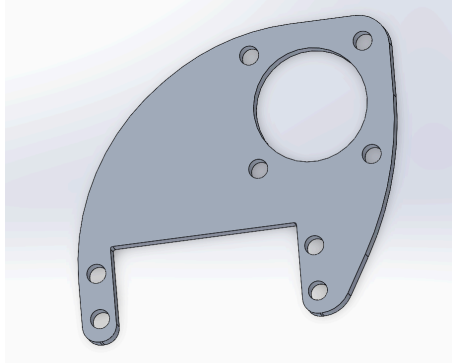
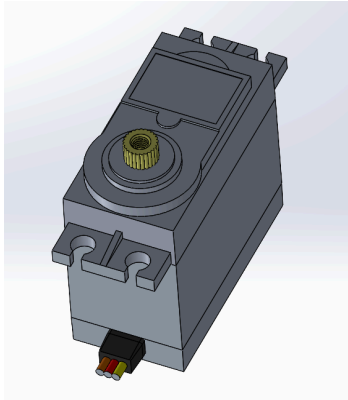
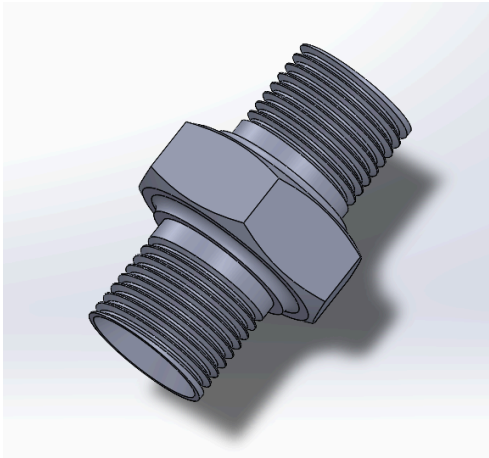
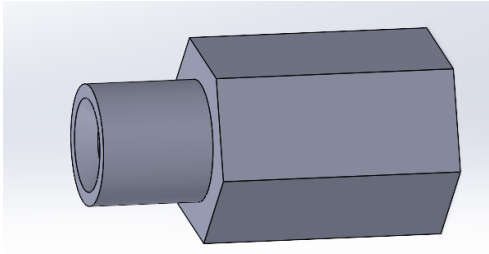
Wrench 19mm	
Ratchet wrench 19mm	
Wrench 17mm	
Wrench 10mm	

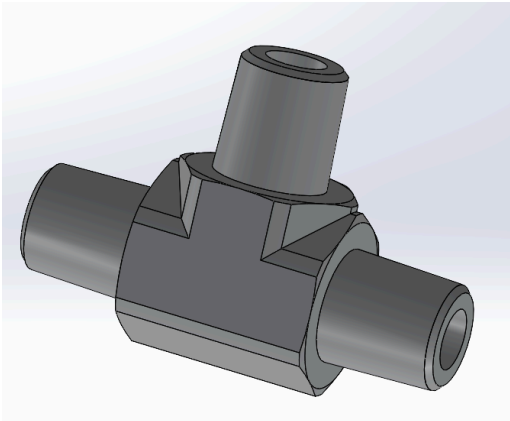
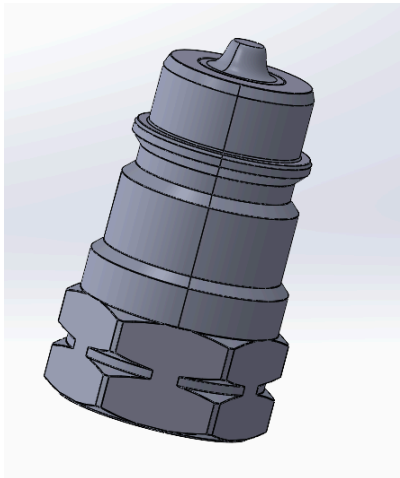
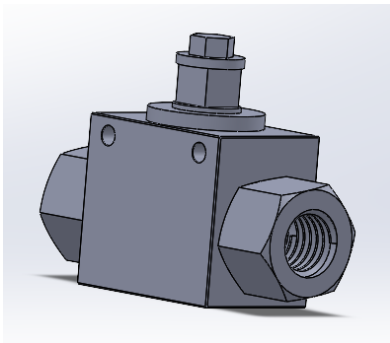
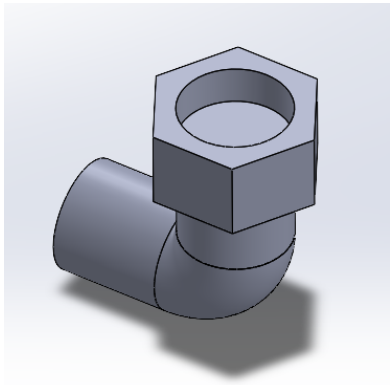
2. Custom parts list

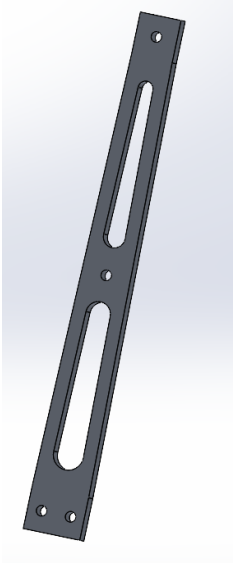
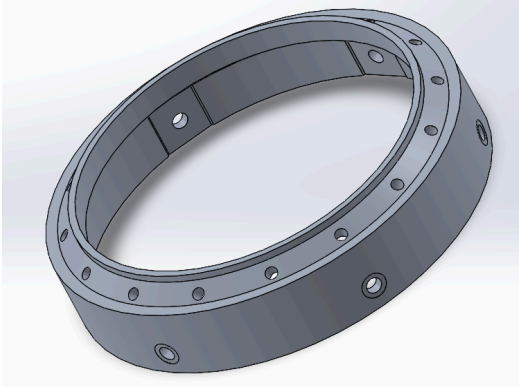
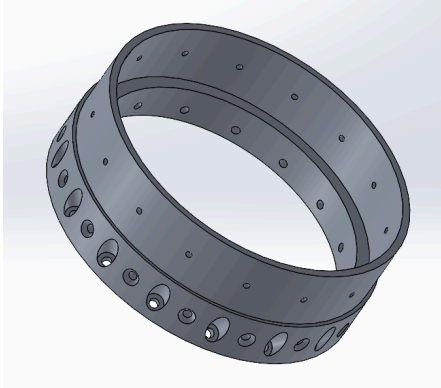
Name	Quantity	Photo	Status
R7_ENG_2100_Walls	1		

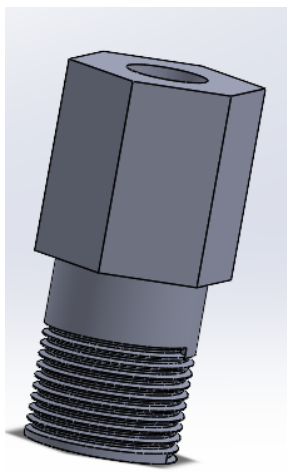
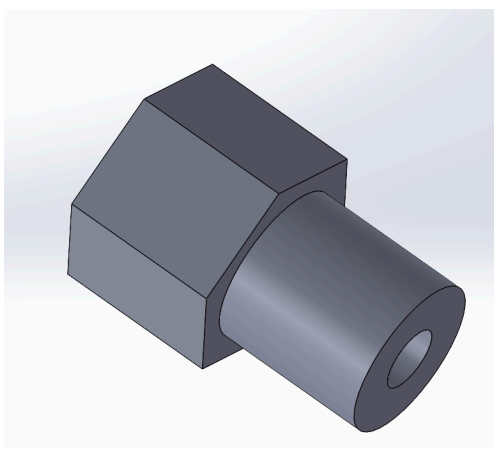
R7_ENG_2300_LowerEndCap	1		
R7_ENG_2200_UpperEndCap	1		
R7_ENG_Straight_Fitting_34	1		

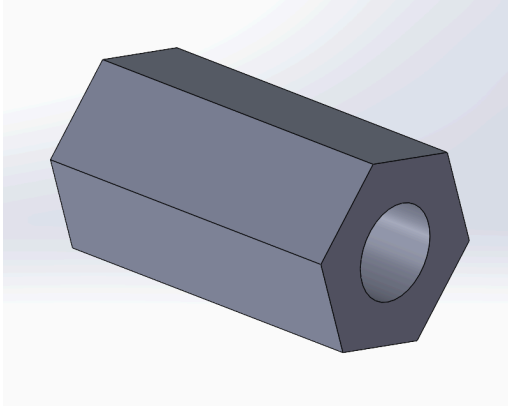
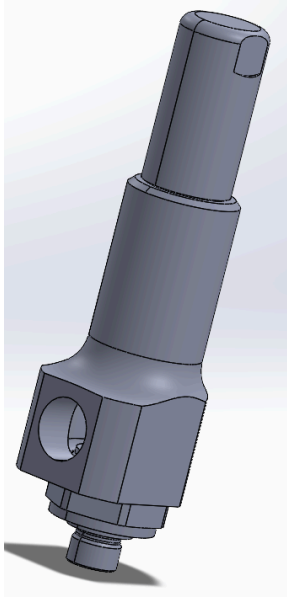
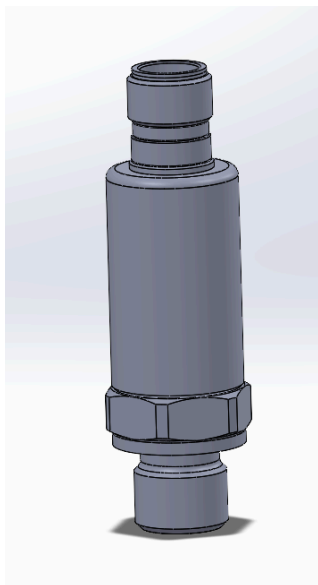
R7_ENG_041_Rotary_34	2		
R7_ENG_3202_Main_Valve	1		
R7_ENG_3208_Valve_Gear	1		
R7_ENG_3207_Servo_Gear	2		

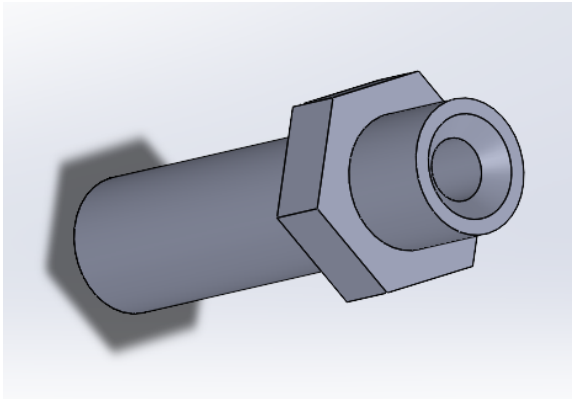
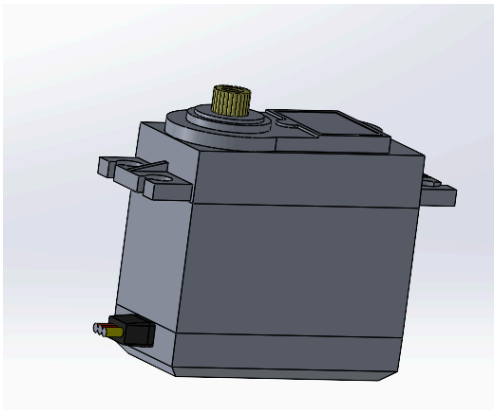
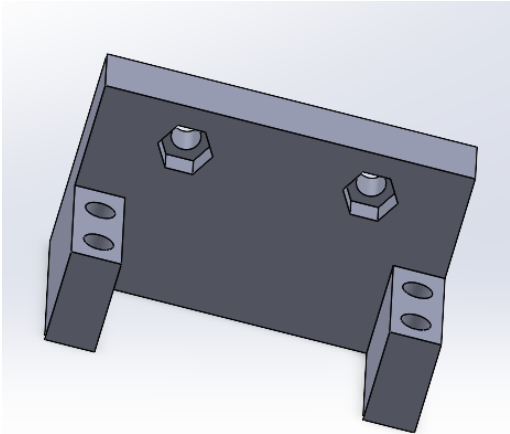
R7_ENG_3209_Servo_Plate	1		
R7_ENG_043_Servo70kg	1		
R7_ENG_046 Straight 14	1		
R7_ENG_045_Rotary_14	3		

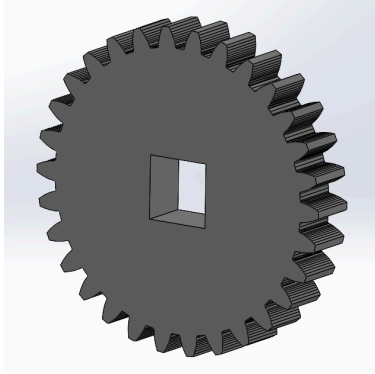
R7_ENG_051_Threeway_14	1		
R7_ENG_052_Quickconnect_14			
R7_ENG_044_Valve_14	2		
R7_ENG_054_90deg_14	3		

R7_ENG_3101_Bracket	12		
R7_STR_6301_Radax_Feed	4		
R7_STR_6302_Radax_Engine	1		

R7_ENG_3211_SiphonTube	1		
R7_ENG_049_Swagelok_14	1		
R7_ENG_050_BSP-NPT_14	1		

R7_ENG_047_2xRotary_14	1		
R7_ENG_2500_Burst Disc	1		
R7_ENG_003_pressure sensor	1		

R7_ENG_048_Long_Straigth_14	1		
R7_ENG_056_Servo46kg	2		
R7_ENG_3209_Plate	1		

R7_ENG_3316_DumpServoGear			
R7_ENG_3315_DumpValveGear	1		
R7_ENG_061_90deg_38	1		
R7_ENG_062_14-38	1		

3. Ready parts list

Name	Status
M5 x 8 hex socket screw	96
O-ring 152x5	2

R7_ENG_040_metal_rubber_3_4_inch	10
R7_ENG_058_M5_Hex_Screw_15	24
R7_ENG_059_M6x20_Screw	36
R7_ENG_060_M6x10_Screw	24

4. Assembly

UPPER HYDRAULICS SUBASSEMBLIES	Status
Take R7_ENG_2500_Burst Disc, apply PTFE tape to the thread, then connect it with R7_ENG_061_90deg_38, then connect that with R7_ENG_062_14-38. Place it in a safe, clean location. This is now called the BURST DISC ASSEMBLY.	
Take R7_ENG_3410_Vent_assembly apply PTFE tape to the thread, connect it with R7_ENG_046_Straight_14, and place it in a safe location. This is now called the VENT ASSEMBLY.	
Take R7_ENG_3420_Dump_valve, connect it with R7_ENG_045_Rotary_14, use a metal-rubber washer. Then connect it with another R7_ENG_045_Rotary_14.	
To the thread of R7_ENG_054_90deg_14 screw a ¼" Nut and apply PTFE tape. Connect it to the R7_ENG_044_Valve_14 and tighten with the nut.	
Connect the other side of the valve, the rotary fitting, to R7_ENG_048_Long_Straight_14 and place it in a safe location. This is now called the DUMP ASSEMBLY.	
Install R7_ENG_3211_SiphonTube into the R7_ENG_049_Swagelok_14. Apply PTFE tape to its thread and screw it into R7_ENG_050_BSP-NPT_14.	
Screw this together with R7_ENG_047_2xRotary_14, secure it, and place it in a safe location. This is now called the SIPHON ASSEMBLY.	
MAIN LINE	Status
Install a metal-rubber washer onto the end of R7_ENG_041_Rotary_34 and screw it together with R7_ENG_3202_Main_Valve.	
On the opposite side of R7_ENG_3202_Main_Valve, install a metal-rubber washer and screw it together with R7_ENG_041_Rotary_34.	
FILL LINE	Status

Connect the male-side of R7_ENG_045_Rotary_14 with R7_ENG_051_Threeway_14.	
Apply PTFE tape to the out-facing male connection of the threeway, then connect it with R7_ENG_052_Quickconnect_14. This is a critical connection with a high risk of leaking and is hard to tighten, so make sure that you seal and tighten it well.	
Connect another R7_ENG_045_Rotary_14 to the lower, male side of the three-way.	
Connect it with R7_ENG_044_Valve_14, use a metal-rubber washer. Align the valve such that its mount is in line with the QuickConnector.	
To the thread of R7_ENG_054_90deg_14 screw a 1/4" Nut and apply PTFE tape. Screw it to the R7_ENG_044_Valve_14 and tighten with the nut.	
To the R7_ENG_054_90deg_14 connect another two R7_ENG_054_90deg_14. Do not tighten them yet. Place the Fill line in a safe, clean location.	

TANK ASSEMBLY	Status
Check o-rings for damage.	
Install the O-ring onto R7_ENG_2300_LowerEndCap, and apply Krytox to it.	
Insert it into R7_ENG_2100_Walls - establish the correct orientation by aligning the marking lines on the walls with the marking lines on the end caps, then screw the parts together using M5x8 hex socket screws.	
The R7_ENG_2200_UpperEndCap 1/4" outlets should be marked not to cause confusion on what is installed where. It is very important that the upper elements are installed in the precise spots.	

If the outlets are not marked, or you are not sure in regard to their markings, use the guide below this checklist to mark them.	
To the R7_ENG_2200_UpperEndCap outlet marked with two lines, install Dump Valve assembly, use a metal-rubber washer. On the inner side of the Cap, connect the Siphon Assembly with a second end of the ¼" long fitting.	
Install the O-ring 152x5 onto R7_ENG_2200_UpperEndCap and apply Krtytox to it.	
Establish the correct orientation relative to R7_ENG_2100_Walls by aligning the marking lines on the walls with the marking lines on the end caps, then screw the parts together using M5x8 hex socket screws.	
Screw the R7_ENG_003_pressure sensor to the outlet of R7_ENG_2200_UpperEndCap marked with one line.	
Screw R7_ENG_3410_Vent_assembly into R7_ENG_2200_UpperEndCap outlet marked with three lines. Establish the correct orientation so that the face is away from the gears of 7_ENG_3420_Dump_valve.	
To the outlet marked with four lines, connect a R7_ENG_046_Straight_14. Then connect the Burst Disc assembly to it.	
Modify clockings of the lowest rotary connections such that everything fits, nothing interferes with gears or the Vent's actuation mechanism, and that this mechanism or anything else will not interfere with a cover installed later.	
Connect 6x R7_ENG_3101_Bracket with R7_ENG_2200_UpperEndCap using 12x M6x20 screws	
Fit check the R7_ENG_3102_Cover elements with all the outlets (Vent, Dump, Burts, fill line's manual dump valve). Modify the clockings of the rotary connections and elbows held with nuts if needed.	
To the R7_ENG_2300_LowerEndCap connect a R7_ENG_046_Straight_14. Use a metal-rubber washer.	
To the R7_ENG_2300_LowerEndCap connect a R7_ENG_Straight_Fitting_34 with PTFE tape applied. Use a metal-rubber washer. The thread on the cap has been manufactured slightly angled, so it is hard to get a proper seal with the washer. Use the strongest people and the longest wrench available to tighten it as much as they possibly can, only then you can achieve a good seal there.	

Screw FILL LINE FEED into R7_ENG_046_Straight_14 on the R7_ENG_2300_LowerEndCap. Set the clocking such that the quickconnector faces outwards of the rocket.	
Connect MAIN LINE FEED to R7_ENG_2300_LowerEndCap, establish the correct position so that the gears do not interfere with the fill line.	
Connect 6x R7_ENG_3101_Bracket with R7_ENG_2300_LowerEndCap	
Fit check the R7_ENG_3102_Cover elements with the fill line's bottom outlet. Modify the clockings of the rotary connections and elbows held with nuts if needed.	
Fit check the quickconnection with the cover and the GS's decoupler. It should not interfere with the cover when connected.	
Install Structure's RADAX connectors to the either side brackets, using a total of 12 M6x20 screws and 12 M6 nuts. Align the Caps and RADAX's markings (dots).	
Check if every connection is tightened.	
Perform servo testing and calibration if needed.	

DUMP ASSEMBLY	Status
Clean R7_ENG_044_Valve with IPA	
Install R7_ENG_044_Valve_14 to R7_ENG_3209_Plate by using 2x bolts M4x35 and 2x nuts M4 use 7mm flat wrench	
Install R7_ENG_3315_DumpValveGear to R7_ENG_044_Valve_14 use bolt M5x15mm and 4x nut m3 and 8mm flat wrench	
Install R7_ENG_3316_DumpServoGear to R7_ENG_056_Servo46kg use 4x bolt M3x12mm and 4x nut m3 and 5mm flat wrench	
Install DUMP VALVE where needed	

How to mark the R7_ENG_2200_UpperEndCap 1/4" outlets:

How to mark the R7_ENG_2200_UpperEndCap 1/4" outlets:

- To the R7_ENG_2100_Walls insert, and hold with 2-3 screws, both R7_ENG_2200_UpperEndCap and R7_ENG_2300_LowerEndCap. Use marking lines on the walls and the caps to align them all properly.
- Look at the 1/4" outlet on the lower cap. On the upper cap, the outlet directly above it is the spot for R7_ENG_003_pressure sensor. Mark it with one line.
- Going clockwise from the pressure sensor outlet, there are:
- Dump Valve outlet (mark with two lines).
- Vent Valve outlet (mark with three lines).
- Burst Disc outlet (mark with four lines).

6. Help

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CHECKLIST - R7 - AVIONICS

27.05.2026, VERSION I

1. Tools list
2. Custom parts list
3. Off-the-shelf parts list
4. Assembly Instructions
 - 4.1 Avionics Assembly
5. Help
 - 5.1 Contact and consultation

1. Tools list

Name	Qty	Status
Multimeter	1	Packed
Portable soldering iron	1	Packed
Soldering station	1	Packed
Solder wire	1	Packed
Desoldering wick	2	Packed
Flux	2	Packed
Solder paste	1	Packed
Portable oscilloscope	1	Packed
Angled side cutters	3	Packed
Molex pin crimper	1	Packed
Wire stripper	2	Packed
Cable crimping tool (do tulejek)	1	Packed
Small combination plier	2	Packed
Kapton tape	1	Outdated
Cable sleeve set	1	Packed
Duct tape	1	Packed
Electrical tape	1	Packed
Isopropyl alcohol (IPA)	1	Outdated
Hot glue	1	Packed
Tweezers set	1	Packed
Utility knife	1	Packed
Pack of long zip ties	2	Outdated
Pack of short zip ties	2	Outdated
Wolfcraft screwdriver with bit set	1	Outdated
Flat-head screwdrivers	3	Outdated

Phillips screwdrivers	3	Outdated
Ethernet cables of various lengths	5	Packed
Heat shrink tubing set (various diameters)	1	Packed
PVC heat shrink set	1	Packed
Roll of nickel tape	1	Packed
Battery terminal insulators set	1	Packed
Spare unterminated cable LIY-CY2X0.5; MPN: 18048795 [m]	4	Packed
Spare unterminated cable LIY-CY3X0.5; MPN: 18048796 [m]	4	Packed
Spare unterminated cable LIYCY4X0.25; MPN: 20031 [m]	1	Packed
Spare unterminated cable H05V2-K05BK; MPN: 64075 [m]	4	Packed
Spare unterminated cable SIF1.50-R; MPN: 23602 [m]	2	Packed
Spare unterminated cable LIYCY-3X0.25; MPN: 0034403 [m]	2	Packed
Spare unterminated cable H05V2-K05RD; MPN: 64079 [m]	4	Packed
Spare unterminated cable SIF1.50-B; MPN: 23601 [m]	2	Packed
MainBoard spare components set	1	Packed
EngineBoard spare components set	1	Packed
PMS_R7 spare components set	1	Packed
CATS Vega Safety Pin spare components set	1	Packed
BlueJay XB spare components set	1	Packed
Safety Pins spare components set	1	Packed
Printed documentation of all SRAD electronics including schematic diagrams	3	Not packed

2. Custom parts list

Name	Designator	Qty	Status
MainBoard V1	HW_01	1	Packed
EngineBoard V1	HW_02	1	Packed
MainBoard V2	HW_03	2	Packed
EngineBoard V2	HW_04	2	Packed
PMS_R7	HW_05	3	Packed
Safety Pins	HW_06	2	Packed
CATS Vega Safety Pin	HW_07	3	Packed
BlueJay XB	HW_08	2	Packed
Safety Pins – pins		16	Packed
Safety Pins housing		3	Packed
4S1P Li-Ion Battery Pack	HW_09	4	Packed
Li-Po Safe Bag	HW_10	3	Packed
Unassembled spare boards set: EngineBoard V2, Main Board V2	HW_11	1	Packed
Igniter adapter with resistors, cables, and Wago connectors for EngineBoard V1	HW_12	2	Packed. New must be made
Cable with MR30PB-FB connector for CATS Vega connection with CATS Vega Safety Pin and battery HW_47	HW_13	2	Packed
Cable with XT30-M and XT30-F connector for CATS Vega Safety Pin connection with Safety Pins	HW_14	2	Packed
Cable with XT30-M and XT30-F connector for BlueJay XB connection with Safety Pins	HW_15	2	Packed
Cable for Safety Pins connection with PMS_R7	HW_16	2	Packed
Short adapter with XT60-M connector for connecting PMS_R7 with umbilical cable	HW_17	2	Must be made
“Y” cable adapter with XT60-F connector for connecting PMS_R7 with 4S2P battery pack	HW_18	2	Packed

Cable with XT60-F connector for connecting PMS_R7 with Stage 0 on MainBoard V2 and EngineBoard V2	HW_19	2	Packed
Cable with XT60-F connector for connecting PMS_R7 with Stage 1 on MainBoard V2 and EngineBoard V2	HW_20	2	Packed
Cable with XT30-M connector for BlueJay XB connection with WAGO terminal block for linecutter	HW_21	2	Must be made
Chamber pressure sensor cable routed from EngineBoard V2 to the pressure feed compartment	HW_22	2	Packed 1
Cable routed from the pressure feed compartment to the chamber pressure sensor with M12 connector	HW_24	2	Packed 1
Tank pressure sensor cable routed from EngineBoard V2 to the vent compartment	HW_23	2	Packed 1
Cable routed from the vent compartment to the tank pressure sensor with the M12 connector	HW_25	2	Packed 1
Tank top temperature sensor cable routed from EngineBoard V2 to the vent compartment	HW_26	2	Packed 1
Temperature sensor mounted to the top of the tank	HW_66	2	Packed
Tank bottom temperature sensor cable routed from EngineBoard V2 to the pressure feed compartment	HW_67	2	Packed 1
Temperature sensor mounted to the bottom of the tank	HW_68	2	Packed
Chamber temperature sensor cable routed from EngineBoard V2 to the pressure feed compartment	HW_69	2	Packed 1
Temperature sensor mounted to the top of the chamber	HW_70	2	Packed
Vent Servo cable routed from EngineBoard V2 to vent compartment	HW_27	2	Packed 1
Main Servo cable routed from EngineBoard V2 to the pressure feed compartment	HW_29	2	Packed 1
Dump Valve Servo cable routed from EngineBoard V2 to the pressure vent compartment	HW_31	2	Packed 1
Cable connecting EngineBoard V2 with LoRa Board	HW_33	2	Packed 1
Igniter cable with XT30-F connector routed from Engine Board V2	HW_34	2	Packed 1
Angled Ethernet cable connecting MainBoard V2 with EngineBoard V2	HW_35	2	Packed

Cable connecting MainBoard V2 with BlueJay XB	HW_36	2	Packed 1
Cable connecting BlueJay Altimeter with BlueJay XB	HW_37	2	Packed 1
Cable connecting MainBoard V2 with WAGO terminal block to connect linecutter	HW_38	2	Outdated
Cable connecting MainBoard V2 with 3DR 433Mhz radio module	HW_39	2	Packed 1
Cable connecting MainBoard V2 with GPS module	HW_40	1	Packed
Cables routed from MainBoard V2 to camera	HW_41	2	Must be made
XT90 to XT60 adapter for Li-Po batteries	HW_42	6	Must be made
Removable plastic pins for Safety Pins board	HW_43	16	Packed
Battery temperature sensor with cable	HW_63	2	Packed
LoRa Board	HW_64	2	Outdated
LoRa antenna	HW_65	2	Outdated
Cable with XT60 connector routed from the pressure feed compartment to PMS_R7 for charging batteries from the ground segment	HW_71	2	Packed

3. Off-the-shelf parts list

Name	Designator	Qty	Status
CATS Vega	HW_44	1	Packed
CATS Vega Antennas		3	Packed
BlueJay Altimeter	HW_45	1	Packed
Redox Gold Line 600 mAh 11,1V 80C – Li-Po Battery	HW_46	2	Packed
Redox 1500 mAh 11,1V 40C - Li-Po Battery	HW_47	2	Packed
Redox Gold Line 600 mAh 7,4V 80C - Li-Po Battery	HW_48	2	Packed
Spare BMS module with balancer	HW_49	3	Packed

Spare Samsung INR21700 cells	HW_50	1	Outdated
Spare Li-Po 4S batteries	HW_51	4	Packed
Pack of M3 screws for BeagleBone Black	HW_52	1	Outdated
Pack of M3 nylon washers	HW_53	1	Outdated
Pack of Plastic standoffs for BeagleBone Black	HW_54	1	Packed
20m Ethernet cable	HW_55	1	Outdated
30m Ethernet cable	HW_56	1	Packed
Redox battery charger	HW_57	2	Packed
Redox battery charger cable and power supply	HW_58	2	Packed
BeagleBone Black computer	HW_59	3	Packed
GPS module - GPS + compass Ublox NEO-M8N GPS + LIS3MDL (Pixhawk 3 Pro)	HW_60	1	Packed
Phone with downloaded BlueJay software	HW_61	2	Packed
Set of spare WAGO and other connectors	HW_62	1	Outdated
CATS Vega antenna SMA to SMA cable	HW_72	2	Packed

4. Assembly Instructions

4.1 Avionics Assembly

No.	Required elements	Instructions	Status
0	HW_09 HW_46 HW_47 HW_48	Check batteries Voltages: - Check both SRAD 4S1P Li-Ion battery Packs (HW_09) voltage, it shall be no less than 14,4V	

		- Check 600 mAh 11,1V 80C Redox Li-Po battery (HW_46) Voltage, it shall be no less than 11,1V - Check 1500 mAh 11,1V 40C Li-Po Battery (HW_47) Voltage, it shall be no less than 11,1V - Check 600 mAh 7,4V 80C Li-Po Battery (HW_48) Voltage, it shall be no less than 7,4V	
1	HW_05 HW_19 HW_20 HW_16 HW_63 HW_18	- Prepare PMS_R7 (HW_05) and cables listed in required elements, - Connect XT60-F connector of HW_19 for STAGE_0 connection to STAGE_0 with XT60-M connector (J1) on PMS_R7 - Connect XT60-F connector of HW_20 for STAGE_1 connection to STAGE_1 XT60-M connector (J3) on PMS_R7, - Connect Safety_Pins cable HW_16 to Safety Pins connector (J7) on PMS_R7, - Connect battery temperature sensor with cable (HW_63) to BatteryTempSens connector (J4) on PMS_R7 - Connect "Y" cable adapter with XT60-F connector HW_18 to XT60-M battery connector (J6) on PMS_R7. <u>Do not connect battery at this step.</u>	
2	HW_03 HW_36 HW_41 HW_39 HW_40 HW_19 HW_20 HW_35	- Connect BlueJay XB with Main Board V2 (HW_03) to Blue Jay connector (J10) using HW_36 cable, - Connect 2 cameras to J9, J7 connectors on Main Board using HW_41 cables - Connect Radio Module with Main Board to Radio(J2) connector using HW_39 cable, - Connect radio module to J2 connector on Main Board using HW_39 cable - Connect GPS module to J3 GPS connector using HW_40 cable, - Connect Stage_0 from PMS_R7 to STAGE_0 (J1) on Main Board using HW_19 cable - Connect Stage_1 from PMS_R7 to STAGE_1 (J4) on Main Board using HW_20 cable	

		- Connect Main Board with Engine Board using HW_35 cable. - In case of Main Board V2 (HW_03) failure use Main Board V1 (HW_01)	
3	HW_04 HW_22 HW_23 HW_26 HW_67 HW_69 HW_27 HW_29 HW_31 HW_64 HW_33 HW_19 HW_20 HW_34	- Connect Chamber pressure sensor cable (HW_22) to J4 on Engine Board V2 (HW_04), - Connect Tank pressure sensor cable (HW_23) to J5 connector on Engine Board, - Connect 3 Temp sensors cables (HW_26,HW_67,HW_69) to J8, J9, J1 connectors on Engine Board - Connect Vent servo cable (HW_27) to J12 connector on Engine Board - Connect Main servo cable (HW_29) to J11 connector on Engine Board - Connect Dump Valve servo cable (HW_31) to J13 connector on Engine Board - Connect LoRa board (HW_64) using LoRa cable (HW_33) to H3 connector (UART) and H6 connector (3,3V,GND) on Engine Board - Connect Stage_0 from PMS_R7 to STAGE_0 (J3) on Engine Board using HW_19 cable - Connect Stage_1 from PMS_R7 to STAGE_1 (J2) on Engine Board using HW_20 cable - Connect igniter cable (HW_34) with J16 connector on Engine Board - In case of Engine Board V2 (HW_04) failure use Engine Board V1 (HW_02)	
4	HW_08 HW_21 HW_45	- Connect J5 connector on BlueJay XB with linecutter WAGO terminal blocks using linecutter cable (HW_21) - Connect MainBoard using HW_36 cable to J2 connector on BlueJay XB - Connect BlueJay altimeter (HW_45)	

	HW_37 HW_15 HW_46	with BlueJay XB connector (J3) using (HW_37) cable, - Connect Safety Pins cable (HW_15) to J4 connector on BlueJay XB - Connect Li-Po 3s 600mAh (HW_46) to J1 connector on BlueJay XB	
5	HW_45 HW_48 HW_37 HW_08	- Connect BlueJay altimeter to BlueJay XB with HW_37 cable - Connect Li-Po 2s 600mAh battery (HW_48) to BlueJay	
6	SW	- Check CATS Vega with CATS Vega are not in TEST mode - Set valid channel - Check gps signal detection - Check connection with GSE - Check apogee and Main Parachute triggers and signals - Check that logging is enabled	
7	HW_07 HW_44 HW_13 HW_14 HW_47 HW_72	- Connect CATS Vega with CATS Vega Safety Pin J1 connector using HW_13 cable, - Connect CATS Vega Safety Pin J2 connector with Safety Pins board using HW_14 cable - Connect Li-Po 3s 1500mAh (HW_47) to XT60-M connector on HW_13 cable - Connect HW_72 SMA to SMA cable to CATS Vega and antenna	
8	HW_06 HW_16 HW_14 HW_15	- Connect J1 connector on Safety Pins board with PMS board using HW_16 cable. - Connect J3 connector on Safety Pins board with CATS Vega Safety Pin using HW_14 cable. - Connect J2 connector on Safety Pins board with BlueJay XB using HW_15 cable	
9	HW_09	Connect HW_09 Li-Ion Battery Pack to the J6 connector on PMS_R7	
10	HW_22 HW_24	Connect HW_22 to HW_24	

11	HW_23 HW_25	Connect HW_23 to HW_25	
12	HW_26 HW_66	Connect HW_26 to HW_66	
13	HW_67 HW_68	Connect HW_67 to HW_68	
14	HW_69 HW_70	Connect HW_69 to HW_70	
15	HW_27 Vent Servo	Connect HW_27 to the Vent Servo	
16	HW_29 Main Servo	Connect HW_29 to the Main Servo	
17	HW_31 Dump Valve Servo	Connect HW_31 to Dump Valve	
18	HW_34	Connect HW_34 to WAGO terminals on the pressure feed compartment	
19	HW_71 HW_57	Connect HW_71 to the J5 connector on PMS_R7 and screw it to the pressure vent compartment	
20 SW	Assembled HW, Laptop with srp-app and ethernet port	Using srp-app check all sensors (2x pressure sensor, 6x temperature sensors, 1x barometer sensor, 1x IMU sensor, 1x GPS)	
21 SW	Assembled HW, Laptop with srp-app and ethernet port	Using srp-app test all Valves (Main Valve, Vent Valve, Dump Valve) Procedure: Open, Close, Open (for vent valve you need to also check pulsing mode)	
22 SW	Assembled HW, Laptop with srp-app and ethernet port	Using srp-app test Igniter (DO NOT USE Igniters connected to ENGINE)	
23 SW	Assembled HW, GSE Control Panel	Using GSE Controll Panel, check that we receiving all data	
24 SW	Assembled HW, GSE Control Panel	Using GSE CP check that you cant move any valve or ignite rocket without ARM mode	
25 SW	Assembled HW, GSE Control Panel	Using GSE CP check that you can move ALL Servos when rocket is ARM	
26	Assembled HW,	Using GSE CP check that Launch procedure	

SW	GSE Control Panel	work correctly (require arm mode)(Igniter should turn on 0.9 - 1.1s before main valve open) (DO NOT USE IGNITERS CONNECTED TO ENGINE)	
27 SW	Assembled HW, Laptop with srp-app and ethernet port	Using srp-app close main valve	

5. Help

5.1 Contact and consultation

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Step	Task	Notes
1	Insert the first mast section into the base and secure it	
2	Sequentially assemble the mast parts using M10x80 bolts, washers, and M10 self-locking nuts.	
3	Attach the antenna and cameras with their cables to the upper part of the mast	
4	Pre-assemble the cylinder and hydraulics stand (with hydraulic components already mounted).	
5	Pre-assemble the mass measurement module (ready for plug-and-play installation on the LP).	
6	Connect the tankbox to the hydraulics (valves & sensors)	
7	Connect the hoses (2) to the hydraulics	
8	Connect the quick disconnect (umbilical) to the hose and the tankbox	
9	Place the launchbox in the designated area (about 8m from the launchrail)	
10	Connect the cable from the launchbox to mass measurement module cable (4 pin)	
11	Connect the data cable from the launchbox to the tankbox (2 pin)	
12	Connect the rocket power cable (launchbox -> rocket)	
13	Connect the tankbox power cable (launchbox -> tankbox)	
14	Connect the cameras with RJ-45 cables to the designed interfaces on launchbox	
15	Connect the radio link with RJ-45 cables to the designed interfaces on launchbox	
16	Connect power supply to launchbox	
17	Turn on the launchbox	
18	Turn on the component fuses	
19	Connect antennas to mission control (SiK Radio Telemetry 433MHz & LoRa)	
20	Connect SDR radio to laptop and launch SDR application	

Step	Task	Notes	Kolumna nr 1
1	Insert the lowest mast segment into the base and secure it	x	
2	Connect the 3 pre-assembled mast segments together using M10x80 bolts, washers, and M10 self-locking nuts	x	
3	Attach the clamp to the mast using the 3x star knobs (M8x60). Fasten the 3 aluminum support legs to the clamp using M10x80 bolts	x	
4	Secure the sleeve to the mast and place the guy wire ring on it. Attach the guy wires to the ring	x	
5	Erect the mast safely (watch out for the pre-mounted equipment at the top)	x	
6	Secure the guy wires to ground anchors and tension them using the M8 turnbuckles	x	
7	Place the mast where cameras can have good view on the rocket and hydraulics (between 10 - 20m from the launchrail)	x	
8	Point the antenna towards Mission Control and hoist the flag	x	
9	Place the mass measurement module in the designated spot on the launchrail	x	check every lane from start to the end
10	Place the hydraulics stand in the designated area (about 8m from the launchrail)	x	
11	Connect the tankbox to the hydraulics (valves & sensors)	x	
12	Connect the hoses (2) to the hydraulics	x	
13	Connect the quick disconnect (umbilical) to the hose and the tankbox	x	
14	Place the cylinder depot in the designated area (about 8m from the launchrail)		
15	Insert the mother cylinder with the oxidizer		
16	Connect the hose to the cylinder		
17	Attach the temperature sensor to the cylinder		
18	Wrap the cylinder with a thermal blanket		
19	Attach the water tank		
20	Start the cooling system by slightly opening the water tank		
21	Close the cylinder depot		
22	Connect the temperature sensor to tankbox		
23	Place the launchbox in the designated area (about 8m from the launchrail)		
24	Connect the cable from the launchbox to mass measurement module cable (4 pin)		
25	Connect the data cable from the launchbox to the tankbox (2 pin)		
26	Connect the rocket power cable (launchbox -> rocket)		
27	Connect the tankbox power cable (launchbox -> tankbox)		
28	Connect the cameras with RJ-45 cables to the designed interfaces on launchbox		
29	Connect the radio link with RJ-45 cables to the designed interfaces on launchbox		
30	Connect power supply to launchbox		
31	Turn on the launchbox		
32	Turn on the component fuses		

Step	Test	Notes
1	Perform short-distance Wi-Fi radiolink test.	
2	Confirm stable radiolink operation (validated if remote control of hydraulics works smoothly).	
3	Verify laptops connected to the Mission Control router receive IP addresses correctly.	
4	Verify the green LED on the 433 MHz radio is solid (not blinking).	
5	Verify data is being received properly (main rocket communication via 433 MHz, GPS via LoRa).	
6	Verify the spectrum of LoRa (GPS) communication is visible in the waterfall display	
7	Verify the module responds correctly to manual physical load (e.g., pressing by hand)	
8	Verify accurate reading using a known mass (e.g., 10 kg).	
9	Verify the system responds correctly to launch angle adjustment commands.	
10	Verify all Launchbox nodes start up correctly (automatically or manually) and full network communication is established.	
11	Verify the 2 valves and the decoupler respond correctly to remote commands.	
12	Verify pressure and temperature sensors return reasonable values (e.g., digital pressure matches the analog gauge).	
13	Perform a system leak test (troubleshoot if leaks are detected).	
14	Perform a quick release (disconnect) test of decoupler.	
15	Confirm hydraulics can be fully tested/controlled via the Control Panel.	
16	Verify all telemetry data is received and updating correctly in Control Panel.	

1	Perform long-range Wi-Fi radiolink test	
2	Confirm stable radiolink operation (validated if remote control of hydraulics works smoothly)	
3	Verify laptops connected to the Mission Control router receive IP addresses correctly	
4	Verify the green LED on the 433 MHz radio is solid (not blinking)	
5	Verify data is being received properly (main rocket communication via 433 MHz, GPS via LoRa)	
6	Verify all Launchbox nodes start up correctly (automatically or manually) and full network communication is established	
7	Verify the weight module responds correctly to manual physical load	
8	Verify the 2 valves and the decoupler respond correctly to remote commands	
9	Verify pressure and temperature sensors return reasonable values (e.g., digital pressure matches the analog gauge)	
10	Perform a quick release (disconnect) test of decoupler	
11	Confirm hydraulics can be fully tested/controlled via the Control Panel	
12	Verify all telemetry data is received and updating correctly in Control Panel	
13	Verify camera transmission and remote control	

ID	Problem	Possible fix
1	Hydraulics leak detected	1. Check all hydraulic fittings, hoses, and valves for visible leaks. 2. Carefully tighten any loose connections. 3. Replace damaged O-rings or Teflon tape if necessary. 4. Re-test
2	Radiolink connection not established / broken	1. Make sure the power is on for the PoE to work. (On both ends) 2. Check for loosely connected antenna cables. 3. Check if nothing obscures the antenna vision. 4. Restart antennas by unplugging the cable.
3	Remote control of valves not working	1. Check if radiolink is working. If not go to ID 2 . 2. Check if ROS2 nodes are running on both launchbox & control panel. Run them manually if needed. 3. Check if control panel locally sees the changes in switches.
4	Control Panel - telemetry not present from the GSE	Same troubleshooting as above.
5	Control Panel - telemetry not present from the rocket	1. Check if radio green diode is not blinking. If it is, then make sure mission control antenna is pointing directly for the rocket. 2. Avionics troubleshooting. Are the flight computers on?



CHECKLIST - R7 - Recovery

13.05.2026, VERSION 1

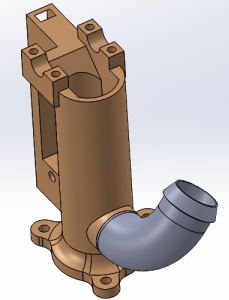
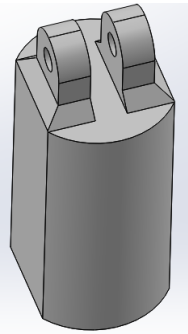
1. Tools list
2. Custom parts list
 - 2.1. CO2 Parts
 - 2.2. BP Parts
 - 2.3. Linecutter Parts
 - 2.4. Body Parts
3. Ready parts list
 - 3.1. Mounting hardware
 - 3.2. Parachute parts
4. Assembly instructions
 - 4.1. CO2 Assembly
 - 4.2. Linecutter Assembly
 - 4.3. BP Assembly
 - 4.4. Body Assembly
5. Lines diagram
6. Safety Concerns
7. Help

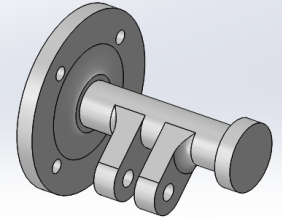
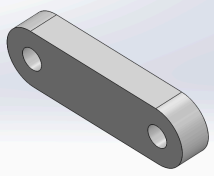
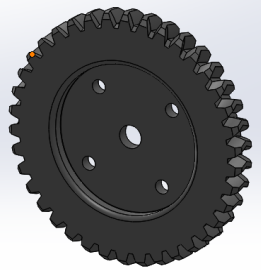
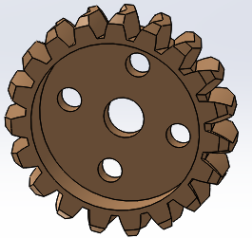
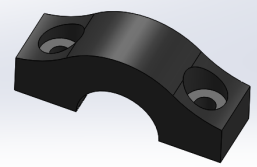
1. Tools List

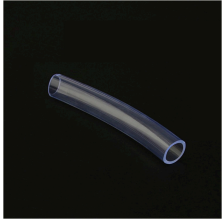
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Allan key no. 1.5		
Allan key no. 2		
Allan key no. 2.5		
Allan key no. 3		
Screwdriver Slotted 1.5		
Screwdriver Philips 2		

2. Custom Parts List

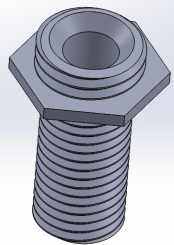
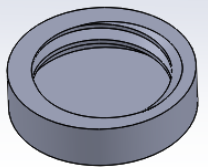
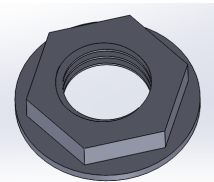
2.1 CO2 Parts

Name	Quantity	Photo	Status	Verified
REC_1101_Cylinder	1			
REC_1102_Piston	1			

REC_1103_Crankshaft	1			
REC_1104_Connecting rod	1			
REC_1105_38t Gear	1			
REC_1106_19t Gear	1			
REC_1107_TopCap	2			
REC_1114_Servo	1			

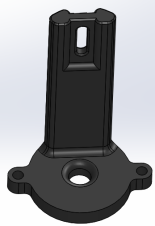
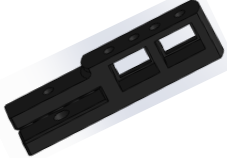
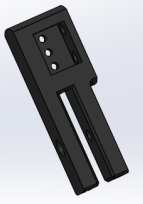
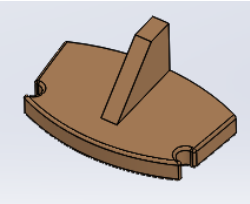
REC_1115_Tube	1			
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2.2 BP Parts

Name	Quantity	Photo	Status	Verified
REC_1601_Chargewell	2			
REC_1602_WellThread	2			
REC_1603_Nut	2			

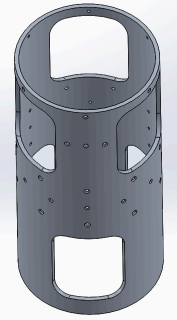
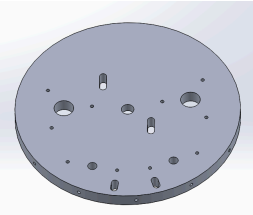
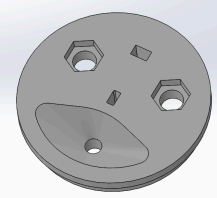
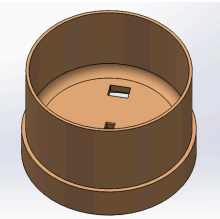
2.3 Linecutter Parts

Name	Quantity	Photo	Status	Verified
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REC_1201_Base	2 (+2)			
REC_1102_Module Left	1 (+2)			
REC_1203_Module Right	1 (+2)			
REC_1204_Tension Plate	1 (+1)			
REC_1205_Dyneema	1 (+n)			
REC_1206_Cutter	3 (+n)	[will add photo onsite, forgot to take one before shipping]		

2.4 Body Parts

Name	Quantity	Photo	Status	Verified
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REC_1301_Coupler	1			
REC_1302_Baseplate	1			
REC_1303_TopRing	1 (+1)			
REC_1304_Pushtube	1 (+1)			

3. Ready parts list

3.1 Mounting hardware

Name	Quantity	Photo	Status	Verified
M2x10 DIN 912 - Bolt	4 (+n)			
M3x6 DIN 912 - Bolt	4 (+n)			

M3x12 DIN 912 - Bolt	2 (+n)			
M3x16 DIN 912 - Bolt	7 (+n)			
M3x20 DIN 912 - Bolt	4 (+n)			
M3 DIN 934 - Nut	4 (+n)			
M3x16 DIN 7991 - Bolt	21 (+n)			
M6 Eyebolt	2 (+4)			
M8 Eyebolt	1 (+1)			

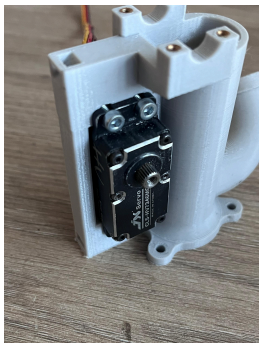
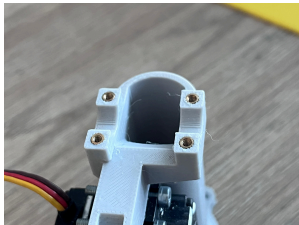
3.2 Parachute parts

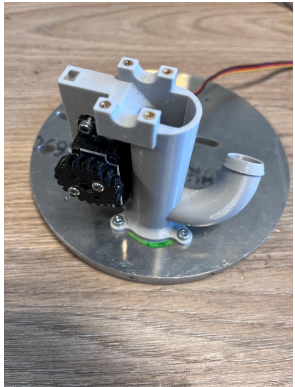
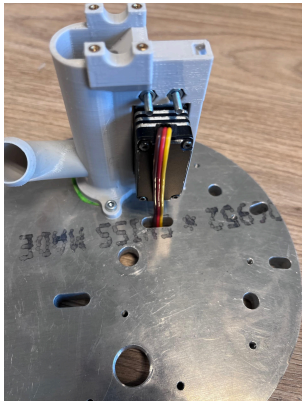
Name	Quantity	Photo	Status	Verified
Parachute	1	[will add photo onsite, forgot to take one before shipping]		
Skirt Line (backup)	(1)	[will add photo onsite, forgot to take one before shipping]		

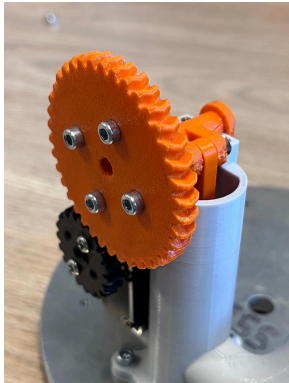
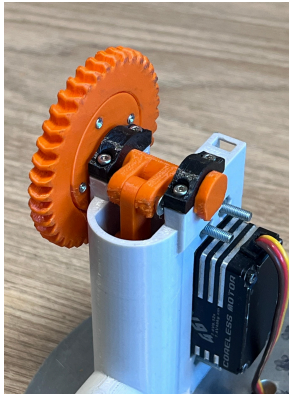
Main Line	1 (+1)	[will add photo onsite, forgot to take one before shipping]		
Reefing Line (backup)	(1)	[will add photo onsite, forgot to take one before shipping]		
Mounting Line (1.5m)	1 (+1)	[will add photo onsite, forgot to take one before shipping]		
Parachute lines (backup)	(8)	[will add photo onsite, forgot to take one before shipping]		
Parachute bag	1 (+1)	[will add photo onsite, forgot to take one before shipping]		
Swivel 25kN	1 (+1)			
Top Carabiner	1 (+3)			
Long shackle	1 (+3)			
Rubber bands	1 (+n)			

4. Assembly instructions

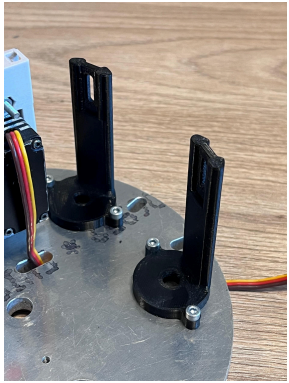
4.1. CO2 Assembly

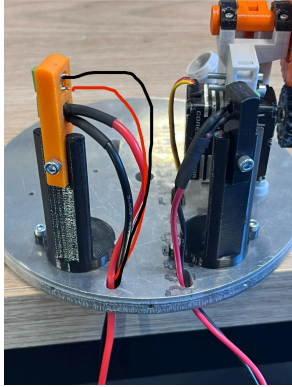
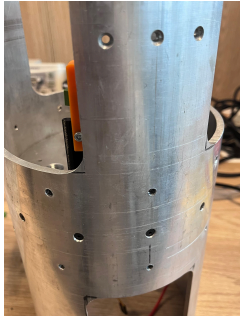
No	Needed Parts	Instruction	Photo	Status	Verified
1.	1xREC_1101 1x46kg servo 4x DIN 912 M3x16 4x DIN 934 M3 Nut	Mount servo to cylinder using 4x M3x16 bolts (DIN 912) and 4x M3 nuts. Servo output gear in to be on the top side. Be sure to push the servo to the top-right position.			
2.	1xREC_1101	Ensure all 4 threaded inserts are in cylinder. If not mounted, mount threaded inserts into cylinder.			
3.	1xServo horn 1xREC_1106 4xBolts	Mount the small gear to the servo horn using 4x bolts supplied with horn.			

					
4.	1x Cylinder Assembly 1x REC_1302 1x Foam seal 3x DIN 912 M3x16	Bolt cylinder to baseplate using DIN 912 M3x16 bolts and pass servo cable through hole. Insert foam seal between cylinder and baseplate	 		
5.	1x REC_1102 1x REC_1103 1x REC_1104 2x DIN 7991 M3x16	Mount crankshaft assembly using DIN 7991 M3x16 bolt.			

6.	1x REC_1105 1x Crankshaft assembly 4x DIN 912 M3x6	Mount large gear onto crankshaft using DIN 912 M3x6 bolts.			
7.	1x Cylinder assembly 1x Crankshaft assembly 2x REC_1107 4x DIN 912 M2x10	Bolt top caps over crankshaft to cylinder. Check torque and ensure the crankshaft rotates freely but has no unnecessary play.			

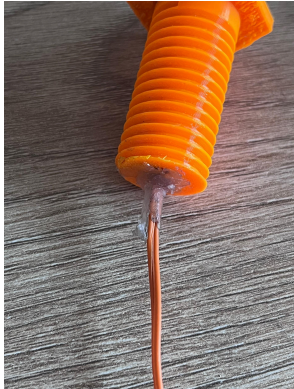
4.2. Linecutter Assembly

No	Needed Parts	Instruction	Photo	Status	Verified
1.	1xREC_1302 2xREC_1201 4xM3x16 DIN 912	Attach the Linecutter base to the Baseplate			

2.	1x Dyneema Line 2x M6 eyebolt	Tie dyneema line to an eyebolt at each end using clinch knot. Line should have proper length to be taught over tension plate			
3.	1x Dyneema assembly 3x Linecutter	wrap linecutters around dyneema line			
4.	1x REC_1102 1x REC_1203 2x DIN 912 M3x12	mount linecutter modules onto baseplates, secure with DIN 912 M3x12 bolt. Pass wires through the appropriate holes			
5.	1x REC_1301 1x Baseplate assembly 12x DIN 7991 M3x16	Mount baseplate with assembled linecutters and CO2 system to coupler using 12x DIN 7991 M3x16 bolts. Ensure that the linecutters face the 3 hole pattern in the wall			

6.	1x Recovery assembly 1x REC_1204 3x DIN 7991 M3x16	Mount Tension plate to the coupler using 3x DIN 7991 M3x16 bolts. The support rib should face the baseplate			
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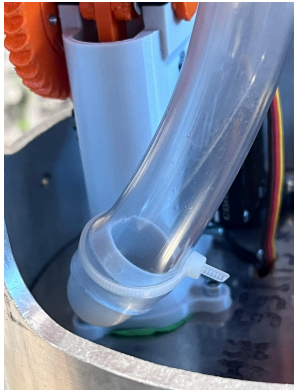
4.3. BP Assembly

No	Needed Parts	Instruction	Photo	Status	Verified
1.	2xREC_1601 2x 1m+ Electric match Hot glue	Insert the electric match through the 3mm hole in the charge well and seal around wire with glue			
2.	2xREC_1602 5g BP FFFF	Pour 2.5g BP per charge well and tightly screw on the cap			
3.	2xPrepared wells 1xREC_1303 2xREC_1604	Insert the wells through the hex holes in the plate, and tighten the nuts on the bottom side			

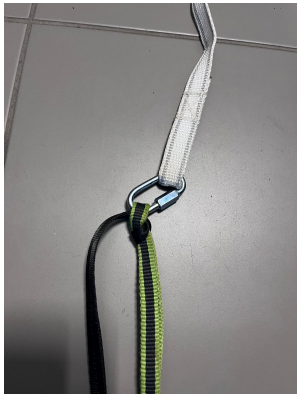
					
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4.3. Body Assembly

No	Needed Parts	Instruction	Photo	Status	Verified
1.	1x BP assembly 1x Bodytube assembly	Mount the assembled plate onto the proper side of the coupler. Align the reefing line hole above the line cutter assembly. Ensure the match wire passes through the CO2 cylinder and servo wire opening to not interfere with servo operation. Pass the second match wire through the threaded M16 hole on the baseplate	 		

2.	1x Tube section 1x Recovery Assembly	Slip on transparent tube over the cylinder exhaust and top plate nozzle. Ensure tight fit and secure with hoseclamp or ziptie.	 		
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4.4 Parachute Assembly

No	Needed Parts	Instruction	Photo	Status	Verified
1.	1x Nosecone 1x Parachute assembly	Attach the nosecone strap to the main line at the knot between the black parachute lines and the green Kevlar strap using a 4mm barrel carabiner			

2.	1x Parachute assembly 1x Mounting Line	Secure the swivel between the main line and the mounting line.			
3.	1x Deployment bag 1x Parachute assembly	Attach the deployment bag to the loop found on the mounting line using a 4mm shackle			
4.	1x Parachute assembly	1. Lay out the parachute and fold in a harmonica pattern along the section lines.	[will add photo onsite, forgot to take one before shipping]		
5.	1x Parachute assembly	Harmonica folds from top to bottom	[will add photo onsite, forgot to take one before shipping]		
6.	1x Parachute assembly	Lay the parachute onto the center of the deployment bag	[will add photo onsite, forgot to take one before shipping]		
7.	1x Parachute assembly	Fold the line at the nosecone attaching point and fold in the figure 8 pattern onto the parachute. Lay the excess main	[will add photo onsite, forgot to take one before shipping]		

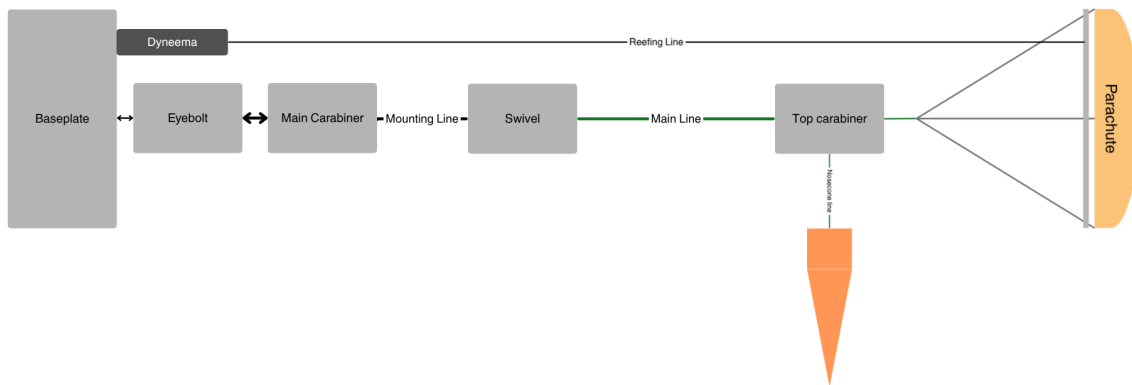
		and reefing line on the other side of the parachute.			
8.	1x Parachute assembly	Fold over parachute deployment bag corners, roll into a proper burrito with only the main and reefing lines exiting. Secure with a single rubber band.	[will add photo onsite, forgot to take one before shipping]		

4.5 Final Assembly

No	Needed Parts	Instruction	Photo	Status	Verified
1.	1x Parachute assembly 1x Recovery Assembly 1x REC_1304	Pass the mounting line and reefing line through the appropriate holes in the push tube			
2.	1x Recovery Assembly	Pass the mounting line and reefing line through the appropriate holes in the top plate			

3.	1x Recovery Assembly 1x Linecutter line	Pass the dyneema assembly through the reefing line loop, secure both eyebolts and tension the dyneema. secure the linecutters in the terminals			
4.	1x Recovery Assembly 1x Recovery rocket body	Assemble the recovery section of the rocket body to the coupler in accordance to the colored lines on both parts. Tighten all 9 DIN 912 M5x8 bolts in a star pattern			
5.	1x Recovery assembly 6x M3 nylon bolts 6x 2cmx2cm alu tape squares	Insert the parachute, push tube, and nosecone into the rocket body. Align using marked lines. Secure with M3 nylon bolts. Cover bolts with aluminium tape.	[will add photo onsite, forgot to take one before shipping]		

5. Lines Diagram



6. Safety Concerns

- Do not operate open flames or hot elements around black powder and CO2 cartridges
- Ensure electric matches have twisted lead wires to prevent ignition
- Handle all parts with proper caution and care
- Ensure all parts are clean and undamaged before mounting
- Do not mount stripped bolts; this creates unnecessary problems in the future
- Use the proper size tools for assembly; this system uses only metric sizes
- No part of the recovery system is edible
- General OSHA standards apply during assembly
- Isopropyl alcohol can be used to clean all parts, nothing stronger, so as not to destroy parts
- Loctite 243 or equivalent should be applied to all threads before installation

7. Help

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SIMLE
SIMBA

CHECKLIST - R7 - STRUCTURE

14.05.2026, VERSION II

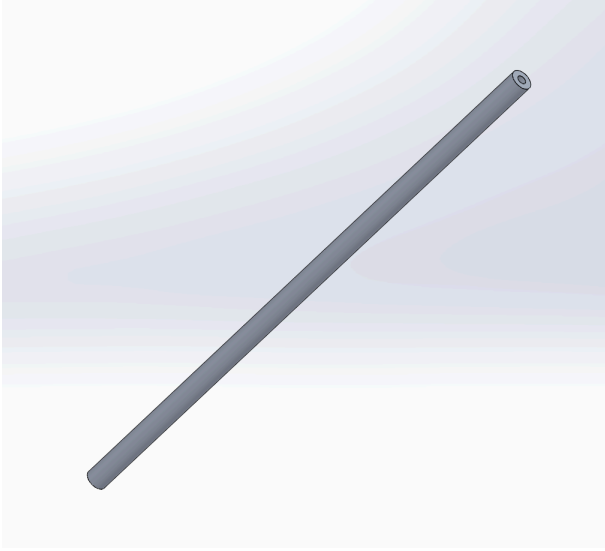
1. Tools list
2. Custom parts list
3. Off-the-shelf parts list
4. Assembly Instructions
 - 4.1. GPS-ORANGE Assembly
 - 4.2. Avionics and Payload Frame Assembly
 - 4.3. Final Structural Assembly
5. Help and Safety
 - 5.1. Contact and consultation
 - 5.2. Standard summaries
 - 5.3. Global torque guide

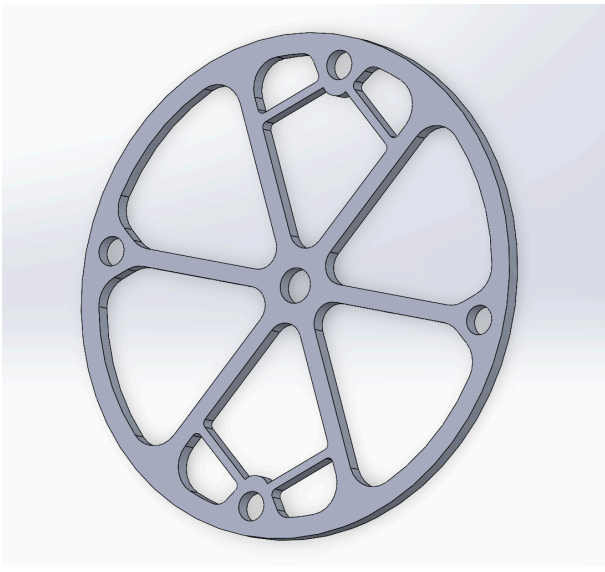
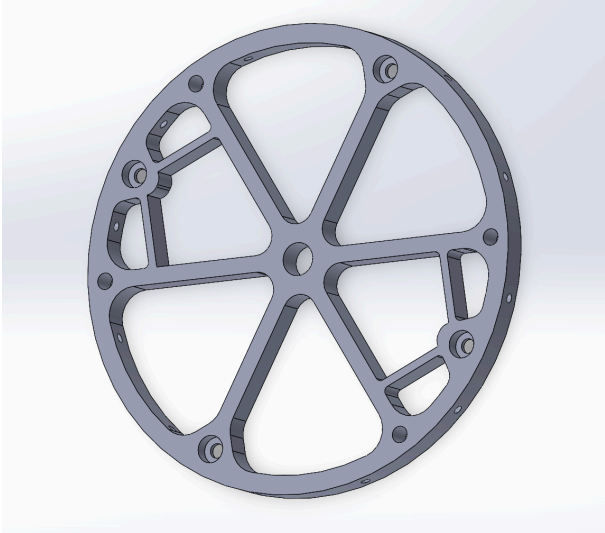
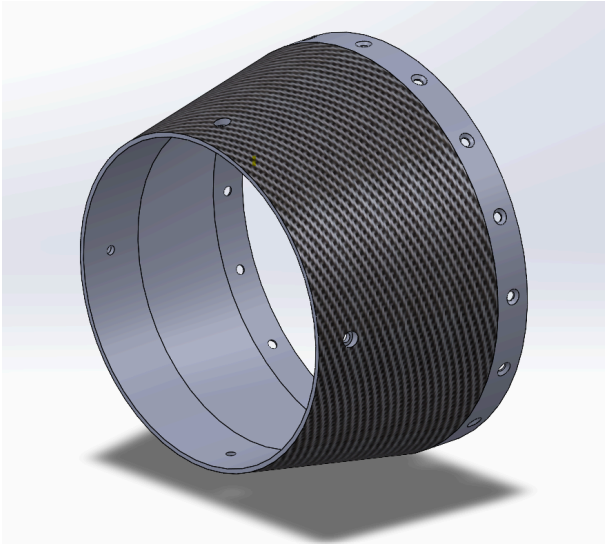
1.Tools list

Name	Status
Allen key no. 2	
Allen key no. 2.5	
Allen key no. 3	
Flat Wrench no. 7	
Flat Wrench no. 8	
Flat Wrench no. 19	
Torque Wrench	
Torque Wrench hexagonal insert no. 2	
Torque Wrench hexagonal insert no. 2.5	
Torque Wrench hexagonal insert no. 3	
Torque Wrench hexagonal insert no. 8	
Torque Wrench hexagonal insert no. 19	
Nut Wrench	
Phillips Screwdriver no. 1	
Flat Screwdriver no. 2	

2. Custom parts list

Name	Visualisation	Qty	Status
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STR_4102_ServiceBody		1	
STR_3102_ROD		8	

STR_3103_ORANGE-IN		2	
STR_3104_ORANGE-OUT		4	
STR_7001_BOATTAIL		1	

Maintenance Hatch 1		1	
Maintenance Hatch 2		1	
RFA - Recovery Final Assembly		1	
EFA - Engine Final Assembly		1	
APATOR_TOP		1	
APAROR_BOT		1	
APATOR_G		1	
R7_STR_3303_RadioAntenaHolder		1	
R7_STR_3304_LORAantenaHolder		1	
R7_STR_3305_GPS_FRONTPLATE		1	
R7_STR_3306_GPS_BACKPLATE		1	
R7_STR_3307_RZUF_GPS_Mount		1	
GS_LORA		1	
GS_RADIO		1	
GPS		1	
EBA - Engine Board Assembly		1	
MBA - Main Board Assembly		1	
EBMP - Engine Board Mounting Plate		1	
MBMP - Main Board Mounting Plate		1	
BlueJayA - Blue Jay Assembly		1	
CATSA - CATS Assembly		1	

PMSA - Power Management System Assembly		1	
QuadroA - Battery Assembly		1	
Main Board Shock Absorber		1	
Engine Board Shock Absorber		1	
Small Shock Absorber		4	
Large Shock Absorber		4	
Rail Lug RADAX		1	
Rail Lug Boattail		1	
M6 Mounting Hooks		2	

3. Off-the-shelf parts list

Name	Qty	Status
Bolt M2x10 (DIN 912)	6	
Bolt M3x10 (DIN 912)	4	
Bolt M3x16 (DIN 912)	8	
Bolt M3x25 (DIN 912)	10	
Bolt M4x14 (DIN 912)	16	
Bolt M4x16 (DIN 912)	8	
Bolt M4x25 (DIN 912)	5	
Bolt-T M3x16 (DIN 7991)	4	
Bolt-T M4x10 (DIN 7991)	48	
Bolt-T M5x20 (DIN 7991)	18	
Bolt-T M12x90 (DIN 7991)	2	
Bolt M12x110 (DIN 933)	1	
Nut M3 (DIN 982)	10	

Nut M4 (DIN 982)		
Nut M5 (DIN 982)	4	
Nut M6 (DIN 982)	2	
Nut M12 (DIN 982)	3	
Washer M5 (DIN 125)	8	
Leveling ring (DIN705)	36	
Zip Tie 5mm	3	
Rubber Band	1	

4. Instructions

4.1. GPS-ORANGE Assembly

No.	Required elements	Instructions	Status
1.	STR_3104_ORANGE-OUT - 1x R7_STR_3305_Lora_GPS_Radio_FRONTPLATE R7_STR_3306_Lora_GPS_Radio_BACKPLATE R7_STR_3307_RZUF_GPS_Mount GPS GS_Radio GS_LORA Bolt M4x25 - 4x Nut M4 - 4x Zip Tie - 3x	Prepare the elements required for the GPS-ORANGE Assembly	

	Rubber Band		
2.	STR_3104_ORANGE-OUT - 1x	Take ORANGE-OUT and place it on the face that has countersunk holes in it. Make sure the ROD markings II and IV are facing you	
3.	R7_STR_3305_Lora_GPS_Radio_FRONTPLATE	Place the Frontplate the the ORANGE-OUT The triangular slot should be facing you and its edge should be laying on support that has the IV marking in front of it.	
4.	R7_STR_3306_Lora_GPS_Radio_BACKPLATE	Put the Backplate under the ORANGE-OUT. The triangular slot should overlap with the one on the Frontplate	
5.	GS_Radio	Place the Radio in a way that it rests between the rectangular slots on the Frontplate The radio antenna should be resting between marks II and VIII visible on ORANGE-OUT	
6.	Zip Tie - 3x	Secure the Radio by feeding and fastening Zip Ties into all of the rectangular slots in the Frontplate.	
7.	R7_STR_3307_RZUF_GPS_Mount	Place the RZUF so that the mounting holes in it overlap with the Frontplate holes next to the Radio and the one in the centre between markings VIII VI.	
8.		Make sure the round cable slot in the RZUF is facing inside the assembly	
9.	Bolt M4x25 - 2x Nut M4 - 2x Allen Key no. 3 Flat Wrench no. 7	Fasten the RZUF with 2 M4x25 bolts and M4 nuts Use an Allen Key no. 3 and Flat Wrench no. 7 Make sure that the connection goes through the Backplate as well.	
10.	GPS Rubber Band - 1x	Place the GPS onto the RZUF and secure with a Rubber Band in an X motion	
11.	GS_LORA	Place the LORA onto the Frontplate so that its mounting holes overlap with the two remaining holes in the Frontplate	
12.		Make sure that the open face of the LORA is	

		facing to the inside of the assembly	
13.	Bolt M4x25 - 2x Nut M4 - 2x Allen Key no. 3 Flat Wrench no. 7	Fasten the LORA with 2 M4x25 bolts and M4 nuts Use an Allen Key no. 3 and Flat Wrench no. 7 Make sure that the connection goes through the Backplate as well.	
14.		You have now completed the GPS-ORANGE Assembly	

4.2. Avionics and Payload Frame Assembly

No.	Required elements	Instructions	Status
1.	STR_3104_ORANGE-OUT - 3x GPS-ORANGE STR_3103_ORANGE-IN - 2x STR_3102_ROD - 8x EBA - Engine Board Assembly MBA - Main Board Assembly EBMP - Engine Board Mounting Plate MBMP - Main Board Mounting Plate Electronic Dampeners - 2x Bolt-T M5x20 - 16x Bolt M4x12 - 16x Bolt M5x30 - 4x Bolt M12x45 - 2x Washer M5 - 8x	Prepare the elements required for the Avionics and Payload Body Assembly	

	Nut M5 - 4x Nut M12 - 2x Leveling ring - 16x Allen Key no. 2 Allen key no. 2.5 Allen key no. 3 Allen key no. 8		
2.	STR_3104_ORANGE-OUT x 1 STR_3102_ROD x 4	You will now start preparing the Payload Assembly (PYA) Insert ROD into all 4 of the counterbored holes of ORANGE-OUT KEEP IN MIND THE LABELING OF ALL PARTS. Each counterbored hole has a number corresponding to the ROD that should be inserted into it. The Payload parts are labeled with ROMAN numbers	
3.	Bolt-T M5x30 - 4x Allen Key 3	Fasten ORANGE-OUT and all RODs together by inserting 4 M5x30 into the countersunk holes of ORANGE-OUT using an allen key no. 3	
4.		Make sure the M5 bolts have their heads fully hidden in the countersunk holes	
5.		Turn the assembly in a way that it now supports itself by laying on the flat face of ORANGE-OUT	
6.	Long Shock Absorber - 4x	Insert one Long Shock Absorber onto all RODs.	
7.		Make sure RODs VII and I are facing you	
8.	APATOR_TOP	Slide the APATOR_TOP onto the RODs The mounting recess for APATOR_G should be resting closer to the RODs away from you.	

9.	APATOR_G	Place the APATOR_G into the mounting recess	
10.		Make sure RODs VII and I are facing you	
11.		Verify the proper orientation of APATOR_G Its screen should be facing to your right	
12.	Short Shock Absorber - 4x	Slide one Short Shock Absorber onto all RODs I and VII	
13.	Leveling ring - 4x	Slide two leveling rings onto ROD I and VII	
14.	Flat Screwdriver no. 2	Fasten the bottom row of leveling rings so it rests on the Short Shock Absorber. Use a Flat Screwdriver no. 2	
15.		Verify that the Leveling Ring fastening bolt is facing to the inside of the assembly	
16.	Short Shock Absorber - 4x	Slide one Short Shock Absorber onto RODS I and VII.	
17.		Make sure RODs VII and I are facing you	
18.	APATOR_BOT	Slide the APATOR_BOT onto the RODs APATOR_G should rest in the mounting recess	
19.	Screw M3x16 - 4x No.1 Phillips Head screwdriver	Secure APATOR_G to the mounting recesses by inserting an M3x16 screw into all 4 holes in APATOR_TOP and APATOR_BOT. Use an No.1 Phillips Head screwdriver	
20.	Flat Screwdriver no. 2	Fasten the second row of leveling rings placed in step so it supports the Small Shock Absorbers. The Small Shock Absorbers should press onto APATOR_BOT. Use a Flat Screwdriver no. 2	
21.		Verify that the Leveling Ring fastening bolt is facing to the inside of the assembly	
22.	Short Shock Absorber - 4x	Slide one Short Shock Absorber onto all RODs	
23.	Leveling ring - 2x	Slide one leveling ring onto RODs VII and V	

24.	Flat Screwdriver no. 2	Fasten the just added leveling rings so that they rest on the Small Shock Absorbers added two steps ago. Use a Flat Screwdriver no. 2	
25.		Verify that the Leveling Ring fastening bolt is facing to the inside of the assembly	
26.	Leveling ring - 2x	Slide one leveling ring onto RODs V and VIII	
27.	Flat Screwdriver no. 2	Fasten the just added leveling ring so that it rests on the previously added Shock Absorbers Use a Flat Screwdriver no. 2	
28.		Verify that the Leveling Ring fastening bolt is facing to the inside of the assembly	
29.	R7_STR_3303_LORAntenaHolder	Slide the LORA Antenna holder onto the other two remaining RODs	
30.	Leveling ring - 2x	Slide one leveling ring onto ROD I and III	
31.	Leveling ring - 2x	Slide one leveling ring onto the two remaining RODs	
32.	Leveling ring - 4x	Slide one leveling ring onto each ROD	
33.	Flat Screwdriver no. 2	Fasten the leveling rings added in step 30 so that they rest on the LORA antenna holder Use a Flat Screwdriver no. 2	
34.	Flat Screwdriver no. 2	Fasten the leveling rings added in step 31 one cm above the Leveling Rings underneath them Use a Flat Screwdriver no. 2	
35.	R7_STR_3303_RadioAntenaHolder	Slide the RADIO Antenna holder onto RODS VII and V	
36.	Leveling ring - 2x	Slide one leveling ring onto RODs VII and V	
37.	Flat Screwdriver no. 2	Fasten the just added leveling rings. Use a Flat Screwdriver no. 2	
38.		Verify that the Leveling Ring fastening bolt is facing to the inside of the assembly	
39.	GPS_ORANGE	Place the GPS_ORANGE onto RODs (the same way as described in step 2).	

		Make sure that the antennas go through the openings in the Antenna Holders KEEP IN MIND THE NUMBERING OF THE RODS AGAINST ORANGE-OUT	
40.	Bolt-T M5x30 - 4x Allen Key no. 3	Secure the recently placed ORANGE-OUT to all RODs by fastening M5x30 Bolts. using an Allen Key no. 3	
41.		Make sure the bolts have their heads fully hidden in the countersunk holes.	
42.		Turn the assembly around, so that it rests on the ORANGE-OUT that was just attached	
43.		You have now completed the Payload Assembly, from now on referred to as the PYA The GPS Board will be secured to the ORANGE OUT it now rests on during the Final Assembly	
44.		You will now start preparing the Avionics Assembly (AVA)	
45.	STR_3104_ORANGE-OUT x 1 STR_3102_ROD x 4	Insert ROD into all 4 of the counterbored holes of ORANGE-OUT KEEP IN MIND THE LABELING OF ALL PARTS. Each counterboded hole has a number corresponding to the ROD that should be inserted into it. The Avionics parts are labeled with ARABIC numbers	
46.	Bolt-T M5x30 - 4x Allen Key 3	Fasten ORANGE-OUT and all RODs together by inserting 4 M5x30 into the countersunk holes of ORANGE-OUT using an allen key no. 3.	
47.		Make sure the M5 bolts have their heads fully hidden in the countersunk holes	
48.		Turn the assembly in a way that it now supports itself by laying on the flat face of ORANGE-OUT	

49.		Verify the tightening torque in all M5 bolts added so far in accordance to point 5.3	
50.	PYA - Payload Assembly	Turn the assembly in a way that RODs 4 and 6 of the AVA are facing you Take the PYA and turn it in a way that its rods III and V are facing you Place the AVA on top of the PYA. Make sure the correct rods are still facing you and their numbers are up-right from how you are looking at them.	
51.	Bolt M5x30 - 4x Washer M5 - 4x	In each of the 4 holes left empty on the perimeter of both ORANGE-OUTs, place an M5 washer and an M5x30 bolt - in that order, from the top.	
52.	Washer M5 - 4x Nut M4 - 4x	Fasten all 4 now sticking out of ORANGE-OUTs by inserting an M5 washer and an M5 nut onto each one of the bolts Secure loosely by hand	
53.	Allen Key no. 3 Flat Wrench no. 8	Verify that the AVA and the PYA align together concentrically. Fasten using an Allen Key no. 3 and a Flat Wrench no. 8	
54.		Verify the tightening torque from previous step in accordance to point 5.3	
55.		Verify that RODs 4 and 6 are facing you	
56.	EBMP - Engine Board Mounting Plate	Place the EBMP on the top most ORANGE-OUT. The rectangular slot should be facing you	
57.	Bolt-T M12x30 - 1x	Secure the EBMP to the ORANGE-OUTs by inserting an M12x30 into the hole in the center.	
58.	Allen Key no. 8 Flat Wrench no. 10	Fasten by inserting an M12 Nut from the bottom. Use an Allen Key no. 8 and a Flat Wrench no. 10	
59.		Verify the tightening torque from previous step in accordance to point 5.3	
60.	EBSA - Engine Board Shock Absorber	Place the EBSA onto the EBMP The rectangular slots should overlap	

61.	EBA - Engine Board Assembly	Place the EBA onto the dampener The rectangular slots should overlap	
62.	M3x24 x 3	Secure the board assembly by inserting 3 M3x25 nuts into the only remaining holes in the board assembly.	
63.	M3 Nut x 3 Allen Key no. 2.5 Nut Wrench	Fasten with M3 nuts from the bottom. Use an Allen Key no. 2.5 and a Nut Wrench as an aid	
64.		Verify the tightening torque from previous step in accordance to point 5.3	
65.		Hand-over to the Avionis Team for Engine Board hook-up	
66.	Leveling Ring - 4x Flat Screwdriver no. 2	Slide 1 leveling ring onto every ROD at the height that keeps a 75mm clearance between the face of the Middle ORANGE-OUTs and the Leveling Rings. Make sure that the fastening heads are facing out of the assembly. LIGHTLY secure using a flat Screwdriver no. 2	
67.	ORANGE-IN x 1	Slide ORANGE-IN onto the RODs so it rests on the Leveling Rings. Make sure that the geometry of ORANGES overlaps in the same way as in the PYA	
68.	Leveling Ring - 4x Flat Screwdriver no. 2	Slide another leveling ring onto the RODs Make sure that the fastening heads are facing out of the assembly. LIGHTLY secure using a Flat Screwdriver no. 2	
69.		Verify that the ORANGE-IN is resting leveled	
70.	Flat Screwdriver no. 2	Fully tighten the Leveling Rings inserted in steps 66 and 68	
71.		Verify the tightening torque from previous step in accordance to point 5.3	
72.	MBMP - Main Board Mounting Plate	Place the MBMP onto the ORANGE-IN The rectangular slot should be in line with the	

		ones on the EB	
73.	Bolt-T M12x30 x 1	Secure the MBMP to ORANGE-IN by inserting an M12x30 into the hole in the center. Fasten it by inserting an M12 Nut from the bottom. Use an Allen Key no. 8 and a Flat Wrench no. 1	
74.	Nut M12x 1 Allen key no. 8 Flat Wrench no. 19	Fasten by inserting an M12 Nut from the bottom. Use an Allen Key no. 8 and a Flat Wrench no. 1	
75.		Verify the tightening torque from previous step in accordance to point 5.3	
76.	MBSA - Main Board Shock Absorber	Place the MBSA onto the MBMP The rectangular slots should overlap	
77.	MBA - Main Board Assembly	Place the MBA onto the dampener The rectangular slots should overlap	
78.	M3x24 x 3 M3 Nut x 3 Allen Key no. 2.5 Nut Wrench	Secure the board assembly by inserting 3 M3x24 nuts into the only remaining holes in the board assembly. Fasten with M3 nuts from the bottom. Use an Allen Key no. 2.5 and a Nut Wrench as an aid	
79.		Verify the tightening torque from previous step in accordance to point 5.3	
80.		Hand-over to the Avionis Team for Main Board hook-up	
81.	Leveling Ring - 2x Flat Screwdriver no. 2	Slide a leveling ring onto ROD 2 and 4 Make sure that the fastening bolt heads are facing the outside of the assembly. Keep a distance of 38mm between these rings and the Main Board LIGHTLY fasten using a Flat Screwdriver no. 2	
82.	Leveling Ring - 2x Flat Screwdriver no. 2	Slide a leveling ring onto the remaining two RODs	

		Make sure that the fastening bolt heads are facing the outside of the assembly. Keep a distance of 28mm between these rings and the Main Board LIGHTLY fasten using a Flat Screwdriver no. 2	
83.	CATSA - CATS Assembly BlueJayA - Blue Jay Assembly	Onto ROD 2 and 4 partially slide on the CATSA, in a way that only the first set of mounting holes is currently on the ROD Repeat the same step by sliding the BlueJayA onto the other two remaining RODs	
84.	Leveling Ring - 4x	Slide 1 leveling ring onto every ROD	
85.		Verify that RODs 4 and 6 are facing you	
86.	Quadro-Copter Assembly (QuadroA)	Partially Slide QuadroA onto all of the rods in a way that only the first set of mounting holes is currently on the ROD The wide side should of the QuardoA should be facing you	
87.		Proceed to slide BlueJayA and CATSA fully down the RODs so they rest on the leveling rings described in steps	
88.	Leveling Ring - 4x	Slide 1 leveling ring onto every ROD	
89.		Proceed to slide the QuadroA fully down	
90.	Flat Screwdriver no. 2	LIGHTLY fasten the Leveling rings from step 84. so they are parallel. The leveling plane is defined by the two rings now resting on the BlueJayA Use a Flat Screwdriver no. 2	
91.		Make sure that the fastening bolt heads from the previous step are facing the outside of the assembly.	
92.	Flat Screwdriver no. 2	LIGHTLY fasten the Leveling rings from step 88. They should be resting on the BlueJayA and the CATSA. Use a Flat Screwdriver no. 2	
93.		Make sure that the fastening bolt heads from the previous step are facing the outside of the	

		assembly.	
94.		Verify that the leveling rings create parallel planes between the faces of all components resting on them	
95.		Verify that the CATSA antenna is located at least 3mm beneath the plane currently created by the top of all 4 RODs	
96.	Flat Screwdriver no. 2	Tighten the side fastenings on all Leveling Rings from steps between 81 and 95.	
97.		Verify the tightening torque from previous step in accordance to point 5.3	
98.		Hand-over to the Avionics Team for Battery and PMS hook-up	
99.	ORANGE-OUT - 1x	Place another ORANGE-OUT onto RODs (the same way as described in step 2). KEEP IN MIND THE NUMBERING OF THE RODS AGAINST ORANGE-OUT	
100.	Bolt-T M5x30 - 4x Allen Key 3	Secure the ORANGE-OUT to all RODs by interesting a M5x30 Bolt-T into each one of the countersunk holes on top of the ORANGE-OUT Make sure the M5 bolts have their heads fully hidden in the countersunk holes	
101.		You have completed the Avionics and Payload Frame Assembly (APFA) You should now hand this assembly over to the Electronics Team for safety checks.	

4.3. Final Structural Assembly

No.	Required elements	Instructions	Status
1.	RFA - Recovery Final Assembly APFA - Avionics and Payload Final Assembly EFA - Engine Final Assembly		

	STR_4102_ServiceBody Maintenance Hatch 1 Maintenance Hatch 2 Rail Lug RADAX Rail Lug Boattail Mounting Hooks M6 - 2x Bolt M4x14 - 16x Bolt-T M4x12 - 48x T-Bolt M4x16 - 4x Bolt-T M5x8 - 9x Bolt M12x110 - x1 Nut M6 - 2x Nut M12 - 1x		
2.	RFA - Recovery Final Assembly APFA - Avionics and Payload Final Assembly	Place the RFA onto the APFA, so that they align concentrically. Mind the registration mark created by the bolt axis on the RFA and the vertical mark on the APFA.	
3.	Hook M6 - x2	Introduce 2 M6 hooks into the assembly in a way that the small hook part rests on the lip of the large rectangular holes in the aluminium connector of RFA and the threaded shank passes through ORANGE-OUT directly beneath the RFA. The first hook should be inserted in the window that shares the alignment mark in the step above. The second directly across from it.	
4.	Nut M6 - x2	Lightly fasten the hook to the ORANGE-OUT with M6 nuts	
5.		Verify the concentric alignment. of the RFA and APFA. Tightly fasten the M6 by hand.	

6.		Allow the electronics team to connect the RFA to the Avionics	
7.	STR_4102_ServiceBody	Insert the whole module into the ServiceBody. Mind the alignment mark inside the ServiceBody and the bottom ORANGE-OUT. A red line should be visible. MIND THE WIRES.	
8.		Feed all wires through the bottom ORANGE-OUT and out of the ServiceBody through the RADAX connector.	
9.	Bolt-T M4x10 - x40	Into the holes that go around the ServiceBody and will screw to the ORANGE-OUTs, insert a M4x10 TBolt. Do NOT fasten yet. Do not insert bolts into the recesses made by the removed maintenance hatches.	
10.		Make sure all 40 M4 bolts can be inserted into the assembly	
11.	Allen Key no. 3.	Fasten the M4 bolts using an Allen Key no. 3. Begin by fastening one row (not circle). Move onto the row across from it (Jump from 1 to 6). Fasten Move onto a row perpendicular to it (ex. row 9) Fasten. Move to the row across from it. Fasten Repeat this motion until all rows of M4 bolts have been fastened.	
12.		Remove the M6 hooks (unscrew the nut) installed in step 3 through the service opening.	
13.		Verify the alignment of the M5 holes in the ServiceBody and RFA.	
14.	Bolt-T M5x8 - 9x	Secure the RFA to the Service body by inserting 9 M5x8 TBolts into the openings. Do not fasten yet.	
15.		Verify that all M5 Bolts can be inserted	
16.	Allen Key no. 4.	Fasten in a star motion (as described in step X with the APFA) using an Allen Key no. 4.	

17.	EFA - Engine Final Assembly	Bring the EFA and the ServiceBody into proximity. Make sure the two dots on both RADAX connectors are aligned with each other.	
18.		Feed all wires through the openings in LEMON.	
19.		Slot the EFA RADAX and the ServiceBody RADAX together. MIND THE ALIGNMENT MARKINGS from step 17	
20.		Remove all dust and debris from the connecting faces of both RADAX parts	
21.	Bolt M4x14 - x16 Allen Key no. 4.	Fasten the RADAX connector together using M4x14 Bolts and an Allen Key no. 3. The bolts should be inserted into the slanted pockets visible on the RADAX.	
22.		Verify the tightening torque from previous step in accordance to point 5.3	
23.	Bolt M12x110 - x1 Nut M12 - x1	Insert an M12x90 bolt through the hole in LEMON and the bottom ORANGE_OUT. Fasten by tightening an M12 nut. Use two Flat Keys no. 19	
24.		Verify the tightening torque from previous step in accordance to point 5.3	
25.	Rail Lug Radax T-Bolt M4x16 - 2x Allen Key no. 3.	Attach the RADAX Rail Lug to the Service-Tank RADAX connector with T-Bolts M4x16. Use an Allen Key no. 3.	
26.		Verify the tightening torque from previous step in accordance to point 5.3	
27.	Rail Lug Boattail T-Bolt M4x16 - 2x Allen Key no. 3.	Attach the Boattail Rail Lug to the Boattail in the Engine Final Assembly with T-Bolts M4x16. Use an Allen Key no. 3.	
28.		Verify the tightening torque from previous step in accordance to point 5.3	
29.		Allow the Avionics Team to inspect all electronic components and attach all sensors.	

30.		Allow the Engine Team to clear all safety checks and attach the Feed Coverings	
32.	Service Hatch 1 Service Hatch 2	Place both Service Hatches into the Service Openings in the ServiceBody. Mind the painting patterns.	
33.	Bolt-T M4x10 - x4	Fasten the Service Hatches by inserting 4 M4x10 TBolts into each one. Fasten using an Allen Key no. 3.	
34.		Verify the tightening torque of all bolts going on the round in accordance to point 5.3	
35.		You have now completed the Final Structural Assembly	

5. Help

5.1. Contact and consultation

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5.2. Standard summaries

Standard Name	Summary
DIN 7991	Countersunk (flat) head screw with a hexagonal socket
DIN 912	Cylindrical head cap screw with a hexagonal socket
DIN 934	Standard hexagonal nut
DIN 125	Round flat washer

5.3. Global torque guide

All fastening torques should be verified using a Torque Wrench and an appropriately sized Hexagonal insert in accordance to the outlined chart:

Bolt	Summary
------	---------

Leveling ring bolts	0.25 Nm
M3 Bolts in contact with electronic components	0.5 Nm
All Bolts going on the round in relation to any composite parts	3 Nm
Bolts used to fasten all RODs or ORANGE-OUTs together	5 Nm
RADAX bolts	5 Nm
M12 Bolts	10 Nm

E Simulation Data

Table E.1: Simulations parameters

R7 Orzeł		
Parameter	Value	Unit
Rocket radius	0.087	[m]
Mass without motor	26.704	[kg]
Rocket inertia	I11 = 10.76248, I22 = 10.76248, I33 = 0.101061	[-]
Center of mass without motor	1.65	[m]
Center of mass with motor	2.59	[m]
Coordinate system orientation	nose to tail	[-]
Nosecone		
Mass	7.9	[kg]
Shape/kind	power series 0.8	[-]
Length	0.762	[m]
Base radius	0.087	[m]
Radius ratio	1	[-]
Bluffness	0	[-]
Center of gravity (CG)	0.417	[m]
Component material	fiberglass	[-]
Nosecone shoulder		
Length	0.010	[m]
Base radius	0.087	[m]
Radius ratio	1	[-]
Component material	fiberglass	[-]
Tube coupler		
Length	0.25	[m]
Outer radius	0.085	[m]
Mass	0	[kg]
Recovery section		
Length	0.38	[m]
Outer radius	0.087	[m]
Mass	0.82	[kg]
Tube coupler		
Length	0.37	[m]
Outer radius	0.085	[m]
Mass	3.5	[kg]
Main parachute		
Diameter	2.5	[m]
Material & Ripstop nylon (67 g/m^2)	[-]	
Drag coefficient CD	2.000	[-]
CdS (Drag coefficient times reference area for parachute)	9.8174	[-]
Number of shroud lines	16	[-]
Line length	1.5	[m]
Material	Elastic cord (round 2 mm, 1/16 in)(1/8 g/m)	[-]
Mass	1.5	[kg]
Deploys at	specific altitude during descent plus 0 seconds, altitude 450 m	[-]
Sampling rate	100	[Hz]
Lag	1.5	[s]
Noise	[0, 0, 0]	[-]
Drouge parachute		
Diameter	1.25	[m]
Material	Ripstop nylon (67 g/m^2)	[-]
Drag coefficient CD	1.380	[-]
Number of shroud lines	8	[-]
Line length	1.5	[m]
Material	Kevlar thread 800 (round 1.1 mm, 3/64 in)(0.992 g/m)	[-]
Mass	0	[kg]

Deploys at	apogee plus 1 seconds	[-]
Sampling rate	100	[Hz]
Lag	6	[s]
Noise	[0, 0, 0]	[-]
Inner tube		
Length	0.08	[m]
Outer radius	0.085	[m]
Mass	0.350	[kg]
Service section		
Length	0.876	[m]
Outer radius	0.087	[m]
Mass	1.140	[kg]
Mandaryny system		
Length	0.65	[m]
Outer radius	0.085	[m]
Mass	1.960	[kg]
PMS _{R7}		
Type	Flight Computer	[-]
Mass	38	[g]
Length	0.5	[cm]
Diameter	10	[cm]
Position	1.57	[m]
Batteries		
Type	Battery	[-]
Mass	842	[g]
Length	7.3	[cm]
Diameter	7	[cm]
Position	1.46	[m]
COTS trays		
Type	Flight Computer	[-]
Mass	200	[g]
Length	10.5	[cm]
Diameter	6.5	[cm]
Position	1.46	[m]
Main board		
Type	Flight Computer	[-]
Mass	150	[g]
Length	0.5	[cm]
Diameter	10	[cm]
Position	1.68	[m]
Engine board		
Type	Flight Computer	[-]
Mass	162	[g]
Length	0.5	[cm]
Diameter	10	[cm]
Position	1.77	[m]
Payload		
Type	Payload	[-]
Mass	950	[g]
Length	7.5	[cm]
Diameter	10	[cm]
Position	1.84	[m]
Jebediah Kerman		
Type	Payload	[-]
Mass	50	[g]
Length	7.3	[cm]
Diameter	7.0	[cm]
Position	1.93	[m]
CATS Vega Safety Pins		
Type	Flight Computer	[-]

Mass	10	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.58	[m]
Blue Jay XB		
Type	Altimeter	[-]
Mass	22	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.57	[m]
Safety Pins		
Type	Flight Computer	[-]
Mass	20	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.97	[m]
Radio LoRa		
Type	Tracker	[-]
Mass	50	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	2.05	[m]
Cats Vega		
Type	Flight Computer	[-]
Mass	30	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.55	[m]
BlueJay		
Type	Flight Computer	[-]
Mass	10	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.57	[m]
Cables		
Type	Mass	[-]
Mass	500	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	1.65	[m]
GPS		
Type	Tracker	[-]
Mass	10	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	2.07	[m]
Radio		
Type	Mass	[-]
Mass	10	[g]
Length	2.5	[cm]
Diameter	2.5	[cm]
Position	2.07	[m]
Engine Board assembly		
Type	Mass	[-]
Mass	100	[g]
Length	1	[cm]
Diameter	10	[cm]
Position	1.75	[m]
Main Board assembly		
Type	Mass	[-]

Mass	100	[g]
Length	1	[cm]
Diameter	10	[cm]
Position	1.68	[m]
Radax		
Length	0.054	[m]
Outer radius	0.087	[m]
Mass	0.940	[kg]
Tube coupler		
Length	0.067	[m]
Outer radius	0.085	[m]
Mass	0	[kg]
Rail button up		
Outer diameter	4	[cm]
Inner diameter	2	[cm]
Base height	0.5	[cm]
Flange height	0.47	[cm]
Total height (excl. screw)	2	[cm]
Screw height	0	[cm]
Position	2.14	[m]
Angular position	180	[°]
Tank and brackets		
Length	1.28	[m]
Outer radius	0.087	[m]
Mass	0	[kg]
Flux time	4.9	[s]
Initial liquid mass	9.87	[kg]
Initial gas mass	0.13	[kg]
Liquid mass flow rate in	0	[kg/s]
Liquid mass flow rate out	1.4	[kg/s]
Gas mass flow rate in	0	[kg/s]
Gas mass flow rate out	0	[kg/s]
Position	0.6395	[m]
Tank geometry		
Length	0.75	[m]
Outer radius	0.087	[m]
Spherical caps	True	[-]
Fluids		
Liquid name	nitrous oxide	[-]
Liquid density	745	[kg/m ³]
Gas name	nitrous oxide	[-]
Gas density	188	[kg/m ³]
Fake fairings		
Length	0.24	[m]
Outer radius	0.087	[m]
Mass	540	[kg]
Cable harness		
Type	Mass	[-]
Mass	500	[g]
Length	1.70	[m]
Diameter	2.5	[cm]
Position	1.68	[m]
Radax		
Length	0.058	[m]
Outer radius	0.087	[m]
Mass	0.940	[kg]
Tube coupler		
Length	0.067	[m]
Outer radius	0.085	[m]
Mass	0	[kg]

Motor tube		
Length	0.77	[m]
Outer radius	0.087	[m]
Mass	906	[kg]
Motor tube		
Position on rocket	2.194	[m]
Dry mass	25.698	[kg]
Dry inertia	[10.35703, 10.35703, 0.0972541]	[kg * m ²]
Nozzle radius	0.036	[m]
Grain number	1	[-]
Grain density	779.5	[m ³]
Grain outer radius	0.063	[m]
Grain initial inner radius	0.035	[m]
Grain initial height	0.5	[m]
Grain separation	0	[m]
Grains center of mass position	1.687	[m]
Center of dry mass position	0.89375	[m]
Nozzle position	2.186	[m]
Burn time	7.25	[s]
Throat radius	0.018	[m]
Reshape thrust curve	False	[-]
Coordinate system orientation	combustion chamber to nozzle	[-]
Only radial burs	False	[-]
Trapezoidal fin set		
Mass	1.708	[kg]
Number of fins	4	[-]
Fin cant	0	[°]
Root chord	20.3	[cm]
Tip chord	13.6	[cm]
Height	12.2	[cm]
Sweep length	3.4	[cm]
Sweep angle	15.6	[°]
Fin cross section	square	[-]
Span	0.122	[m]
Thickness	0.6	[cm]
Position	4.08	[m]
Fins basket		
Length	0.238	[m]
Outer radius	0.95	[cm]
Mass	0.772	[kg]
Center of gravity	0.138	[m]
Position	4.04	[m]
Bottom rail button		
Outer diameter	4	[cm]
Inner diameter	2	[cm]
Base height	0.5	[cm]
Flange height	0.47	[cm]
Total height (excl. screw)	2	[cm]
Screw height	0	[cm]
Position	3.89	[m]
Angular position	180	[°]
Boat tail		
Mass	0.2	[kg]
Transition shape	Concial	[-]
Length	0.101	[m]
Fore radius	8.7	[cm]
Aft radius	7.3	[cm]
Position	4.279	[m]

*every position is counted from the tip of the rocket