EPFL Rocket Team – MATTERHORN Project

Team 35 Project Technical Report to the 2018 Spaceport America Cup

E. Brunner, H. Boross, E. Mingard, L. Amez-Droz, C. Nussbaumer, Q. Talon, N. Appfle, J. Triomph, M. Eckstein, M.Goury du Roslan, G.Herment, G.Locher, L. Giezendanner
Swiss Federal Institute of Technology, EPFL, Lausanne, Switzerland

C. Cardinaux [1]
School of Engineering and Management Vaud, HEIG-VD, Yverdon-les-Bains, Switzerland

Project Matterhorn is an interdisciplinary project of the Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. It aims to participate in the 2018 Intercollegiate Rocket Engineering Competition (IREC) at the Spaceport America Cup (SA Cup) in New Mexico, USA. The Project's rocket will participate in the 10'000 ft Commercial-Off-The-Shelf (COTS) category with a payload designed to do muon tomography. The team's goals are to fulfill the competition's requirements, while being student driven, establishing contact with industrials, companies and laboratories. It has led the team's members to explore ways to fulfill these goals and find solutions to the challenges that come with such a project.

Nomenclature

Ah = Ampere hour
APS = Active Pixel-Sensor
BOM = Bill of Materials
CAD = Computer-Aided Design
CCD = Charge Coupled Device
Cd = Drag coefficient
$C_d S$ = Drag coefficient times effective area of the parachute $[m^2]$
CDR = Critical Design Review
CMOS = Complementary metal–oxide–semiconductor
ConOps = Concept of Operations
COTS = Commercial Off The Shelf
dBm = decibel-milliwatts
DMA = Direct Memory Access
EPFL = Ecole Polytechnique Fédérale de Lausanne
FRR = Flight Readiness Review
g = 9.81, Earth gravitational acceleration $[m/s^2]$
GNSS = global navigation satellite system
HDMI = high-definition multimedia interface
IMU = inertial measurement unit
IREC = Intercollegiate Rocket Engineering Competition
Kb/s = kilo bit per second
LFP = lithium iron phosphate ($LiFePO_4$) battery
LiPo = lithium polymer battery
LOS = line-of-sight
LV = Launch Vehicle
LVDS = low voltage differential signaling

[1] Detailed information about each author can be found at the end of this document

NMOS = N-type metal-oxide-semiconductor
OR = OpenRocket software
PCB = Printed Circuit Board
PDR = Preliminary Design Review
PMOS = P-type metal-oxide-semiconductor
RF = radio frequency
RS = RockSim software
RSPS = Reloadable Solid Propulsion System
SA Cup = Spaceport America Cup
SD = secure digital
SE = System Engineering
SiPM = Silicon Photomultiplier
SRAD = student researched and developed

I. Introduction

1. Motivation

In the context of the Spaceport America (SA) Cup 2018 Intercollegiate Rocket Engineering Competition (IREC), the EPFL Rocket Team has set out to build a launch vehicle (LV) to participate in the 10'000ft commercial off the shelf (COTS) propulsion category. Except for the propulsion, the team strived to build as many elements of the rocket as possible, including the structure, avionics, recovery system, parachute, payload and air-braking system. Apart from its competitive objectives, the construction of the rocket has educational implications including its development in many academically supervised projects.

The project gives the opportunity to team members to put their engineering skills to the test. Since building a rocket and launching it abroad is expensive, the team has had to collaborate with many stakeholders that showed their support financially and material wise. While this allowed to make our ideas turn into reality, working with the various companies and suppliers set constraints that we had to adapt to. Working as a team in such an environment has been a highly educative process for our future careers and has taught us skills that exceed the frame of pure engineering, in fields such as management, logistics and leadership.

2. Academic project

Project Matterhorn is an interdisciplinary project, in which students from many different fields (Mechanical engineering, Microengineering, Material sciences, Physics, Math and Informatics & Communication Science) apply their knowledge to a common goal. Some aspects were even developed for credits in Bachelor or Master semester projects. A number of professors have gracefully proposed their advice, lab space and materials to help the team accomplish this project.

3. Team organization

The team is led by a Project Manager, who supervises two main divisions: management and technics.

As part of the management division, there are Business, Finances, Logistics and Operations. The Business team takes care of sponsoring and communication, and the Finances one of accounts and budgets. The Logistics team takes care of team travels such as test launches, Preliminary and Critical Design Reviews (PDR and CDR) as well as on site organization of life at the SA Cup. Finally, the Operations team takes care of all technical aspects of launches such as buying motors for Tripoli certifications and tests, finding launch sites and above all compiling checklists and procedures to make sure the rocket launch goes as flawlessly as possible. At launch days the Chief of Operations is responsible that the checklists are followed and the rocket ready to be launched on time.

The technics division is led by System Engineering and is made up of seven sub-teams: Airbrakes, Avionics, Ground Station, Payload, Propulsion, Recovery and Structures. Each one takes care of its namesake part in the rocket.

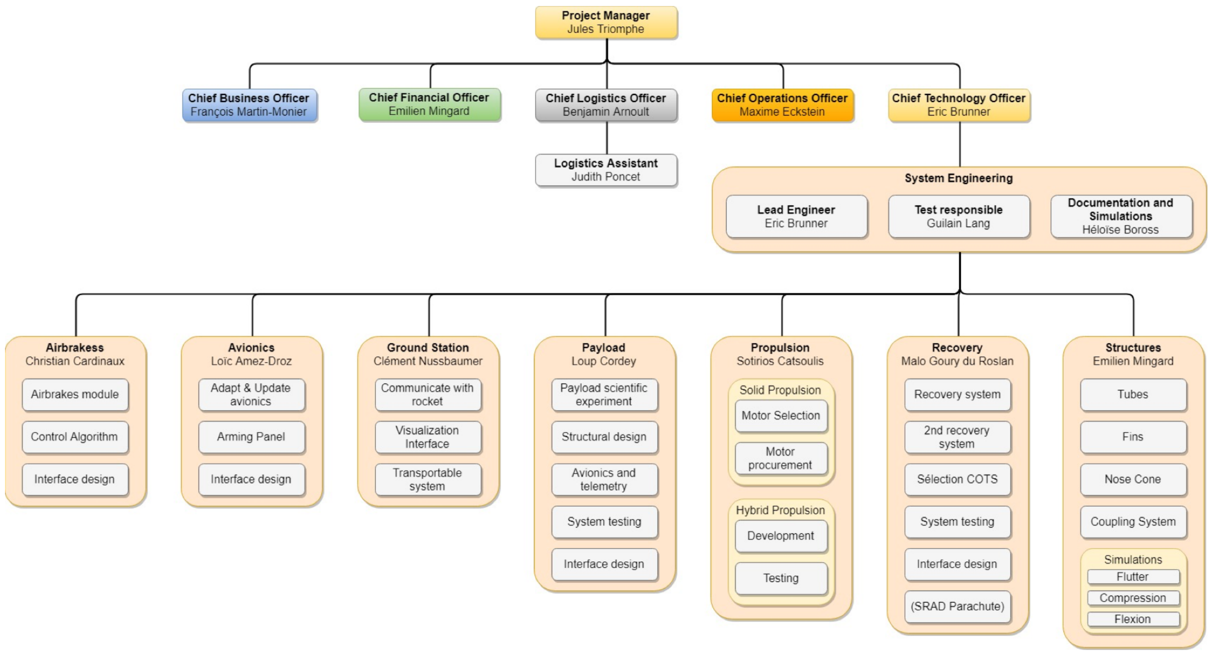


Figure 1. Team organigram

Figure 1 illustrates the team's organization and chain of command as well as a synthesized view of each technical team's main tasks.

4. Management strategies

The team's chain of command as shown in Fig. 1 is designed to have a clear assignment of responsibilities and a flow of high level decisions to all the members of the team. However, each member acknowledges the others' skills and experience in their respective jobs and discussions are encouraged among interested parties in the team. Each team has weekly meetings in order to keep up to date and the team leaders have weekly meetings to stay on point on the advancement of the project as a whole. Any conflict in the teams is resolved by the respective team leader and any conflicts among team leaders are resolved by the Project Manager.

Budget and accounting are managed by the Finances team, however the Project Manager and System Engineering (SE) approve any large expense made by the team, in consultation with the team leaders. The technical budget was established by System Engineering at the beginning of the project and reevaluated with the sponsorships obtained and the unpredictable extra expenses that have to be made along the way.

The Project Manager is the spokesperson for main sponsors, but the Chief Business Officer is the reference contact for all other sponsors. The latter also defines business strategies for the team, such as communication, promotion and fundraising planning and objectives.

5. Swiss collaboration definition

Project Matterhorn works alongside Project Tell of the ETHZ (Eidgenössische Technische Hochschule Zürich) to find sponsors and organize both teams' trips to the competition. Both Projects also collaborate to organize their PDR and CDR with sponsors and professors from both schools. This enables both projects to benefit and learn from each other's reflections, mistakes and solutions. It also provides each team with advice and insight from shared experts. The long-term goal of this collaboration is to establish a Swiss-wide entity that promotes and coordinates such projects between more universities than just the two swiss polytechnic schools.

6. Launch days

Switzerland is a very densely populated country. Although many regions in the mountains are practically free of habitations, launching a rocket from there and recovering it would be unreasonably complicated. To cope with the complexity of finding a suitable launch site and getting the consent from air traffic control, we rely on the experience of the national TRIPOLI club called ARGOS. Many team members have built a personal level one rocket and launched it at an official ARGOS event. They are now TRIPOLI members. ARGOS president, Jürg Thüring, has helped us with his expertise and his availability, especially for flight testing our competition LV at a specially organized launch day.

7. Planning

Project Matterhorn has milestones and deadlines both internal (i.e. set by the team) and external (i.e. set by the competition, the school, sponsors, or ARGOS launch dates). Many internal deadlines are set by the System Engineers, who have a detailed planning, precise to the day for each technical team. Table 1 lists the project's main milestones.

Table 1. Main Project Matterhorn milestones

Date	**Event**	**Comments**
October 2016	Start of the project	
November 19th 2017	Launch at Kaltbrunn	Individual rocket tests, certifications for future test fliers and first telemetry integration test
December 8th 2017	PDR	PDR at ETH with RUAG Space engineers, Muriel Richard from eSpace and a few sponsors
Febuary 17th 2018	Launch at Kaltbrunn	Various systems integrations and certifications
March 23rd 2018	CDR	CDR at ETH with RUAG Space engineers, professors and a few sponsors
March 24th 2018	Launch at Cernier	Parachute ejection test and certifications
March 26th 2018	Launch review	Review of weekend launch, operations successes and failures
April 15th 2015	Rocket assembly	Full integration of sub-systems in the rocket
April 27th 2018	Full rocket test in Payerne	Integrated flight test to 1150m in collaboration with ARGOS and the swiss military.
May 25th 2018	Roll-out	Presentation of the finished launch vehicle to academic supervisors, sponsors and students.
May 25th 2018	IREC Documents due	3rd Progress Update, Project Technical Report, Poster Session Materials, Podium Session Materials, School Participation Letter, Proof of Insurance
May 29th 2018	Shipping Rocket and tools to the US	
June 21st 2018	SAC IREC Launch	Launch at 9:00 am New Mexico local time
July 2nd 2018	Post Launch Review	Recap on the gained experience at the competition with the 2019 team. Official transition from the 2018 to 2019 rocket team.

II. System Architecture overview

Figure 2 presents the LV as it will be configured for flight at the 2018 IREC. The LV is composed of five parts. A nosecone, an upper frame, airbrakes, a lower frame and the fin module. The nosecone houses telemetry avionics and a pitot tube. The cones material was selected such that it is permeable to electromagnetic waves as opposed to carbon fiber reinforced polymer (CFRP) which makes out most of the other parts of the LV. The upper frame contains the payload, a muon detector, the parachute, ejection system and control avionics for dual deployment and airbrake regulation. Between the upper and lower frame, an airbrake system is installed. The airbrake module is replaceable or removable thanks to the custom designed coupling system fitted on every non-separating interface. The lower airframe is fully occupied by the motor, a 75mm Aerotech M1850W, contained in an RMS 75/7680 casing. The motor extends through the fins module but transmits thrust through a bulkhead bolted to the middle coupler. The fin module is designed to enable easy replacement of the fins. General specifications of the LV are included in Table 2.

1. Top Level requirements

The top level requirements are determined based on provided rules, requirements and design guidelines as well as constraints set by System Engineering to ensure the mission is completed taking into account stakeholder interest and logistical issues. The top level requirements are stated in Table 3. To keep the presentation light, the complete set of specifications is presented in appendix G, under 2018_SE_MS_0001_SPECIFICATIONS_R04.

Table 2. General LV specifications.

Specification	Value
Length	267 cm
Empty mass (w.o. Motor and Payload)	11.2 kg
Diameter – internal	120 mm
Diameter – external	122.4 mm
Nosecone length	56 cm
Fin root cord	24 cm
Fin tip cord	12 cm
Fin semi-span	11 cm

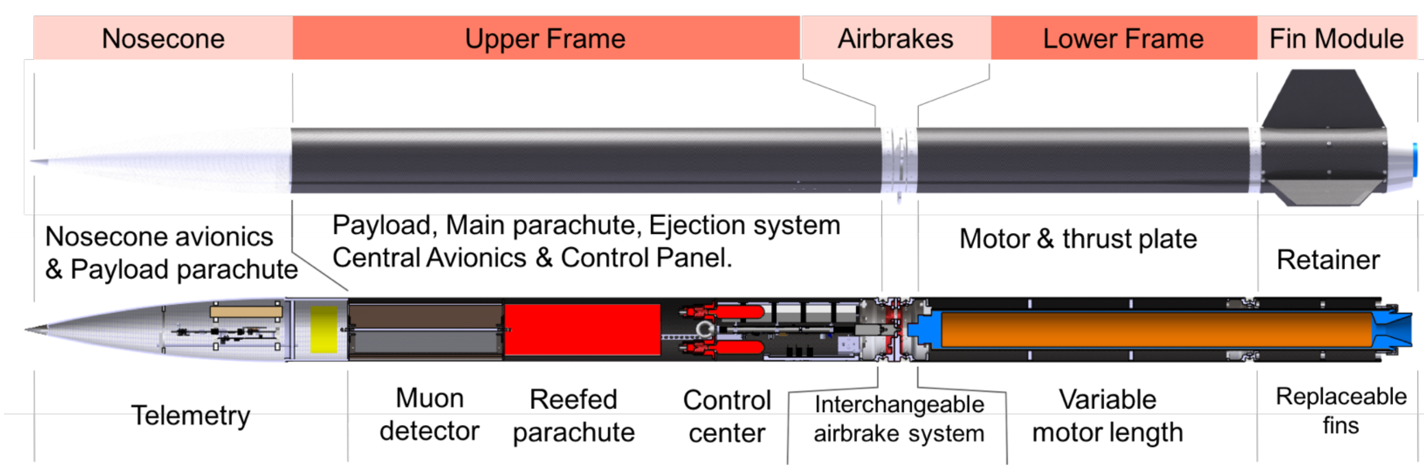


Figure 2. System overview as configured for launch.

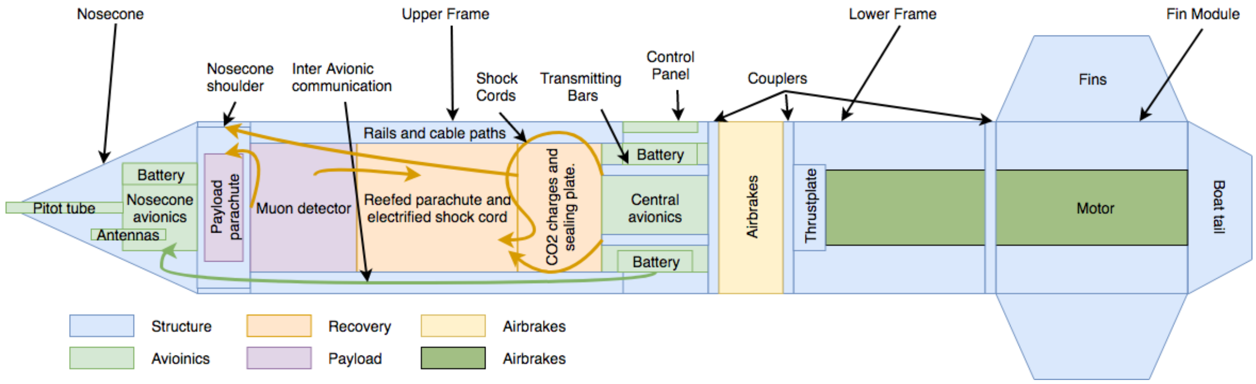


Figure 3. General block diagram

2. *General Block diagram*

The LV is presented in the form of a block diagram in Fig. 3. System location is identified, as presented fot the four body parts, fixed interfaces fastened together by the couplers and the motor located in the lower part of the LV. The upper portion of the LV contains the central avionics surrounded by the control panel and batteries. The avionics are mounted on rods linking the shock cord to the middle couplers. A construction with two rods was chosen to replace the need for swivel eyelets and to add redundancy to the structure. The recovery ejection system isolates the central avionics from the shock of ejection generated by the CO2 capsules. The payload is located above the main parachute

Table 3. Top Level requirements

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Validation Date
GE-FP01	Reach the apogee	Altitude	3048 m	+/- 600	IREC	Simulations and flight test	23/03/2017
GE-FP02	Remain stable during flight without ACS implemented	Stability	stable	0	IREC	Simulations and flight test	23/03/2017
GE-FP03	Contains a payload	Mass	3.992 kg	0/+1	IREC	Mass budget and weighting of the prototype	23/03/2017
GE-FP04	Carry a payload to the target apogee	Altitude	3048 m	+/- 600	IREC	ConOps and payload design	23/03/2017
GE-FP05	Recover safely	Number of deployment event	2	0/+2	IREC	Recovery design review	TBD
GE-FP06	Recover independently of any active or passive payload function	dependenci es to payload	0	0	IREC	Design of the recovery system	23/03/2017
GE-FC01	Weight optimization	Mass	23.6 kg	maximum	SE	Mass budget subsystem level and prototype weighing	23/03/2017
GE-FC02	Size optimization	Length	3000 mm	-700 to +200	SE	Volume budget at subsystem level and prototype measuring	23/03/2017
GE-FC03	Size optimization	Inner diameter	120 mm	0	SE	Must conform to mandrel	23/03/2017
GE-FC04	Costs constraints	CHF	25'000	-5'000 to +5'000	TR	Money budget	23/03/2017

to ensure it doesn't get tangled in it when ejected as explained in the recovery ConOps in section III. The payload has its own parachute located right above it and in the cone's shoulder. In the cone, avionic systems are also mounted on rod like structures.

3. Applicable technical plans

To document the LV system and its sub-systems, standard documents were regularly updated by SE and the sub-teams during the project. Thanks to the constant assessment of the system's performances, SE can insure that the produced LV satisfies mission requirements. The specific documents are listed as follows:

1. Technical performance is documented by:
    a. System level and sub-system level mass budgets, included in appendix A.
    b. System and sub-system level power budgets included in appendix A.
    c. Trajectory simulation results as presented in section 10.
    d. Technical drawings included in appendix G.
    e. Test reports, outlined in appendix B
2. To track the readiness state of the rocket and to set up a checklist of rocket parts, a bill of materials (BOM) was populated. The BOM is included in appendix G. In the report, parts are referred to by their BOM number (5 digits) and name (e.g. BOM: 11301 Tube Ring).
3. No specific environment control plan was set up, except for a hazardous material control plan, included in appendix C.
4. Manufacturing procedures for major manufacturing operations done by the students are included in appendix G, especially for the structure.
5. Reliability and quality assurance are evaluated by testing and inspection of the manufacturing procedures.

4. Safety analyses and plans

Risk assessment has been part of the project from its very beginning because it has given us the credibility needed to be accepted as a university project and allowed us to avoid any bad accidents that might compromise the project and its future iterations. To mitigate the risks and be able to prioritize, a risk classification system was used. Risks were sorted in levels of severity presented in Table 4. A detailed risk assessment is included in appendix F.

Table 4. Risk matrix

			Consequence				
			1	2	3	4	5
			Almost no impact, < 4 man hours to solve	No critical impact, < 4-20 man hours to solve	Critical impact, < 20-40 man hours to solve	Highly critical impact, 40+ man hours to solve	Mission failure
Probability	5	80-100% Chance	5	10	15	20	25
	4	60-80% Chance	4	8	12	16	20
	3	40-60% Chance	3	6	9	12	15
	2	20%-40% Chance	2	4	6	8	10
	1	0%-20% Chance	1	2	3	4	5

5. Interface control documents.

Interfaces are identified and tracked by system engineering. They are summarized in the block diagram presented in Fig. 4. Interfaces between systems are closely taken care of by system engineering who supervise that they are well defined and that a responsible is clearly selected to make sure the interface is regularly checked and updated if needed.

6. Verification and validation plan.

Tests were defined by System Engineering and carried out by each subsystem. For each test, pass/fail criteria were defined as well as a plan of action depending on the outcome of the test. Each test is documented according to a test procedure template created by System Engineering. Some tests became obsolete as the design changed or couldn't be carried out because of logistical or time constraints. Tests that were finally done are described in appendix B.

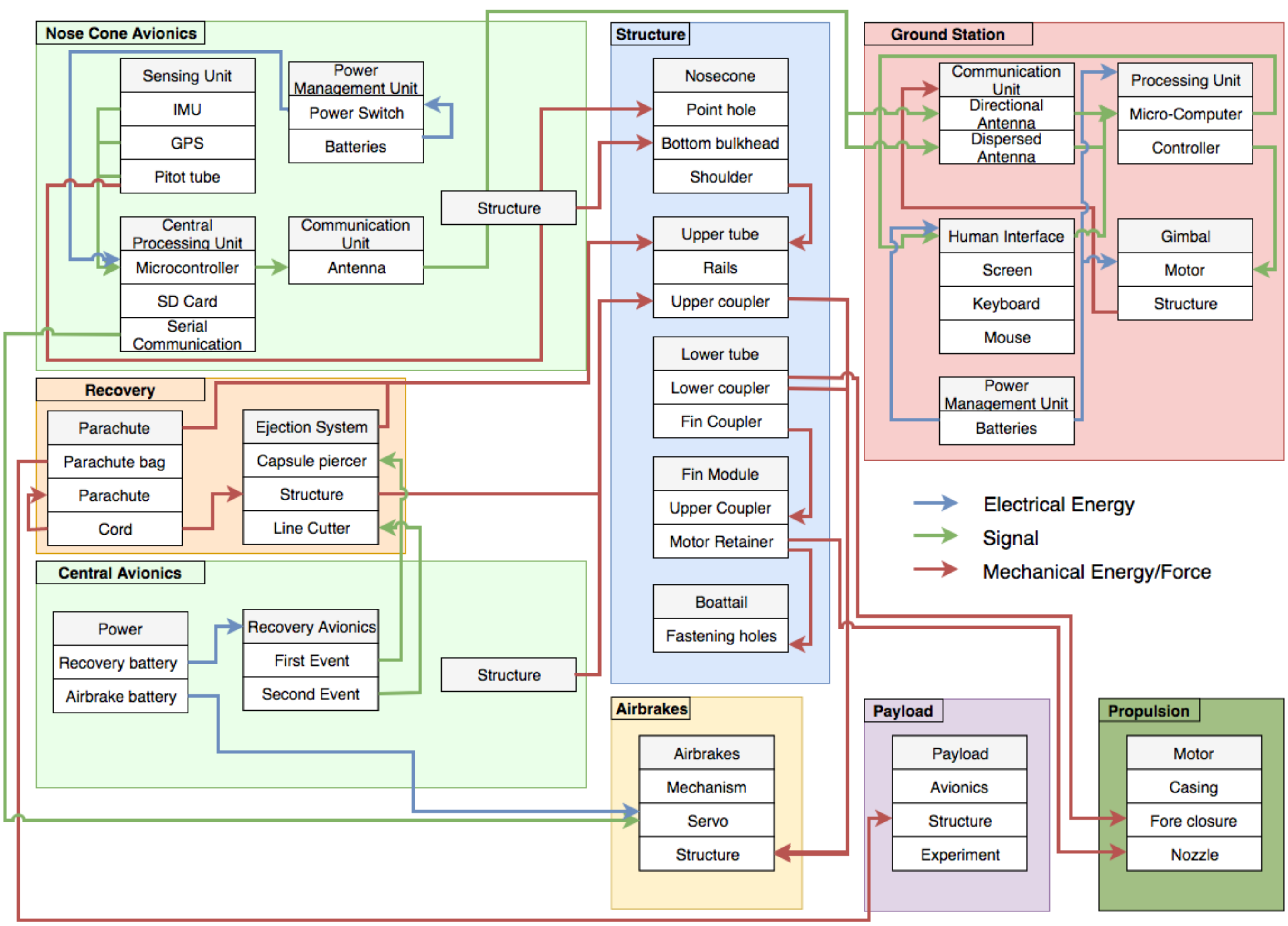


Figure 4. Interface identification and control diagram

Table 5. System-level mass budget

Structure	Mass	Contingency	Mass w. contingency	Mass allocated by SE	Margin
Aerobrakes	847.321	0	847.321	1400.000	552.679
Avionics - Main	1244.103	0	1244.103	1750.000	505.897
Avionics - Nosecone	661.392	0	661.392	1250.000	588.608
Payload	4103.428	0	4103.428	4100.000	-3.428
Propulsion	6786.190	0	6786.190	6100.000	-686.190
Recovery	2477.948	0	2477.948	3000.000	522.052
Structure	5835.266	0	5835.266	6000.000	164.734
Total	21955.648		21955.648	23600.000	1644.352

Genral contingency	5.000
Total mass w general contingency [kg]	23053.431
Total margin w general contingency [kg]	546.569

7. Technical resource utilization estimates and margins.

Simulation results depend greatly on the rocket mass, therefore monitoring the mass of the LV during development and construction is of utmost importance to the SE team. Sub-system masses were assigned by SE at the beginning of the project based on system requirements, design concepts and lessons learned from last year's rocket. The budgeted mass for each sub-system was adapted as the needs of the systems evolved during the design and production phase. The assigned masses acted on upper limits for the sub-systems and were to be respected with adequate margins. The margin system for masses works as follows, for components or assemblies:

- The concept is known : 20%.
- The CAD exists and the mass is estimated from it: 10%.
- A prototype was built: 5%.
- The final part was manufactured: 0%.

for the whole sub-system, a 5% contingency is applied except for propulsion which is COTS and Payload which is tailored to weigh exactly 8,8 lbs. A summary of the mass budget at the system level is included in Table 5.

8. Costs data

The presented costs are the sum of all the spent money according to our accounting. Money spent on each sub-system of the LV up to now is tracked by our accountant and presented in the first column of Table 6. Money available for the design and construction of the launch vehicle was shared between sub-systems based on their needs and lessons

Table 6. Technical budget for the LV

Sub-system	Spent [CHF]	Allocated [CHF]	Remaining [CHF]
Airbrakes	35.5	3500.00	3464.50
Avionics & Ground Station	5034.9	6000.00	965.10
Payload	300	3000.00	2700.00
Propulsion	983.06	4000.00	3016.94
Recovery	2411.91	3000.00	588.09
Structure	1258.95	3000.00	1741.05
Launches & Tests	3987.8	4000.00	12.2
Tools & Others	2539.96	0.00	-2539.96
Total	16552.08	26500	9947.92

Note : Exchange rates as per May 2018 are of 1.01$ for 1CHF.

learned from last year's expenses. Notable aspects of this year's budget are the large expenses in the avionics sector where material sponsoring was scarce, and many errors were committed entailing even more expenses to repair. On the other hand, the payload was totally sponsored by a university lab, such that it did not present many additional costs to the team. For the airbrakes, since they were totally manufactured with privately owned machines, only the cost of the material appears. In propulsion, high costs due to the development of a hybrid motor were expected but the objective had to be postponed to another year due to its technical difficulty. A big bulk of the cost is in test launches, certification launches to gain experience and other tests. A main expense which was underestimated is the cost for tooling and various other material that had to be bought because the rocket team is still very young at EPFL.

In conclusion, the real cost of the rocket is much larger than the actual money spent by the team, because we were offered many services and materials by sponsoring companies.

9. Stability analysis

Stability is predicted according to Barrowman's method [1]. The calculated coefficients are presented in Table 7. The mass distribution is estimated in OpenRocket (OR). The measured center of mass without motor was found experimentally to be 130 cm from the tip of the nose while OR indicates a center of mass at 127 cm. This suggests a reasonably good estimation of the center of mass with the selected motor which is then at 154 cm from the nosecone's tip. Taking into consideration these parameters, a stability margin of 3.1 is computed with the fully loaded rocket.

Stability at low velocities off the rail was further shown during a test launch in Payerne, Switzerland. Since the altitude limit above ground in Switzerland is low (2000m AGL) and there are practically no open places where a launch above 1500m wouldn't put locals in danger, the rocket was launched to 1109m on a L1150-R off a 4m rail.

Table 7. Stability analysis

Section	$C_{N\alpha}$ [rad^{-1}]	$\bar{X}$ [cm]
Cone	2	25.07
Boattail	-0574	264.23
Fins	7.03	245.23
Total	**8.458**	**-**
Center of pressure	**-**	**191.88**

Figure 6. Rocket stability margin. Center of pressure shown in red and center of mass in blue.

t =   t = 1s   t =   t = 2s   t =

Figure 5. Stability at low rail departure speeds. Full rocket test near Payerne military airbase in Switzerland.

The rocket left the rail at 19m/s. A sequence of images of the rocket leaving the pad is presented in Fig. 5. Wind speeds varied between 2 and 3 m/s at the moment of the launch.

10. Flight simulation

The details of the flight are given by simulation data presented in Fig. 7. The flight location and main hypothesis are listed in Table 9. Simulations were ran on commercial softwares, namely OpenRocket (OR) and RockSim (RS). A 6DOF simulator was also developed internally (ERT) to generate control tables and better integrate experimental data from the rocket in a simulation. This simulator was equally used to predict the rocket's nominal flight path. Since it is the only one which can accurately simulate the recovery phase with the reefed parachute, descent data was only included for that simulation giving an idea of the descent time from apogee required by the rocket.

The rocket leaves the rail at quasi optimal speed of at least 29.1 m/s (95.5 ft/s). IREC guidelines require that the velocity off the pad be at least of 100 ft/s, but stability at this lower speed is proven by flight simulations and especially by the flight test in Switzerland as presented in chapter II.

Table 9. Simulation parameters

Variable	**Value**
Launch location	Spaceport America (New-Mexico)
Longitude	-106°E
Latitude	32°N
Altitude launch site	1401 m
Wind speed	2 m/s
Launch rail length	5 m
Rocket Mass (no motor)	15241 g
Temperature (launch in morning)	15°C
Pressure (last year's pressure)	1011 mbar

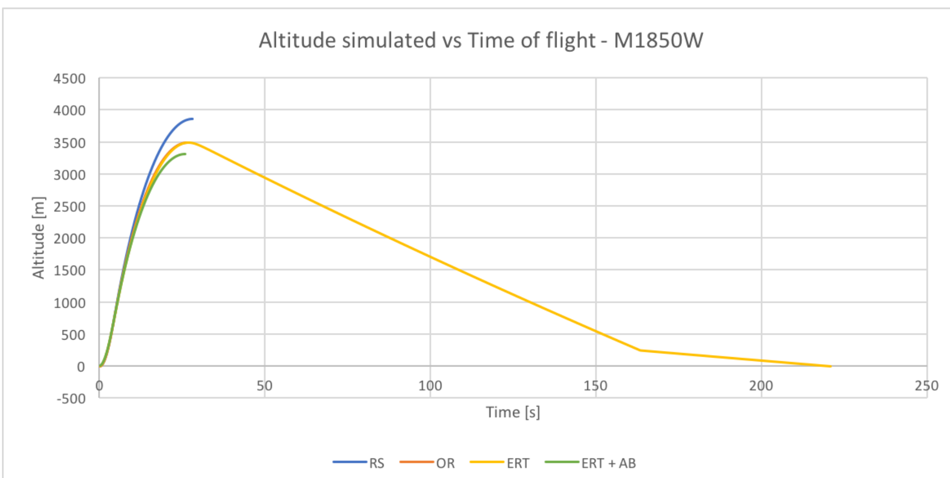


Figure 7. Rocket flight profile time plot. Calculations were done with the following softwares: RockSim (RS), OpenRocket (OR) and an internally developed rocket simulator (ERT). Also, apogee was predicted for fully deployed aorbrakes after burnout (ERT + AB).

Table 10. Simulation results

Variable	**OpenRocket**	**RockSim**	**ERT**	**ERT + AB**
Apogee altitude [m]	3853	3482	3486	3306
Apogee time [s]	28.24	26.6	26.8	25.9
Rail departure velocity [m/s]	29.2	29.8	29.1	29.1
Maximal acceleration [m/s^2]	99.7	98.9	95	95
Maximal velocity [m/s]	284.4	277	263.1	263.1
Time of flight	-	-	3min 40 sec	-

Predicted apogees vary between 3853 and 3486. These values are well above the maximum apogee required by IREC. The discrepancy between OR and RS is well known, with RS systematically predicting higher apogees when rocket speeds tend towards Mach 1. Such high apogees are due to the fact that the rocket motor was selected based on mass budgets with large margins. As the rocket was finalized, the weight was on the lower end of the expected mass pallet. The motor being already ordered; it was decided to use trim masses to reduce the apogee. The expected trim mass is between 1.5 and 2kg. It will be distributed between the motor bulkhead and the central avionics bay. Trim mass at the bulkhead has been machined at this time and weighs 800g. For the central avionics, the added mass will have little impact on the location of the global center of mass when the LV is fully loaded which mitigates the effect on the stability margin. The exact amount of trim mass is still to be determined after the rocket comes back from painting, shortly after the report submission deadline. Therefore, simulation data is presented as in the rocket's current state.

The effect of the airbrakes is included (ERT + AB) to show how much the apogee can be regulated. In this case, the apogee is expected to be reduced by 180m if the airbrakes were fully opened right after burnout.

A. Propulsion Subsystem

The choice of a COTS Reloadable Solid Propulsion System (RSPS) for the Matterhorn Project stems from the short time available to design and develop another propulsion system, given that the rocket team was created one year ago. For the competition, an Aerotech M1850W was selected based on trajectory simulations. Because all high power motor imports in Switzerland pass through the ARGOS club and they have a special arrangement with Aerotech, we chose to limit ourselves to their systems since we are used to operate them. At the SA Cup we plan on using two J-Tek (for redundancy) electric matches dipped in pyrogen with a Pyrodex pellet to ignite the motor.

B. Aero-structure Subsystem

1. Block diagram detailed

Figure 8 is an illustration which reflects how structure team sees the rocket and its interfaces with other sub-systems, namely the nose cone and central avionics, the recovery chute and system, the payload bay, the airbrakes and the motor. The lower airframe assembly and the fins module, are used as the motor mount when joined. The upper airframe and the nose cone host all the mentioned sub-systems.

2. Choices justifications and proof of design

a. Coupling System

Apart from the nosecone which slides into the upper frame, rocket parts are linked using a coupling mechanism. Even the airbrakes can be linked using the same system. Figure 10 presents an exploded view of the coupling system. Each Tube Ring (BOM: 11301) has a cylindrical surface, used to glue the coupler to the carbon airframe. Two halves are joined using an Inside Ring (BOM: 11302) and 8 Outside Rings (BOM: 11303) constrained by 8 screws (BOM: 11304). The solid design can afford all torques produced during transportation, the shock due to main chute inflation and the peak thrust. The strength and rigidity is achieved by the V-design, shown in Fig. 11 which holds both Tube Rings together when preloaded. The airbrake system has the exact same V-shape such that it can connect to the coupler. More details concerning load cases, simulations and utilities are given in appendix G.

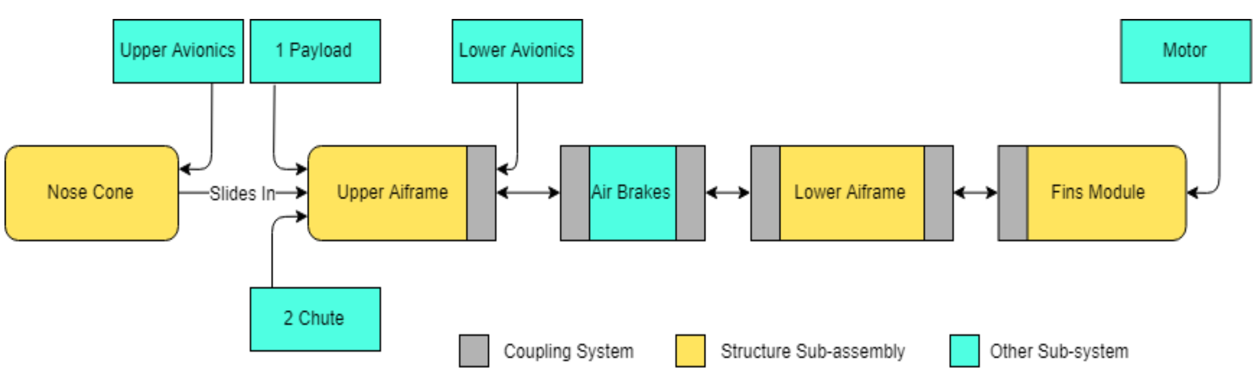


Figure 8. Structure Block Diagram. Interfaces Overview

b. Fins Module

The fins module is illustrated in Fig. 9, it allows the motor phenolic tube (BOM: 11406) to slide in. The Upper Ring (BOM: 11401) has the same V-shape used to connect the coupling system. As it is located at the rocket aft, the assembly must absorb all energy at landing. Thus, the boat tail (BOM: 11414) is a sacrificial element supposed to deform plastically when it hits the ground. If the LV undergoes more damage than expected at touch-down, the versatility of the design allows every single part to be replaced. The Rings (BOM: 11401 to 11403) are joined using the fins (BOM: 11405) which are load bearing. Carbon panels (BOM: 11408) are used to close the sides. Once the motor is loaded in, a motor retainer (BOM: 11404) is screwed at the back of the Lower Ring (BOM: 11403).

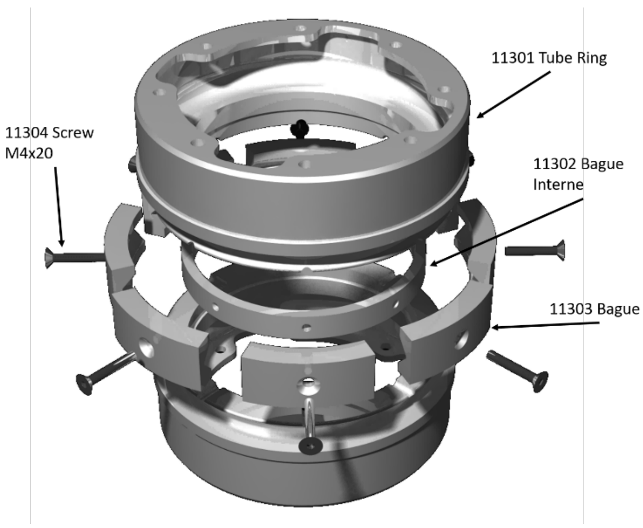


Figure 10 Coupling System - Exploded view

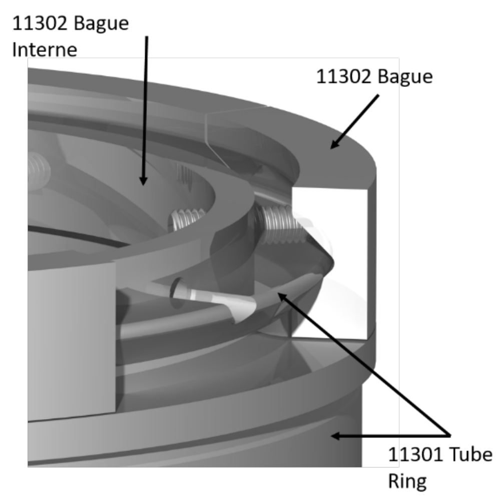


Figure 11 Coupling System - V design

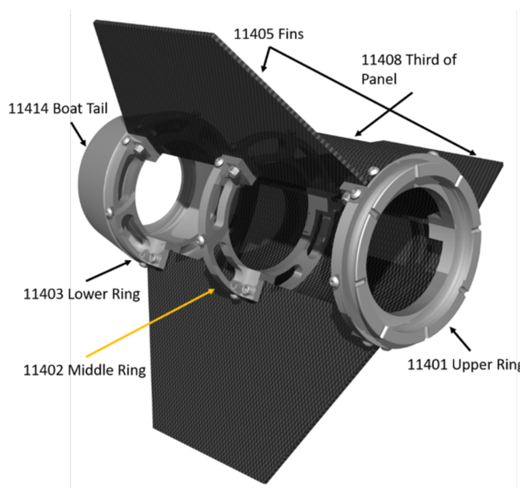


Figure 9. Fins Module - Open view

c. Thrust Plate

In Fig. 13 the motor tube coming from the fins module can be seen. It is centered using 2 carbon sandwich rings (BOM: 11409) glued inside the lower airframe (BOM: 11501). At the top of the motor tube, illustrated in Fig. 12, two thrust plates (BOM: 11502) are screwed to the coupler. They transmit the thrust produced by the motor to the upper structure through the coupling system and the airbrakes. The simulations are presented in appendix G.

d. Upper Airframe

The upper airframe module is presented in Fig. 15. It holds many subsystems such as the Payload, Recovery and Avionics. The load coming from the motor is transmitted to the subsystems using the Recovery Attachments (BOM: 11606). These also connect the parachute shock cord to the structure by means of the Recovery module's structural

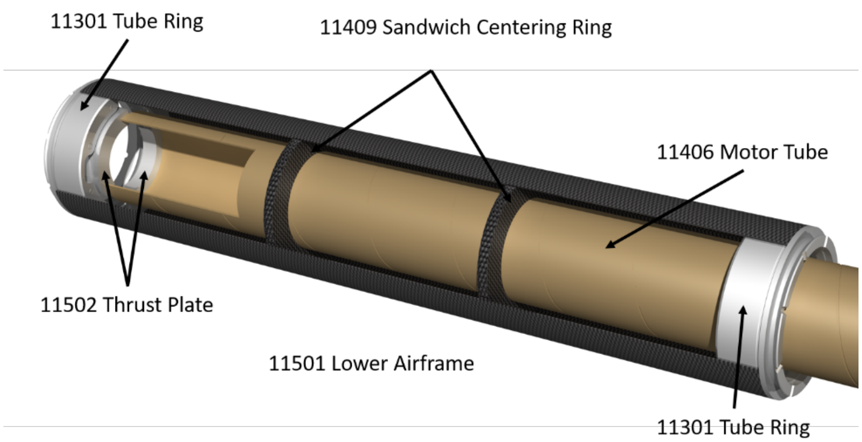


Figure 13 Lower Airframe - Open view

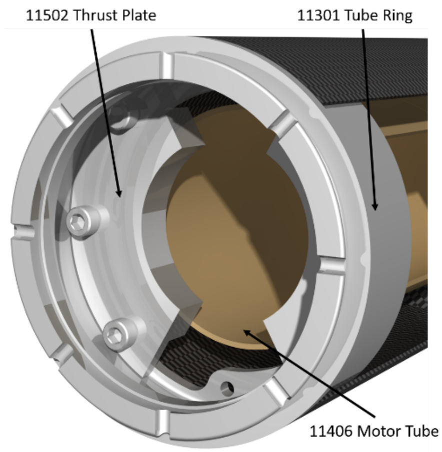


Figure 12 Lower Airframe - Thrust plate

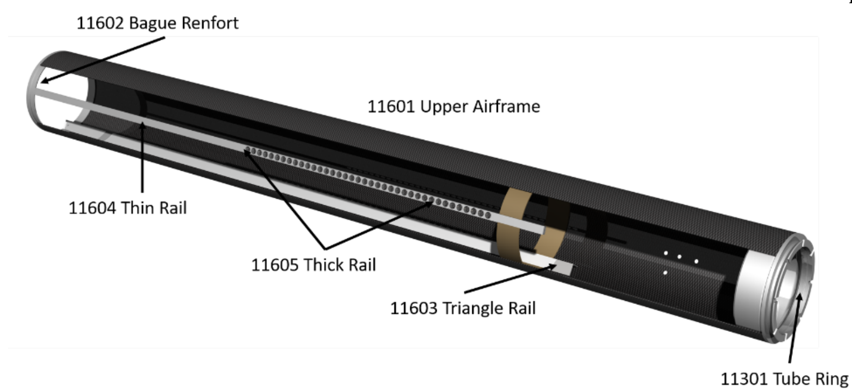


Figure 15 Upper Airframe - Open view

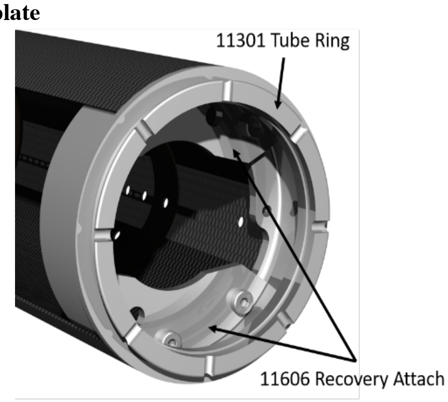


Figure 14 Upper Aiframe - Subsystem attachements

shafts (BOM: 12102) which are bolted to the attachments. In the tube three types of internal rails are glued. A triangular rail (BOM:11603) is used to run electrical connections between the nose cone and central avionics. It also prevents the payload from rolling inside the tube.

In Fig. 17 a protective ring can be seen (BOM: 11602) at the top of the tube which prevents composite delamination. As a drawback, it is glued inside the rocket and thus reduces the effective diameter. Two thin rails (BOM: 11604) are used to compensate the loss of radius such that the payload slides with ease guided by the rails with no risk of jamming. As the payload is first ejected, thick rails (BOM: 11605) are used to support it, the payload sits on them rather than directly on the parachute. These rails are glued such that the motor force is transmitted through the carbon airframe to the payload. Both upper and lower airframe simulations and details are given in appendix G.

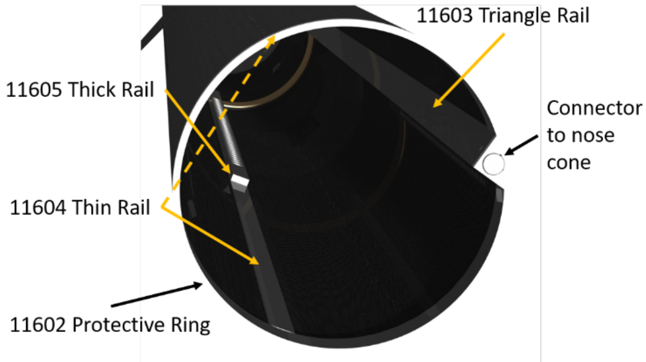


Figure 17 Upper Airframe - Top view

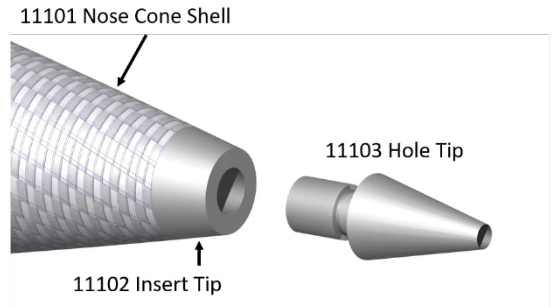


Figure 16 Nose Cone - Removable tip

Table 11. Production Plan

Part	BOM	COTS/SRAD	Supplier/Production processes
Carbon Tube	11601, 11501, 11408	SRAD	Prepreg Carbon with internal aluminium mandrel. Cured in autoclave a 180°C under 4 atm.
Coupling system	11301, 11302, 11303	COTS/SRAD	CNC machining and lathing at RUAG Suppliers
Fins module	11401, 11402, 11403, 11404, 11405, 11408, 11409, 11414	SRAD	Milling, lathing, diamond cutting.
Nose Cone	11101, 11102, 11103	SRAD	Impregnation glass fiber under vacuum condition. Post-cured at 70°C. Lathing.
Thrust Plate	11502	COTS/SRAD	3 axes CNC machining at university metal shop
Recovery Attach	11606	COTS/SRAD	3 axes CNC machining.
Protective Ring	11602	SRAD	3 axes CNC machining.

e. Nosecone

The nosecone remains conventional, it is made of glass fibers, which allows radio waves to be transmitted through it. It holds the second avionics. Fig. 16 illustrates the particularity of this nosecone, a versatile tip (BOM: 11103). As a pitot tube may be used or not, a solid tip can replace the drilled one. In case of damage, the tip can be easily changed. More precisions can be found in appendix G.

3. Manufacturing

Table 11 presents the global production plan that structure follows regarding manufactured parts. The table references all part to the BOM. Only the motor mount (BOM: 11406) and all the screws were bought as COTS parts.

Figure 18 Carbon airframe and lamination process

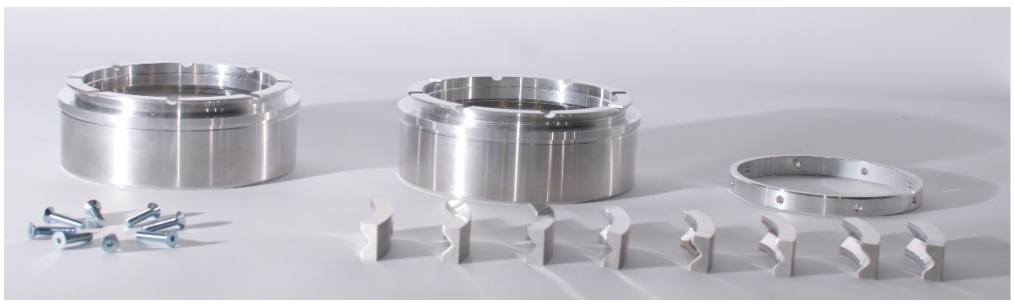


Figure 19. Coupling system at delivery

a. Carbon Tubes

The airframe is designed by the structure team. It was manufactured in RUAG Aerospace infrastructures with the help of professionals. Details on the manufacturing of the tubes are included in appendix G. The resin was cured in an autoclave to achieve optimal mechanical properties. Fig. 18 illustrates a few steps of the process, the result of demolding as well as the lamination process.

b. Coupling System

Coupling system: The coupling system is designed by the structure team as well. The geometry is the result of many simulations and 3D printing tests. As the manufacturing of a series of these parts with conventional milling tools would have been very time consuming, we decided to delegate it to RUAG Aerospace suppliers. They were manufactured using a CNC lathe. Figure 19 shows the coupling system final results. Again, more details regarding the system are given in appendix G. The parts are made of aluminum 6082.

Figure 20. Fins module Machining

c. Fins module

This module is composed of many parts. The fins and the lateral panel (BOM: 11405,11408) were cut using a diamond saw installed on a circular grinder (Fig. 20 left).The rings and aft enclosure (BOM:11401-11404) are made of 6082 aluminum and produced using a lathe and milling machine (Fig. 20 right).

d. Nose Cone

The nosecone was fully SRAD since no commercially available nosecone with a 120mm diameter shoulder exists. A negative half nosecone mold made of MDF wood was machined using a CNC. Woven Glass fiber (300g/m^2) impregnated with Epoxy Resin L+EPH161, which is a high temperature resistant matrix, was laid up in the mold. The

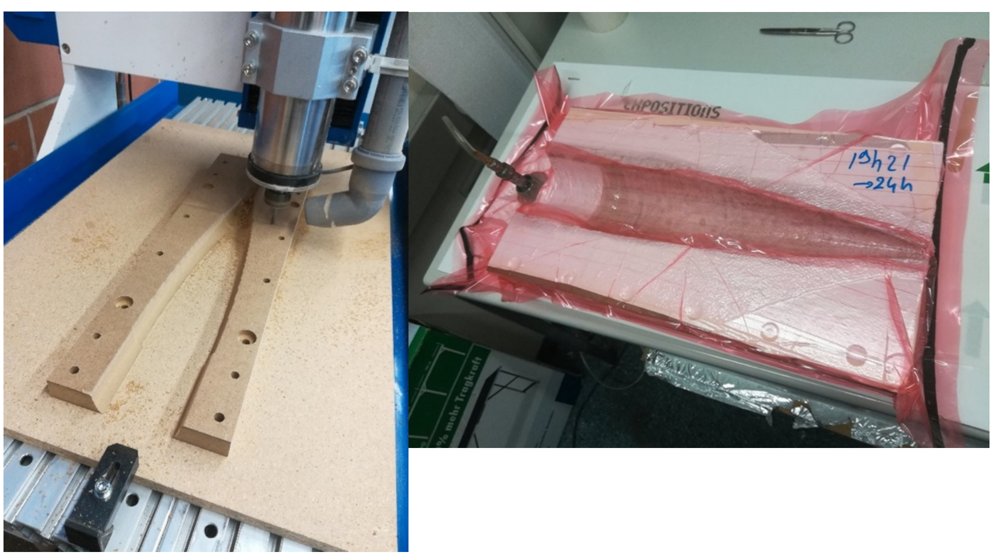


Figure 21. Mold fabrication & curing setting

nose cone cured under vacuum at ambient temperature for 24 hours to which a post curing at 70°C in an oven was added. The two halves were joined using high resistant glass fiber (500g/m^2). Figure 21 presents the manufacturing process. Finally, the tip was made using a lathe.

e. Other parts

The thrust plate, the recovery attachments and the protective ring were all designed by students but given to the university metal shop for manufacturing. These parts were made by 3 axis CNC milling. The quality of such a piece is illustrated in Fig. 22.

4. Simulations and Tests

As the structure team has a lot of simulations they won't be all explained in detail for the sake of keeping the report brief. An overview of the simulations is presented in Table 12. The part name is specified as well as the important outcome from the analysis. A simulation is nothing without a completed explanation, more details are provided in appendices which are also specified for each load case.

Table 12 Simulations overview

Part	Load Case	Criteria	Security Factor
Upper Airframe	Compression	Ultimate Strength	>100
	Buckling	1st Mode	37
Lower Airframe	Traction	Ultimate Strength	>100
Thrust Plate	Thrust peak	Yield Strenght	1.5
Recovery Attach	Chute inflation	Yield Strenght	1.6
Coupler	Initial acceleration	Yield Strenght	1.3
	Chute inflation	Yield Strenght	1.3
Glue	Shear traction	S < S_max	>4

Full simulations are included in appendix G.

Figure 22 CNC milled thrust plates screwed in a coupler

C. Recovery Subsystem

A dual event recovery generally implies that a drogue is released at apogee and a main parachute is opened a couple hundred meters above ground. To satisfy ESRA's requirements of having a controlled descent velocity during the first phase of recovery and less than 9 m/s of descent rate during the landing phase, Matterhorn will use another approach. Thanks to a reefing method, a single canopy will produce the drag required for the first and second phase by adapting its aperture. Since the parachute had to be tailored to the rocket's mass and the competition criteria, it was fully designed and sowed by students.

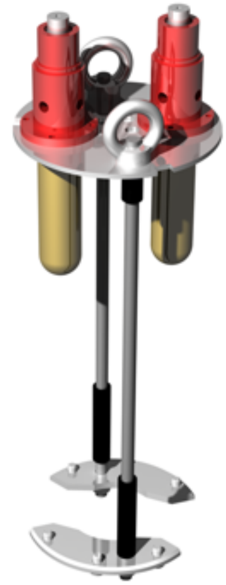


Figure 23. Recovery module.

Matterhorn's specifications for the competition are a first descent rate of 20m/s, which is rather slow to reduce the shock when unreefing and a final descent rate of 5m/s to have as little damage as possible.

To deploy the parachute, the Pergrine RAPTOR ejection system based on a pyrotechnic CO_2 cartridge piercing mechanism was selected instead of black-powder. Two RAVENS are used for recovery avionics. Although using twice the same avionics is not ideal for redundancy, this configuration has been flight tested and was preferred over using another avionic that the team is not used to operating. The unreefing mechanism is triggered by two AEROCON line cutters in series for redundancy.

1. Block diagram detailed

The line of force between the rocket body and the parachute is illustrated in Fig. 24. It starts to the right with the coupler transmitting the shock force to the airframe. Then, two titanium bars link the coupler to the recovery plate where the Raptors are located. The plate also provides partial sealing with the upper tube to maximize the ejection pressure. Directly screwed to the titanium bars, on the opposite side of the recovery plate are two eyelets, which are linked to a harness. The role of the harness is to prevent the eyelets from un-screwing due to torsional forces. The main parachute is connected to the harness by a 5m long shock cord. The nosecone is also fastened to the harness as it descends with the rocket. On the other hand, the payload is free to descend on its own once it has been ejected. More details on the ConOps are included in chapter III.

Redundancies were considered at each step of the recovery ConOps. Thereby, for both recovery events, two independent deployment systems are triggered by two independent electrical circuits. So, each recovery event can be achieved in two independent ways. The implementation of these redundancies is detailed in Fig. 24. For the second recovery event, both triggers are carried all the way through the shock cord to the junction point of the parachute lines where line-cutters are located. These will "un-reef" the parachute by cutting the central retention line.

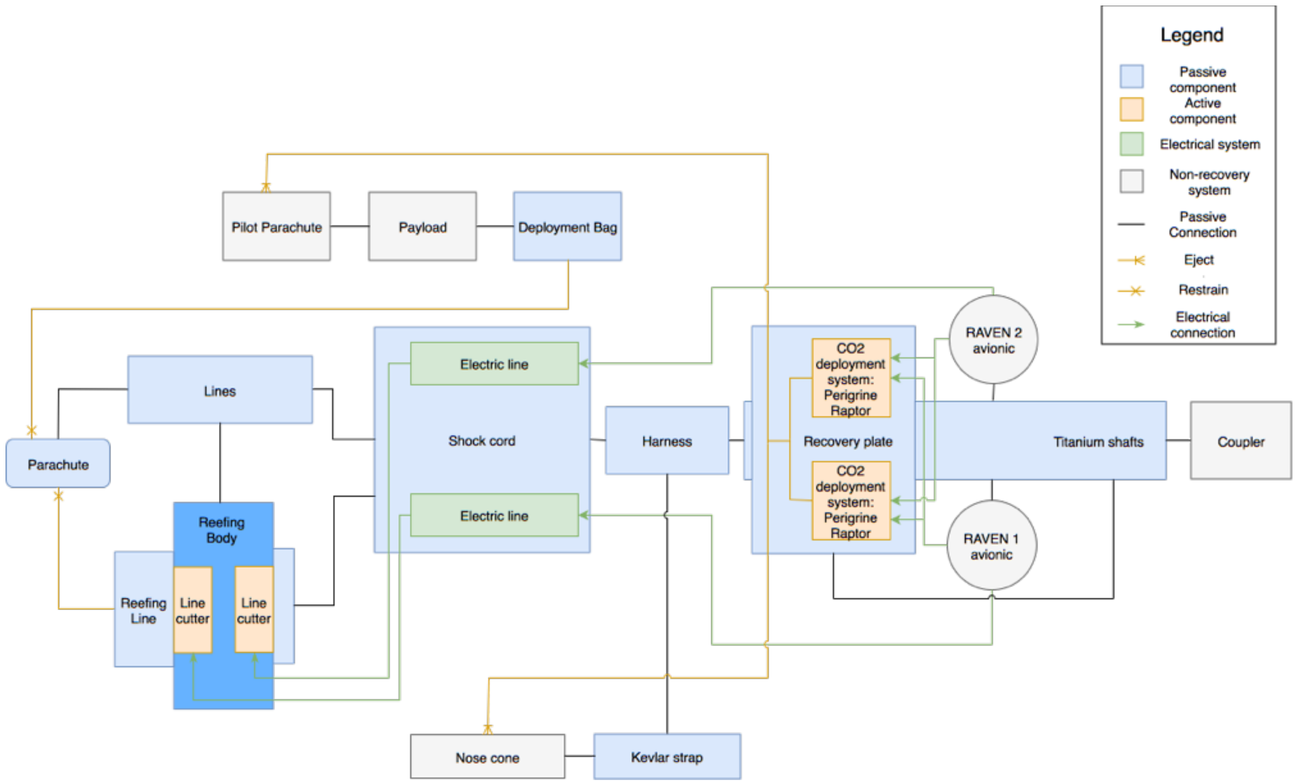


Figure 24. Block diagram of the recovery systems

2. *Choices justifications and proof of design*

a) Reefing

Different reefing technics detailed in reference [2] were explored. Since a central line is already implemented in classical rocketry parachute[2], we decided to use the method consisting of retracting the central lines of the parachute. This reduces the projected area of the canopy and its effective drag, $C_d S$. The drawings from reference [3] (p. 5-78) are represented in 25a). Furthermore, this method can be implemented at the base of the parachute's lines, where entanglement can be mitigated.

The evolution of the drag force as a function of the length of the central lines can be found in Figure 26b).Reference data [2] (p. 5-78) is plotted in Orange whereas the blue curve is the result of our experiment, using a smaller scale

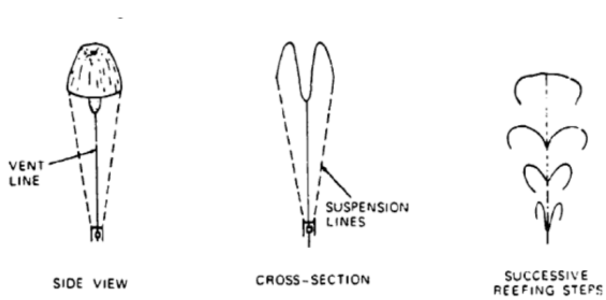


Figure 25 a). Parachute vent reefing

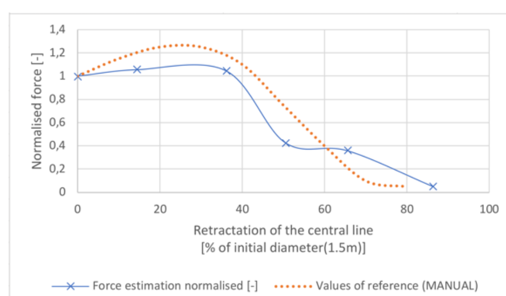


Figure 26 b). Drag force evolution as function of the retraction of central lines

[2] Fruity Chute : https://fruitychutes.com/buyachute/iris-ultra-standard-chutes-c-29/

parachute in the EPFL wind tunnel. The results show that the effective drag of the reefed parachute, $(C_dS)_r$, can be less than 16% of the maximal drag, $(C_dS)_m$, obtained when fully deployed. Furthermore, in first approximation we consider the rocket of mass m obeys the following equation, where $\dot{z}$ is the vertical descent speed, $\ddot{z}$ is the vertical acceleration and ρ the air density.

$$m\ddot{z} = mg - \frac{1}{2}\rho C_d S \dot{z}^2 = 0$$

From this we deduce the relation between efficient drag and the speeds of the different phases:

$$(C_dS)_r = \frac{\dot{z}_{landing}^2}{\dot{z}_{phaseI}^2}(C_dS)_m \leq \left(\frac{5m.s^{-1}}{20m.s^{-1}}\right)^2 (C_dS)_m \simeq 12.5\%(C_dS)_m$$

A reefing with such a drag reduction is achieved by the prototype for approximately 80% of line reduction. Plus, this is an overestimation of the required reefing ratio since the change in air density was not taken into account. The final version of the parachute was then built based on the tested prototype.

b) Parachute

The parachute's design was inspired by existing rocketry parachutes and research papers [4]. Using existing designs helped achieving a basic level of reliability. The actual performance of the parachute was then determined through testing.

For the canopy, the toroidal shape was selected because it is known to produce the highest drag coefficient. Some modifications were then added to the design. Vents were made such that the drag coefficient is reduced even more in the reefed position, while the drag in the unreefed position is much less affected. Furthermore, smaller vents at the line attachment points help to stabilize natural oscillations which can be observed on very basic high power rocket parachutes. Figure 27 shows the location of the upper vents when the parachute is in reefed and un-reefed position.

c) Reefing release system

The reefing release is using two COTS AEROCON line cutters fitted in a part called "reefing body", shown in Fig. 28. The reefing body is placed at the base of the parachute lines, which has a dual purpose. Firstly, it permits to separate every line from the central line, helping to avoid entanglement when the reefing is released. Secondly, it is in this structure that the line cutters are placed.

The electrical shock cord, composed of a modified shock cord with an electrical cable passing through it, allows current to be sent from the recovery plate to the line cutters. By first approximation, the deceleration when the parachute is unreefed is of 25g. With a mass of 15kg at the end of the cord, a tensile force of 3750N is achieved. The chosen shock cord is graded to 9800N to withstand the shock.

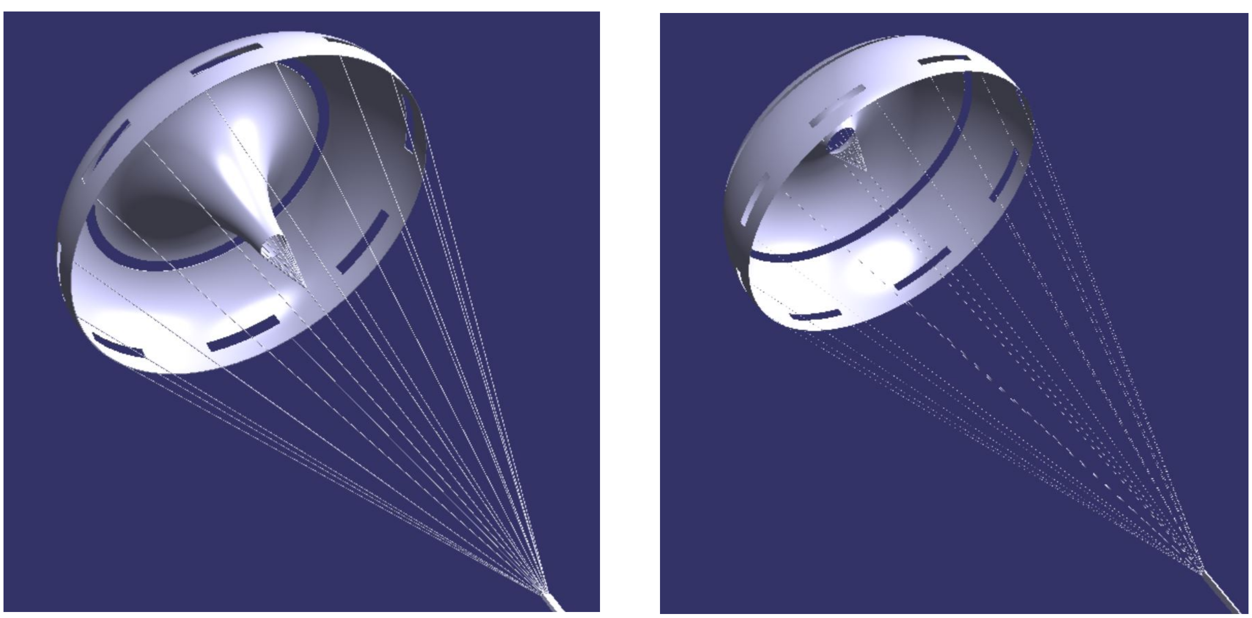


Figure 27. SRAD parachute in reefed (left) and unreefed (right) position

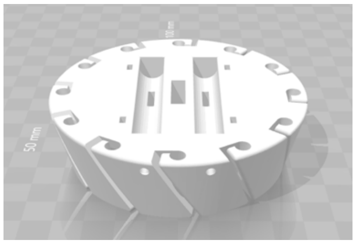


Figure 28. Isometric view of the reefing body.

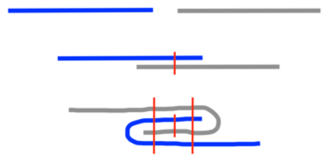


Figure 30. Sewing technique

Figure 29. Canopy manufacturing

a. Redundancy

Both events of the recovery are fully redundant, mechanically and electrically speaking. For the first event, there are two RAPTORs. Both can eject the nosecone on their own. Each RAPTOR possesses two igniters; they are each ignited by an independent COTS recovery avionics. The second event is cabled similarly, there are two AEROCON line cutters, each containing an igniter routed to a separate avionics. The reefing line is attached in such a way that it unreefes even if a single line cutter functions properly. The recovery block diagram, the Fig. 24, sums up the implementation of the redundancies for the recovery.

3. Manufacturing

Recovery system parts and assemblies are summarized in Table 13 with their respective origins. The production process of the parachute and the electrical shock cord are described in more details.

a) Parachute

The parachute was designed on CAD software, the different 3D drawings were then projected on a 2D plane in order generate the patterns to cut the fabric. The fabric parts were joined using a sewing technique detailed in Fig. 30 where four layers of fabric overlap. Once all the fabric parts were sewn together, each line ends were sewn at two opposite point of the canopy's base. The final result is included in Fig. 31.

b) Electrical shock cord

A hollow shock cord was used to pass the line in its core. Under stress, the cord expands much more than the electrical cable. To avoid compromising the cable, loops were made giving it the necessary slack to compensate for the cord's elongation. The total length of the wire is 20 % longer than the shock cord.

Figure 31. Inflation test right after completing the manufacturing.

4. Simulations and Tests

A failure in one of the recovery systems would result in critical consequences for the mission. In addition to adding redundancies to the different systems, maximizing the number of tests is a consistent way to minimize the risks.

For the electrical shock cord, it was necessary to test if the electric signal was still carried by the electrical wires passing through the shock cord during and after a shock. For the parachute, a test in a wind tunnel was made but on a smaller scale parachute, assuring that with this design the parachute is stable enough and more importantly that the reefing can satisfy the requirements of dual event recovery.

Then, a first series of ground tests were done implementing the reefing technology but without the payload and a smaller scale rocket body and parachute. This permitted to familiarize ourselves with the preparation of the COTS deployment system RAPTOR and the COTS line cutter. In addition, a drop test was done with this smaller scale module and parachute to check that the design of the reefing body is permitting the reefing line release without entanglement.

Finally, those two last tests were executed again with a real scale module, including the payload's structure. The ground test permitted to check that the electrical connections of the six igniters were correct, that the choice of CO_2 cartridge recommended by the Peregrine RAPTOR was sufficient and that the payload would not stay stuck in the rocket body and block the parachute. Then, a final drop test being as close as possible to the flight conditions for recovery was executed to check that the ConOps chosen is functional and that the parachute can with stand the opening shock when un-reefed.

Further details of the different results of those tests can be found in appendix G.

Table 13. Recovery parts' manufacturing

Part / Assembly	BOM	COTS/SRAD	Supplier / Production process
Recovery Structure	12101, 12102	SRAD	Conventional machining
Connectors	12105, 12016	COTS	LEMO SA
Parachute and Deployment bag	12201, 12206	SRAD	Para-Gear
Electrical shock cord	12203	SRAD	Blue Water Rope
Strap and Harness	12204, 12205	COTS	Fruity Chute
Line cutter	12303,12304,12305,12306	COTS	AEROCON
Reefing Body	12302	SRAD	3D printing
Deployment System	12400	COTS	Peregrine RAPTOR

D. Avionics Subsystem

1. Block diagram detailed

The detailed block diagram is presented in Fig. 32.

2. Choices justifications and proof of design

The avionics were designed to fulfill a number of tasks defined by System Engineering. These tasks were separated between SRAD and COTS systems as follows:

- SRAD avionics:
  - Communicate by radio with the ground station.
  - Log flight data such as attitude, position, and speed
  - Control the airbrakes
- COTS avionics:
  - As stated earlier, two RAVEN recovery systems are used to trigger the recovery events.

The SRAD and COTS systems are completely independent on the energetic as well as the informational level. The SRAD avionics are located in the nosecone to take advantage of the glass fiber frame which is permeable to radio waves, whilst the COTS avionics and airbrakes are at the center of the rocket.

a. SRAD avionics specs

The SRAD avionics revolves around an STM32 F405 microcontroller who is connected to a number of peripherals. More specifically, these are an IMU with +/-24g acceleration detection range, a barometer to estimate altitude, a differential pressure sensor for the pitot tube, a GPS antenna, an SD card adapter, an RS232 communication interface to control the airbrakes and two radio communication modules 434 MHz and 900 MHz.

b. Power

The power supply for the nosecone avionics is an 11.1V LiPo battery with a capacity of 2.6 Ah (103'896 J equivalent). The airbrakes have their own power supply, a 12V LFP battery with a capacity of 3 Ah (129'600 J equivalent), chosen for its thermal stability. According to the power budgets presented in appendix A, this setup has an autonomy of 4 hours with security factor of 2. Since we are unsure how the autonomy of the battery is influenced by high high ambient temperature, a large margin was taken. Both RAVENs are powered by separate 9V batteries. Although these batteries seem very common, their autonomy has been tested over 24 hours on an armed system which is judged sufficient for the competition.

c. Airbrake control

The airbrakes are controlled through an RS232 serial communication protocol defined by the motor constructor, Faulhaber. The airbrake aperture is determined by a control program running on the microcontroller and is transmitted by cable connection to the airbrake module. The connection must be detachable to allow the ejection of the cone, therefore vibration resistant, detachable LEMO connectors designed especially for such situations were used.

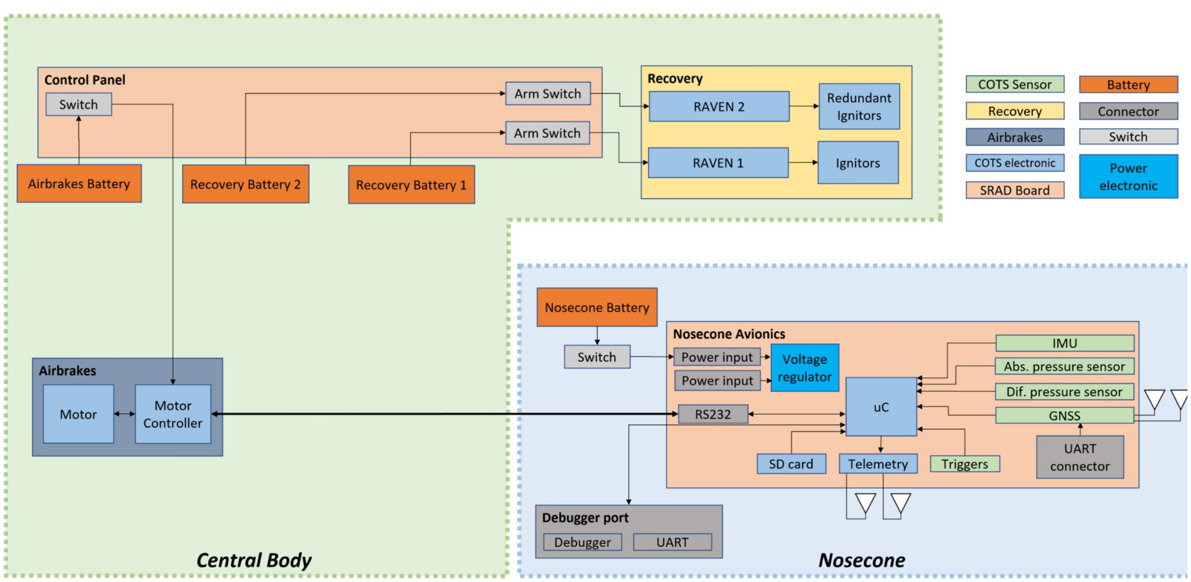


Figure 32. Avionics block diagram. Each large region represents a separate sub-system: the central body and nosecone avionics.

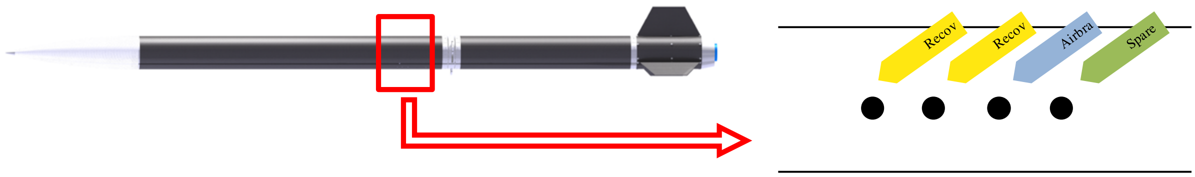


Figure 33. Control panel location and switch arrangement.

d. Structures

Both the central and nosecone avionic modules are based on a slide on, slide off design where, in both cases, two rods serve as rails to fasten the modules. This allows for easy integration and repair if needed.

e. Control Panel

The control panel houses arming switches to arm the recovery systems and to power on the airbrake. It is located right above the airbrakes as shown in Fig. 33and as far as possible from the nosecone which is normally ejected at apogee. four switches are implemented, one for each RAVEN, one for the airbrakes and a spare switch in case another system should be added at the last moment. The nosecone also has a switch to power the avionics on the pad. Since it is not linked to any pyrotechnique systems the nosecone avionics are turned on right before raising the launch rail.

3. Manufacturing

To produce the SRAD avionics, the team went through the whole manufacturing process. The boards were designed by students and outsourced to Würth Electronics for printing. Each board production included: a schematic and final design, semi-automatic component placement, Fluor-oven based soldering and finally control, correction and short circuit testing. Avionics integration in the rocket needed design and manufacturing of a holding structure, and a custom cables fitted with appropriate connectors.

4. Simulations and Tests

To ensure that the avionics will operate properly, we performed several tests, that range from the electric tests to the in-situ functioning. We first measured that the regulated voltage where correct. We then proceeded to check the power consumption to ensure that there were no leaks when everything was powered off, and to ensure that the autonomy in sleep mode will be sufficient. We then proceeded to communicate with the various sensors of the boards and monitored the various communication protocols with an oscilloscope, to make sure that the values read from the sensors were accurate and fetched in real-time.

E. Payload Subsystem

1. Motivation

Muon detection technology has applications for muon contamination, measurements such as radiography, as well as particle detection. Scintillator-based detectors benefit from widespread use and heritage, and since flux intensity of muons and other particles can be strongly dependent on altitude, their use as rocket payloads is common [5]. In recent years, efforts have been made to make muon detection technology more accessible [6] [7]. It is with a similar goal that this experiment aims to demonstrate and document how a low-cost and compact muon detector could be built.

Such an experiment was fit for a rocket as scintillator-based detectors can theoretically be made in many shapes and sizes, providing design flexibility. Furthermore, muon flux received at sea level is only a fraction of that in upper levels of the atmosphere, due to their rapid decay. Given a high enough detection rate, muon flux can be correlated

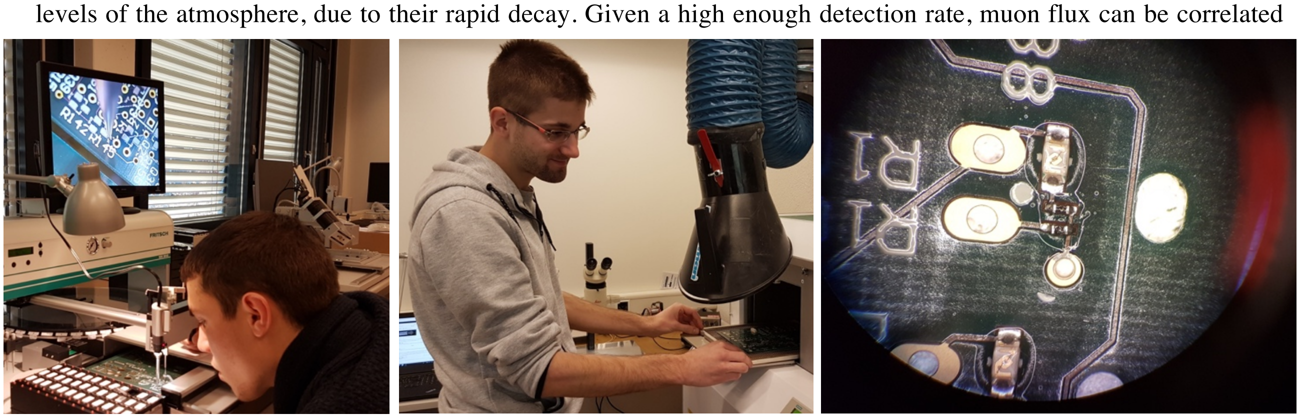


Figure 34. Electronic components are placed on the boards with a pic'n place tool, the components are soldered in an oven and the soldering is checked with a microscope.

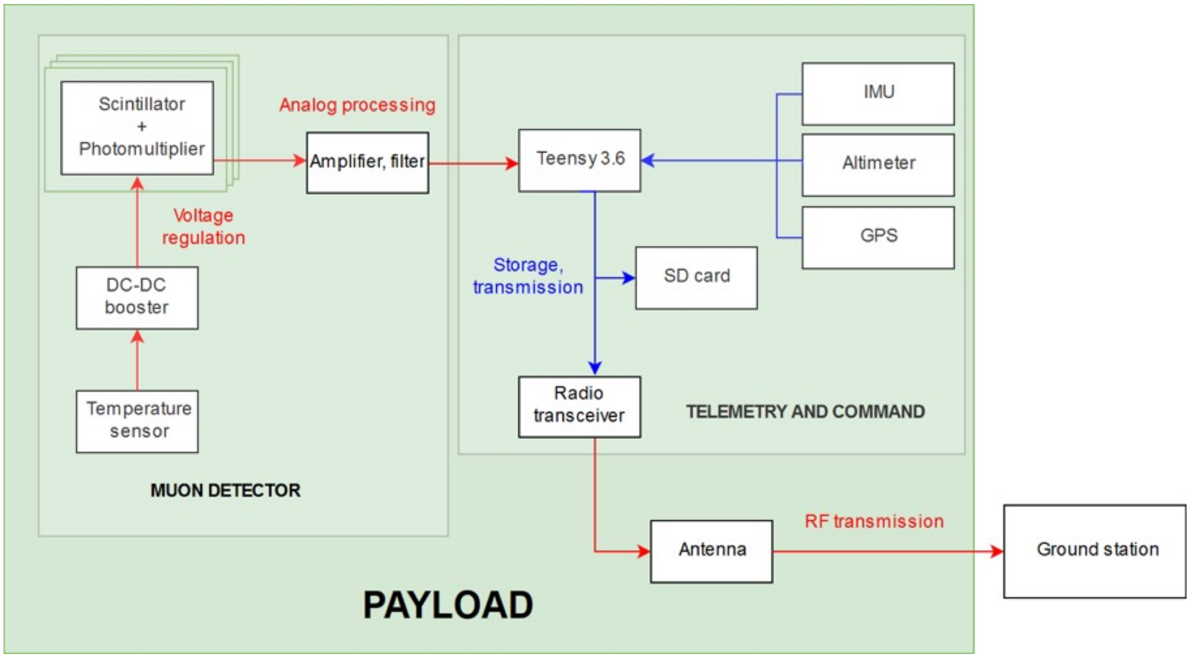


Figure 35. Payload block diagram

with altitude, which we hope to prove more conclusively than previously with this experiment. In the future, this technology could be used as a means of non-barometric altitude measurement inside the troposphere.

1. Block diagram detailed

The muon detector is the core of the payload. Muons generate an optical signal, with a wavelength of 425 nm, when passing through transparent scintillators made of polyvinyl toluene. This optical signal of low intensity is converted to a current by Silicon PhotoMultipliers (SiPM) whose characteristics are highly dependent on temperature; hence their input voltage is regulated according to this parameter. This newly created electrical signal undergoes analog processing before being converted to a digital signal within the Teensy 3.6 microcontroller, alongside the data coming from the GPS, from the barometer and from the Inertial Motion Unit (IMU) that constitute the sensors of the telemetry and command unit. Once retrieved, these data will temporarily transit through the RAM before their storage on the internal SD card of the Teensy. During the descent, the flight data of the payload will also be transmitted to the ground station through the antenna, to facilitate its recovery after touchdown. To conserve battery, muon data recording starts only once the payload is airborne.

2. Choices justifications and proof of design

a. Hardware

Muons are detected using a scintillator with a photomultiplier affixed to its end. Indeed, this technology is robust and well understood, and we expect such a setup to be able to detect a flow of 11 muons per second on average. The initial project would have used CCD or CMOS-APS camera sensors as detectors, however extensive testing with this technology revealed a far too low rate of 0.4 events per minute per CCD, therefore SiPMs were selected instead.

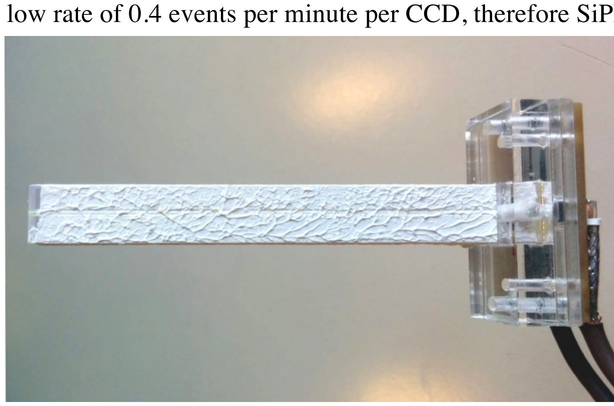


Figure 36. Scintillator (white rod) connected to SiPM (on the right)

The actual experimental setup consists in two rows of four scintillators, with one row on each side of the central plate of our payload. These emit on the order of 10^7 photons when a muon passes through, which are transferred, and wavelength shifted by an optical fiber to the SiPM. The SiPM converts photons into an analog current, which is passed through a low ohmic resistor to minimize the thermal noise and convert it into a voltage, which is input to the amplifying block. The amplifying block is an active low pass (5 MHz) filter, that will both amplify the low amplitude voltage at its output and filter out the high frequency shot noise coming mostly from the SiPM. A peak detector increases the duration of the event to a couple of milliseconds, so the intensity can easily be sampled by the Analog to Digital Converter of the Teensy.

The Teensy was chosen as a processor because of its ability to manage the sensors and antenna, as well as its built-in microSD slot, providing a reliable means to store experiment and flight data. The many I/O options also reinforced the future-proofing of these avionics and their reusability for other flights and other experiments. The assembled avionics are presented in Fig. 37. Power is provided by NiMH battery cells, chosen for their safety and their good energy retention at temperatures above 45°C. To account for the possibility of an extended wait time on the launchpad, the amount of batteries in the payload is double what would be needed for the measurements. Temperature also affects the gain of the SiPMs, which can prevent signal acquisition and therefore data collection. In order to avoid this, their input voltage is managed by a power supply that varies according to the temperature measured inside the payload.

b. Structure

As shown in Fig. 38, the frame is built from steel to resist to the trauma of rough landings, and to protect the experiment from alpha and beta radiations, and electrons, that could cause noise or false positive events. Dry lubrication from Teflon skates is used to smoothly eject the payload from the rocket. Within the frame, the electronics are mounted on 3 removable plates, which are in turn on dampers to reduce the possibility of vibration damage to the electronics.

c. Software

The software of the Teensy is defined in 3 classes, for data acquisition and storage, measurement triggering, and radio communications. The trigger class listens for two conditions: a sustained high acceleration reading (above 3g for several seconds) from the IMU indicating lift-off, or a pressure spike from the barometer indicating ejection at apogee. Upon either of these events, the other two classes are initialized, and a recording loop begins, lasting for 15 minutes. During this loop, the data acquisition class uses DMA technology to read muon data from the ADCs as fast as possible, using a buffer to save data before transferring it to the SD card which logs all the data. The radio communications class, also in the loop, manages acquisition of GPS data and periodically transmits it to the ground via the RF module, while also activating the buzzer, which will help the recovery team find the payload on the ground.

3. Manufacturing

Most components in the payload sub-system are SRAD. The frame is built so as to best fit inside the rocket's frame, while maximizing the volume for the experiments and allowing for passage of wires and a shock cord. Custom PCBs were built by the team for the payload's avionics, to reduce its footprint, and the muon detector was also custom-built. Components and sensors in the payload's avionics and the SIPM themselves are COTS.

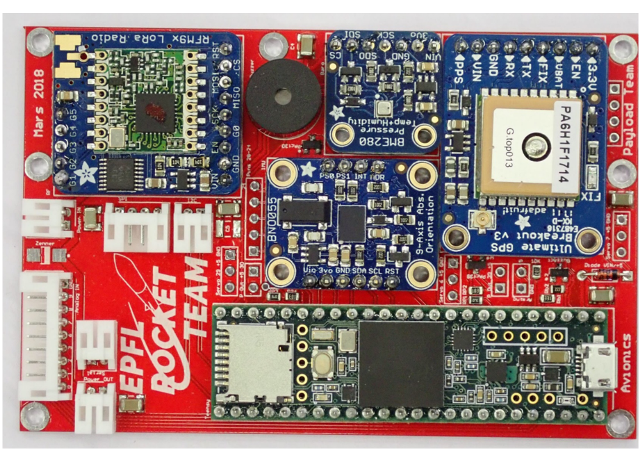


Figure 37. Payload avionics


Figure 38. Payload frame

Table 14. Payload production plan

Part	BOM	COTS/SRAD	Production processes
Steel frame	17101-17113	SRAD	Cylindrical frame in steel. Machined using EDM (Electro Discharge Machining) and then soldered. Side panels made out of spring-steel sheet. Central experiment plate made with glass fiber materials.
Avionics PCB	17201	SRAD	Developed at the physics department of EPFL. Soldered.
General avionics	17202-17208	COTS&SRAD	The GPS, IMU, RF transmitter, pressure sensors and the computer unit are Arduino and teensy 3.6 components, bought on the internet. The integration is SRAD.
Scintillator experiment	17301,17302 ,17304	SRAD	Scintillating acrylic rod cut at EPFL's physics department. PCBs developed and soldered at EPFL's physics department.
SiPM	17305	COTS	The photomultiplier units have been provided by Hamatsu.
Parachutes	17119-17120	COTS	Fruity chutes parachute.

4. Simulations and Tests

Testing of the payload has been threefold: both the scientific equipment, the structure, and the electronics needed testing to ensure they were fit for flight. The scintillator-based experimental setup has been tested and produced a rate of at least 25 events per minute far better than the previous design. To guarantee the accuracy of these events, the SiPM has been calibrated with ambient light, as well as with an electron gun, to filter out background noise. To further show that the detected events were muons, testing was done at various altitudes and orientations and showed results consistent with a flux of muons. The SiPM gain response versus temperature has been tested by manufacturers and by the team, as well as our Ampli/OP circuitry designed to manage the SiPM temperature, which performed as intended.

For the structural tests the team has performed a drop test, showing the strength of the frame. Several ejection and parachute-opening tests have also been performed.

Several electronics-related tests have also been planned and completed. The payload's behaviour has been tested at temperatures above 45°Celsius to better assess our power needs before and after takeoff, but also to guarantee continued functionality of the payload and the integrity of the batteries. The GPS/RF system for the payload was tested in conjunction with the Ground Station team, verifying that the signal can be acquired over long distances.

F. Airbrakes Subsystem

The main issue in designing a rocket in Switzerland is the lack of launch opportunities due to the high density of population and mountains. Without a lot of testing and empirical data, it is difficult to achieve a precise apogee only by playing on the motor/weight parameter. Regarding this, an airbrake module will fly on the rocket with an automated control of the apogee. The rocket's motor will be oversized, entailing an overshoot that will be corrected if necessary by the airbrake module.

Two modules have been designed and built. The first one, called "Shuriken", shown in Fig. 38, is based on three eccentric triangular winglets pivoting out of the module, adding some surface facing the airflow. The second one, called the "Flaps" system, is made of three flaps flush with the tube when closed and lifted open by a linear screw and links. The Shuriken module has been chosen to fly at the competition, but the Flaps system, which is fully operational, will be brought along in case of a last minute failure of the other module or specific weather changes. In case the Flaps module were to fly, full documentation will be provided on it at the event.

Figure 38. The Shuriken Airbrake Module

1. Block diagram

As shown in Fig. 39, the sensors measure the rocket's state (speed, altitude, and maybe the inclination of the rocket in the future). The values are sent to a Kalman filter, which estimates the vehicles altitude and ascent velocity. The required airbrake opening is given by a look-up table computed beforehand thanks to numerical simulations. For a certain combination of altitude and speed, the table returns the opening angle needed to reach the target apogee. The look-up table was generated by doing a backward simulation from the apogee of the rocket's evolution for various airbrake apertures. The table has now 3, the first one is the altitude, the second one the speed, and the third one the needed opening angle which, if maintained, will lead the rocket to the target altitude. Of course, there are states for which the target altitude is impossible to reach (overshoot or undershoot). The states for which it is possible to reach the goal, form a "control band". For combinations outside the control band, the airbrakes are either fully open or fully closed. A schematized version of the control table is included in Fig. 41.

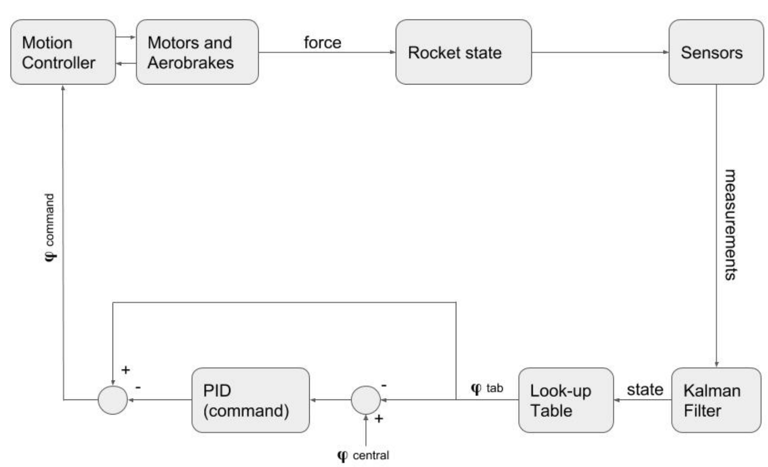


Figure 39. Control block diagram

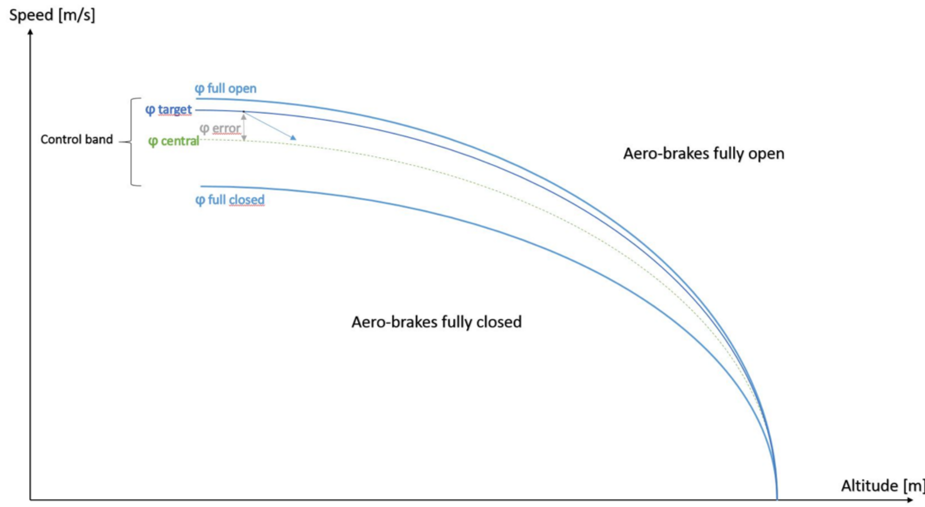


Figure 41. Speed curve margin principle

A PID controller is implemented on top of the lookup table to steer the rocket as much as possible towards the center of the control band. In fact, in case of disturbances. the rocket should be as far as possible from the edges of the band to have some space for correction. The command for the motor is computed by the PID which takes as input the difference between the proposed opening angle for the actual rocket state and the mean opening for the ideal rocket trajectory.

2. Choices justifications and proof of design

The team's main concern regarding the airbrakes was to be able to ascertain that a faulty operation of the airbrakes wouldn't jeopardize the whole flight or destroy the rocket. To always keep aerodynamic symmetry, the winglets are driven by a single steppe motor and a pinion. Ball bearings provide pivots for each winglet mitigating the risk of having them lock-up. Extremely precise and reliable positioning is achieved thanks to high quality stepper motors mounted with an encoder provided by Dr. Fritz Faulhaber GmbH & Co. Electrical connection between the module and the avionics is ensured by anti-vibration connectors provided by LEMO. The airbrakes are powered by a completely separate 3Ah LFP battery. Finally, aluminium EN AW-6082 T6 has been chosen for its good mechanical properties.

Because of these features which thought out for precision and reliability, the Shuriken system has been selected as the most promising airbrake module to be flown at the competition.

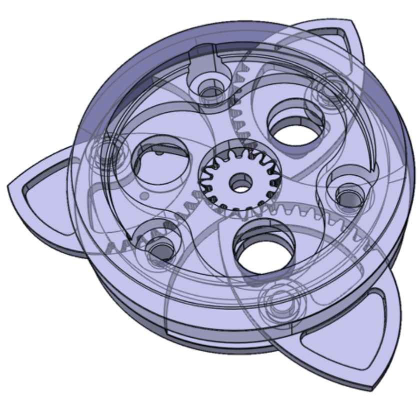


Figure 41. Shuriken system

3. Manufacturing

The shuriken system was almost fully manufactured by the student in charge of this design. Thanks to his experience in machining and his personal workshop, he managed to make himself all the aluminum parts of the Shuriken system. After a first wooden prototype was made on a CNC at the university and the concept proven, the parts were machined using a milling machine. The central gear was also made by the student in his workshop. The motor was then screwed to the module. A carbon fiber ring was added to the surface, ensuring a flush connection and no aerodynamic disturbances.

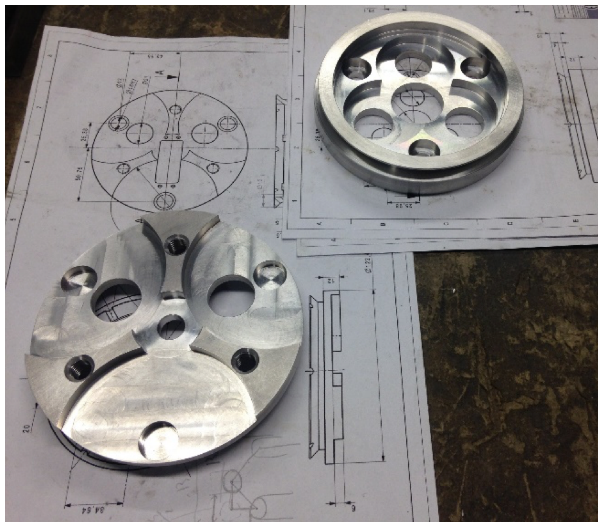


Figure 42. SRAD manufactured parts

Table 15. Shuriken production

Part	Seller/Sponsor	COTS/SRAD	Bought/Sponsored
Aluminium frame	-	SRAD	Home made
Aluminium triangles	-	SRAD	Home made
Servo motor 223212 BX4	Faulhaber	COTS	Sponsored
Gear 22 F	Faulhaber	COTS	Sponsored
Encoder AES 4096	Faulhaber	COTS	Sponsored
Ball bearing	SKF	COTS	Bought
Bolts	Bruetch	COTS	Bought
Screws M10/M3	Bruetch	COTS	Bought

G. Ground station Subsystem

1. Block diagram detailed

The block diagram of the ground station is included in Fig. 44. The red lines depict a power connection. The blue line represents the communication between the computers (which is done with a networking protocol such as TCP/IP). Green lines depict low-level binary data transfer.

In order for the user to specify settings that cannot be pre-programmed into the ground station software (such as the atmospheric pressure, the launch pad position, etc.), a keyboard is connected to the computers.

2. Choices justifications and proof of design

The ground station is telemetry acquisition and visualization device, which permits to check the status of the rocket during its flight. It consists of a software part, which is a tailored user interface that displays the flight data, graphs as well as a 3D visualization of the position of the rocket, and a hardware part, which is depicted in **Figure 44. Ground station block diagram**, and consists of a rolling suitcase that contains two high-brightness screens, small onboard computers and a battery.

A computer is dedicated to receiving and unpacking data from the transmitters. It saves all this data and operates in standalone mode. It forwards this data via TCP/IP to the user interface. This permits us to have several instances of the visualization running in different location and even working remotely.

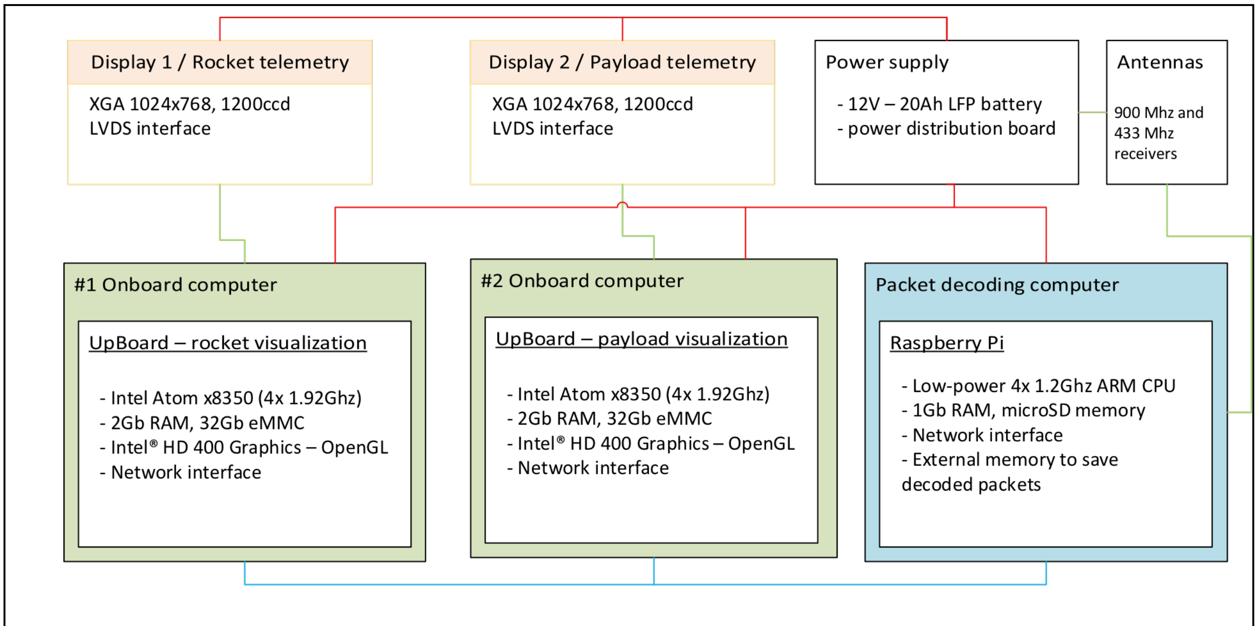


Figure 44. Ground station block diagram

Figure 45. Ground station at test launch in Payerne

The user interface is a SRAD C++ software that uses the Qt API as well as OpenGL to render the high frequency flight data using low-power computers. Graphs allow us to determine the altitude and acceleration of the rocket, and the 3D visualization also helps to find the rocket during its descent. The prediction of the landing point of the rocket, which is calculated based on flight data and wind speed data, is also displayed in the 3D visualization.

To reliably receive data during the flight, two separate transceivers operating on different frequencies (900 MHz, 433 MHz) are used. As the 433 MHz transceiver operates in a licensed band reserved for amateur radio, one of the team members has this license to be able to operate the ground station legally. The ground station will be positioned far from the launch pad to avoid interferences, to have a direct line-of-sight with the rocket and to have an elevation angle that is less than 70° during the whole flight.

The portable case contains a 12V / 20 Ah LFP battery, which permits us to have a 5 hours autonomy. An LFP battery was chosen because of its large temperature range (-20°C to 65°C). The case is operational in less than 1 min, with minimal user interaction.

3. Manufacturing

The ground station was assembled by the team members, and it mainly consists of COTS parts. The two high-brightness screens are connected to the 12V of the battery and are connected via LVDS to their respective HDMI – LVDS converter. These converters receive the HDMI signal from the embedded computers and are powered using a 5V voltage regulator. The onboard computers are also powered using a 5V regulator, and have a keyboard attached to them. The power distribution board, which distributes the voltage from the battery or an external 12V power supply, is a SRAD component. The whole system is protected by a 10A fuse.

4. Simulations and Tests

The main objectives of the ground station are to be reliable and straightforward to use. To test the software reliability, we let the software run for 10 hours, to see whether a crash was happening or not. We also checked for memory leakss and used randomized testing of the various inputs to the software to check that it would not crash. Regarding the hardware reliability, we tested the autonomy in field conditions (60 °C for 5 hours).

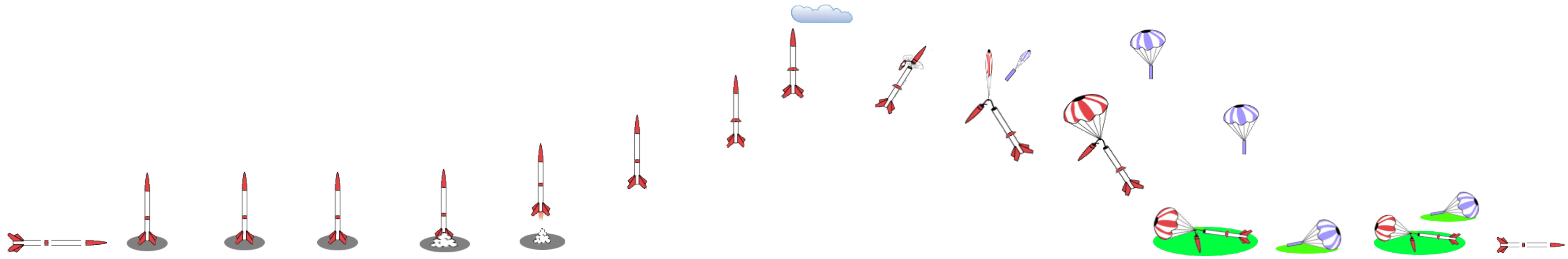
III. Mission Concept of Operations overview

The ConOps is detailed in Table 16 at subsystem level for the whole flight as well as the passing criteria from one mission phase to the next. Additionally, detailed ConOps for Recovery and Payload are included in Section A and C.

A. General ConOps

The general ConOps covers the events 2 hours before the launch, when the assembly checklists must be completed, and the rocket approved to fly and one hour after when the LV is recovered. The general ConOps will obviously be altered by the competition's timetable and environment. For example, it is planned that the LV be approved to fly on the preparation day such that it can be launched early on the first launch day.

Table 16. General concept of operations.



	t - 2h	t - 5 min	t - 4 min	t - 2min 30s	t - 0.4s	t = 0	t = 5s	20s < t < 25s	t + 25 s	t + 26s	t + 27s	t + 1min	t + 1min 30s	t + 5min	t + 30min	t + 60min
General	Assembling	Launch pad setup	Procedures checks	Arming	Firing	Take off	Motor burnout	Altitude control	Apogee	Seperation	Primary Recovery	Secondary Recovery	Ground arrival	Ground arrival Payload	Recovery	Disassembly
Passing criteria	Complete "Assembly procedure"	Rocket on pad with right launch angle	Complete "Rocket preparation"	Complete "Arming checklist"	Motor ignites	Rocket leaves rail	Motor has finished burning	Rocket velocity reaches 0	Rocket starts descent	Nose cone and payload pilot chute ejected	Payload and reefed main deployed	Main unreefed	Rocket lies stable on the ground	Payload lies stable on the ground	All rocket and payload parts are recovered	All rocket and payload parts are stored for shipping
Avionics	Join connectors between systems, insert into rocket.	-	System check	Arming rocket, data aquisition and downlink starting,	-	Detect launch, start attitude measurements	Altitude prediction calculations	Command airbrakes	Wake up recovery systems	Give ejection signal	-	Give unreefing signal	-	-	Turning off systems (except trackers)	Data saving and system packing
Propulsion	Motor assembling, insertion in the rocket	Igniter insertion	Check igniter conductivty	-	Firing	-	Stop burning	-	-	-	-	-	-	-	-	System cleaning and packing
Structure	Securing of each subsystem, rocket closing	Launch lugs slide nominally, structure is stable.	Check coupler tightness	-	-	-	-	-	-	-	-	-	-	-	-	Packing parts
Recovery	Parachute folding, insertion in the rocket	-	-	Check buzzer feedback for nominal recovery system arming	-	-	-	-	-	-	Deploy recovery system	Cut reefing line	-	-	-	Cleaning and packing
Airbrakes	Connect airbrakes to avionics, couple system to structure	-	-	Check for complete opening & closing of airbrakes	-	-	-	Control apogee	Retract in neutral position	-	-	-	-	-	-	-
Payload	Assembling, insertion in the rocket, payload set in standby.	-	System check	-	-	Payload wakes up	-	-	-	Deploy payload pilot parachute	Deploy payload	Detect muons	Detect muons	Detect muons	Turn systems off	Data saving, system packing
Ground Station	Set up ground station	-	System check	Initialize downlink, data aquisition and GPS start	-	Display event: take off	-	Display event: airbrakes	Display event: apogee	Desiplay event: separation	Display event: Payload ejection and riefing	Display event: recovery	Display event: rocket landing	Display event: payload landing	Data saving	Packing

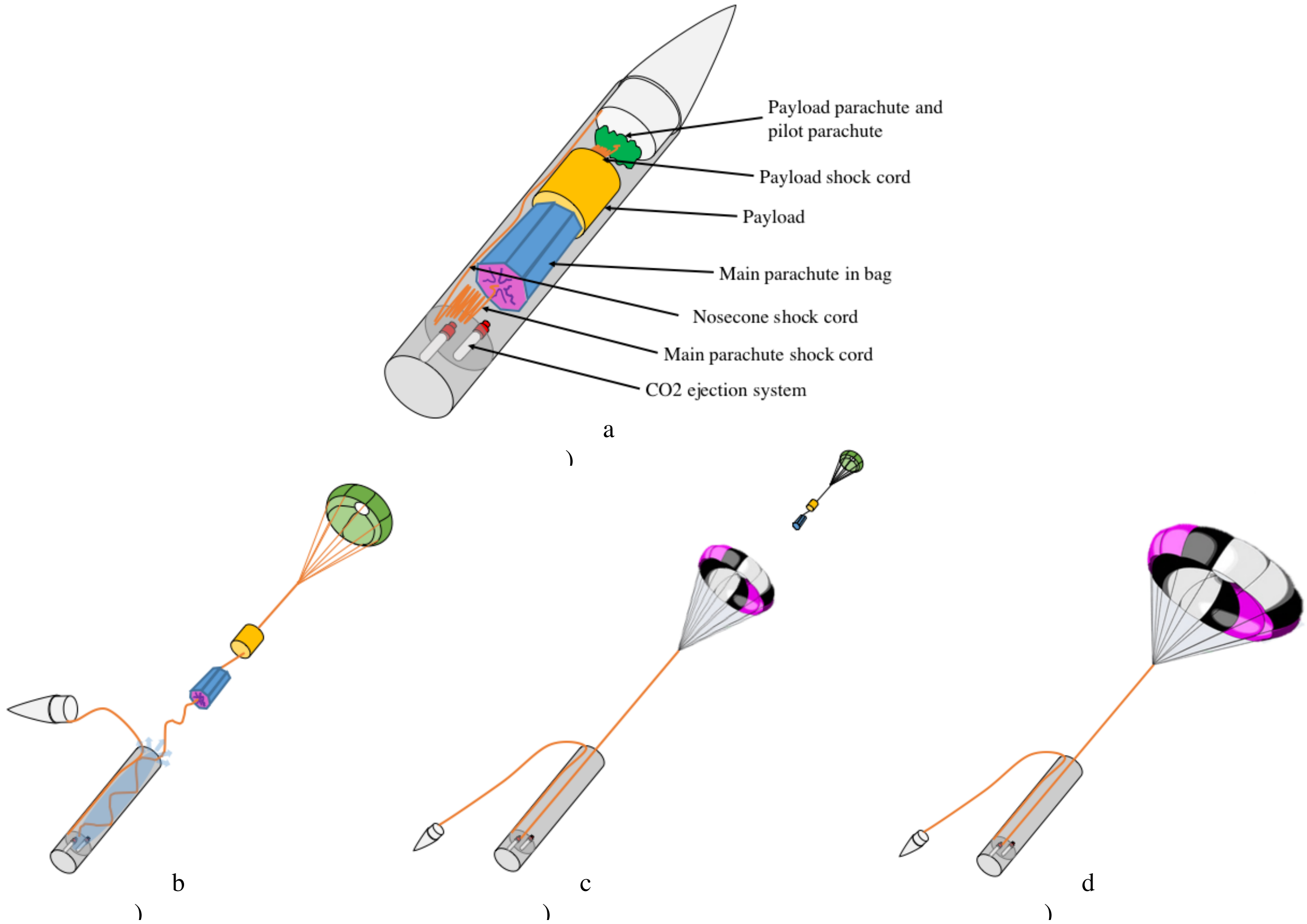


Figure 46. Recovery ConOps. a) Illustration of how the ejected parts are packed in the rocket. b) The CO2 charge ejects the nose and the pilot chute, pulling out the payload and the packed parachute, c) the parachute comes out of its bag and inflates, the payload continues its descent independently, d) the parachute unreefs at 200m above ground level insuring a soft landing to the LV.

B. Detailed recovery ConOps

The recovery ConOps is explained in relation to Fig. 8. First of all, the systems are packed in the rocket in a way that the ejection happens as smoothly as possible. First a pilot chute also acting as the payload's main parachute exits the upper tube as the cone is ejected. The payload and the main parachute are also pushed out by the pressure force. As the pilot chute inflates, the main shock cord is tensioned. The main chute is then extracted from its bag, which is linked to the payload but not the main chute. The payload is now free from the rocket and can descend by itself. The main parachute is in its reefed state. At this point the rocket has fallen about 50m about two seconds after apogee and reaches its stationary descent velocity of 20m/s. At 200m above ground, the parachute is unreefed. and the rocket is slowed down to 9m/s.

C. Detailed payload ConOps

The payload's operation is divided into three phases: standby, recording and recovery. Standby mode begins as the payload is powered on right before raising the launch rail. from that time on the payload listens for measurements indicating liftoff. At liftoff, the sustained acceleration is recorded by the payload's accelerometer, providing the first of two triggers. At apogee, the rocket's recovery system ejects the nose cone using redundant CO2 canisters. These cause a momentary pressure spike, which the payload's barometer records, providing the second trigger. The ejected nose cone pulls the payload's parachute out of the rocket, which in turn pulls out the payload. Once one of the two triggers is received, the payload exits standby mode and enters recording mode. The payload is now airborne, and its GPS and muon detectors are powered on. The parachute is fully opened throughout the descent to maximize airborne time, during which muon data is gathered, as well as pressure, temperature, GPS position, and orientation thanks to the IMU. Meanwhile, GPS position is frequently transmitted to the ground station to facilitate tracking and recovery. Touchdown occurs around T+6 minutes after liftoff, but the payload stays in standby mode until T+15 minutes to ensure no scientific data can be missed. After this mark, the payload enters recovery mode: the muon detectors and all sensors except the GPS are shutdown to preserve battery. The payload periodically transmits its GPS position, and makes a noise to assist recovery. Upon recovery, the payload can be powered off, and all of its flight data, stored on an SD card which can be extracted for analysis.

IV. Conclusions and Lessons Learned

This year's participation of the EPFL rocket team at the SA Cup IREC will be the first for the newly founded association and the second for a team issued from EPFL. Lessons learned from the previous team have been considered as much as possible in the management of the current team, the design and manufacturing of the LV and the organization of the logistical aspects for the stay in New Mexico. Thanks to the commitment of a considerably large number of students (given the project is mostly extra-curriculum), knowledge acquired over the span of 2 years of learning and development, as well as lessons learned from the 2017 IREC team, a rocket could be designed and manufactured to participate in the 10'000ft COTS propulsion category.

From a technical standpoint, building on last year's team experience, getting to a design freeze on the structure and starting manufacturing early on in the project is absolutely key to easing the integration process and boosting sub-system development. Quickly moving from paper, to prototype, to manufacturing the final sub-system and testing it in the rocket allowed for quick validation of the interfaces and iterations when needed.

The main technical issues occurred in the avionics sub-system. In the effort of reproducing last year's achievements of custom designed and manufactured electronics and with the added complexity of controlling the airbrakes and recovery system, the avionics team was faced with a larger challenge than they could handle. Therefore, their system had to be drastically downsized a couple months before the competition. The final iteration of the rocket has its recovery system controlled by COTS avionics and the airbrakes are controlled by the nosecone avionics instead of a separate one which should have been in the center of the rocket. In its current state the SRAD avionics in the nosecone retain the same functionalities as last year's team with the addition of the airbrakes.

In general, regarding human resources, it is very hard to find committed students willing to devote themselves to the project sufficiently to create added value. Among these students only a few have the prerequisites to fulfill their task. While the aim of such a project is of course to learn new skills, the limited time-frame and concurrent curriculum require nonetheless to find members with some basic knowledge of the task they are assigned to. For future iterations of the team's participation at the SA Cup IREC, it would be wise to adapt the design to the available skill set in the team and build on previous years rather than aim for excessively complex ideas without some guarantee of feasibility.

If a future team has the desire to explore a very advanced concept in a sub-system, it is recommended to base the rest of the launch vehicle off a previous design as much as possible such that resources can be put into developing that concept and at the same time ensuring the participation of the team at the competition. For example, developing a SRAD propulsion has been an ongoing project since two years in the team, but the lack of knowledge and the concentration of resources into building the vehicle itself, have always set the development of the motor in the back seat. Therefore, future teams should concentrate on developing a modular, 6" or more in diameter, LV which will serve as a test-bed for detailed research and development of sub-systems.

Regarding management skills, all members have had a unique and valuable experience with real world engineering situations. Working in a large team with members from different backgrounds and time availabilities, making and working with budgets and working in a multi-stakeholder environment with requirements and financial constraints are all experiences which prepare team members to their future careers. Also, these key learnings are what bring us our main sponsors who see our team as a pool of engineers with potential.

Speaking of the sponsoring domain, many improvements can be made for the following team such as approaching companies for cash in September to November before they close their budgets for the following year. For companies providing materials or services, such timing is less of an issue. On the other hand, manufacturing and delivery lead times can have catastrophical implications on the project's timeline. Having lists of components grouped by supplier as early as possible to do batch orders is key to mitigating risks of late deliveries or external manufacturing issues.

To conclude, knowledge transfer to the following team is achieved by thorough documentation and organized workshops, but the most effective mean of knowledge transfer is to have has many veteran members stay as possible. The main reason for veterans to leave the team is that they are ending their studies or leaving to another university. Thanks to the effort made in marketing the rocket team and recruiting bachelor students that have at least two more years of studies including masters, the continuity of the rocket team is guaranteed.

Authors and team members

The people who contributed to the present report are listed below:
Malo Goury du Roslan, Graduate Student, Microengineering, malo.gouryduroslan@epfl.ch
Eric Brunner, Graduate Student, Mechanical Engineering, eric.brunner@epfl.ch
Maxime Eckstein, Graduate Student, Mechanical Engineering, maxime.eckstein@epfl.ch
Jules Triomphe, Undergraduate Student, Mechanical Engineering, jules.triomphe@epfl.ch
Emilien Mingard, Graduate Student, Mechanical Engineering, emilien.mingard@epfl.ch
Quentin Talon, Graduate Student, Physics, quentin.talon@epfl.ch
Guillaume Herment, Graduate Student, Electrical Engineering, guillaume.herment@epfl.ch
Nils Apffel, Undergradute Student, Physics, nils.apffel@epfl.ch
Guillaume Locher, Undergraduate Student, Mechanical Engineering, guillaume@locher-ge.ch
Loïc Amez-Droz, Graduate Student, Microengineering, loic.amez-droz@epfl.ch
Clément Nussbaumer, Graduate Student, Communication Systems, clement.nussbaumer@epfl.ch
Ludovic Giezendanner, Graduate Student, Microengineering, ludovic.giezendanner@epfl.ch
Christian Cardinaux, Undergraduated Student, Mechanical Engineering, christian.cardinaux@heig-vd.ch
Héloïse Boross, Graduate Student, Microengineering, heloise.boross@epfl.ch

The non-author of the present document but team members willing to appear in this document are listed below: Cyrill Baumann, César Toussaint, André Stowasser and Leandro Kieliger.

Acknowledgments

We would like to thank Joseph Moran from RUAG Space for his continuous support throughout this project, the time he has dedicated to it and the fruitful advice he has given, as well as Ulrich Krähenbühl and the other members of his team for their help in this endeavor.

We would particularly like to thank Pierre Vandergheynst, Véronique Michaud, John Botsis, Anja Skrivervik, Aurelio Bay, Geroge Candea, David Atienza, Heinrich Hofmann, Daniele Mari, Karimi Alireza, Muriel Richard, Philippe Müllhaupt, Guido Haefeli, Joël Cugnoni, Candice Norhadian, Michaël Juillard and Sanket Diwale for their support and the time they spent on semester projects or to help implement the project inside the university. Their involvement was most appreciated.

Finally, we would like to thank all of our sponsors and their representatives, without whom this project could not have taken off: Ryan Giroud from EVS, Sauber, Caroline Bleiker and Thibault Von Euw from STA Travel, Faulhaber, Innovaud, Bic, the Swiss Space Center, ForumEPFL, AéroPoly, Espace Montage, Lemo, Chatteau de Ferrand, Swiss Composite, Kuehne+Nagel, Swiss Tools, Kifa, Mouser Electronics, Bienno Power, Mädler, Hamamatsu, Swaytronic, Options and Peacock Solutions.

References

[1] J. S. B. a. J. A. Barrowman, "The Theoretical Prediction of the Center of Pressure," 8 August 1996.

[2] T. W. Knacke, "Parachute Recovery Systems Design Manual, US Navy Edition," 1991.

[3] L. M. Couch, "Drag and stability characteristics of a variety of reefed and unreefed parachute configurations at mach 1.80 with an empirical correlation for supersonic mach numbers," NASA, Langley Research Center, Hampton, 1975.

[4] D. Poynter, The Parachute manual a technical treatise on the parachute, Santa Barbara, Calif. : Parachuting Publications , 1977.

[5] J. M. M. a. T. A. Harri, "A Rocket Borne Scintillation Spectrometer for Observing Cosmic X Rays," *Review of Scientific Instruments,* vol. 40, no. 5, 1969.

[6] S. C. J. a. K. C. Axani, "The Desktop Muon Detector: A simple, physics-motivated machine- and electronics-shop project for university students," *American Journal of Physics,* vol. 85, no. 12, 2017.

[7] D. M. M. S. C. C. K. B. K. a. B. D. Whiteson, "Observing Ultra-High Energy Cosmic Rays with Smartphones," *Astroparticle Physics,* vol. 79, pp. 1-9, 2016.

Appendices

A. Appendix - System Weights, Measures, and Performance Data

Here are presented the individual system mass budgets. As well as the power budgets for avionics and airbrakes. The recovery power budget isn't presented because powering the RAVEN systems with 9V batteries is sufficient to ensure nominal performance over more than 4 hours of operation. The payload operates completely independently from the LV. Therefore, only the mass budget is included.

1. Propulsion

Table 17. Propulsion mass budget.

At Lift off					
REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
13100	Motor	1	3962.000	1	**4001.620**
13200	Motor casing	1	2757.000	1	**2784.570**
Total					**6786.190**
System contingency					**0.000**
Total w system contingency					**6786.190**
Mass allocated by SE					**6100.000**
Margin					**-686.190**

After burn out					
REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
13100	Motor	1	0.000	1	**0.000**
13200	Motor casing	1	2757.000	1	**2784.570**
Total					**2784.570**
System contingency					**1.000**
Total w system contingency					**2812.416**
Mass allocated by SE					**6100.000**
Margin					**3287.584**

2. Structure

Table 18. Structure mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
11100	Nose cone	1.000	517.500	5.000	**543.375**
11300	Coupler	3.000	137.000	5.000	**431.550**
11400	Fins module assembly	1.000	1160.200	5.000	**1218.210**
11500	Lower tube assembly	1.000	1396.100	5.000	**1465.905**
11600	Upper tube asembly	1.000	1362.600	1.000	**1376.226**
-	Trim mass	1.000	800.000	0.000	**800.000**
Total					**5835.266**
System contingency					**0.000**
Total w system contingency					**5835.266**
Mass allocated by SE					**6000.000**
Margin					**164.734**

3. *Recovery*

Table 19. Recovery mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
12101	Recovery plate	1	78.600	1	**79.386**
12103	Eyelet	2	101.300	1	**204.626**
12104	Screw and nuts	1	40.000	5	**42.000**
12102	Titanium bar	2	66.900	1	**135.138**
12400	Raptor CO2 system	2	213.400	2	**435.336**
12106, 12107	Connectors and cables	2	22.200	5	**46.620**
12203	Electrical shock cord	1	200.000	5	**210.000**
12207	Nose shock cord	1	45.200	1	**45.652**
12202	Links	5	25.000	2	**127.500**
12204	Y harness	1	14.600	1	**14.746**
12201	Parachute	1	900.000	5	**945.000**
12206	Deployement bag	1	74.600	1	**75.346**
12304-12307	Line cutter	2	20.400	1	**41.208**
12301-12303	Reefing body and lines	1	71.800	5	**75.390**
Total					**2477.948**
System contingency					**0.000**
Total w system contingency					**2477.948**
Mass allocated by SE					**3000.000**
Margin					**522.052**

4. *Avionics*

Table 20. Central avionics mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
14100	motor controler	1	41.500	1	**41.915**
14300	COTS avionics	2	20.000	5	**42.000**
14107	9V battery	2	55.200	1	**111.504**
14104	LFP battery	1	400.400	1	**404.404**
14100	Structure elements	1	500.000	5	**525.000**
14700	Cables and connectors	4	28.400	5	**119.280**
Total					**1244.103**
System contingency					**0.000**
Total w system contingency					**1244.103**
Mass allocated by SE					**1750.000**
Margin					**505.897**

Table 21. Nosecone avionics mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
14201, 14202	Nose avionics	1	149.000	5	**156.450**
14204	LiPo battery	1	254.200	1	**256.742**
14200	Structure Elements	1	85.000	5	**89.250**
14211, 14212	Antennas	2	30.000	5	**63.000**
14205, 14214	Plate and eyelet	1	95.000	1	**95.950**
Total					**661.392**
System contingency					**0.000**
Total w system contingency					**661.392**
Mass allocated by SE					**1250.000**
Margin					**588.608**

Table 22. Nosecone avionics power budget.

REF	Components	#	Mean Power [mW]	Time in use [s]	Contingency [%]	Power w. contingency [mW]	Energy w. contingency [J]	Battery
14201	Microcontroller	1	340.000	14400	10	**374.000**	**5385.600**	**Nose**
14202	5V DCDC converter	1	110.000	14400	10	**121.000**	**1742.400**	**Nose**
14201	XBee	2	860.000	14400	10	**1892.000**	**27244.800**	**Nose**
14201	LEDs	20	10.000	14400	10	**220.000**	**3168.000**	**Nose**
14201	Other systems	9	50.000	14400	10	**495.000**	**7128.000**	**Nose**
Total						**3102.000**	**44668.800**	
System contingency						**10.000**	**10.000**	
Total w system contingency						**3412.200**	**49135.680**	

5. *Payload*

Table 23. Payload mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
17100	Structure	1	3995.000	1	**4034.950**
17200	Parachute	1	67.800	1	**68.478**
Total					**4103.428**
System contingency					**0.000**
Total w system contingency					**4103.428**
Mass allocated by SE					**4100.000**
Margin					**-3.428**

6. *Airbrakes*

Table 24. Airbrakes mass budget.

REF	Components	#	Mass [g]	Contingency [%]	Mass w. contingency [g]
15100	Drive train	1	40.432	1	**40.836**
15200	Mechanism	1	166.300	1	**167.963**
15300	Module	1	632.200	1	**638.522**
Total					**847.321**
System contingency					**0.000**
Total w system contingency					**847.321**
Mass allocated by SE					**1400.000**
Margin					**552.679**

Table 25. Airbrakes power budget.

REF	Components	#	Mean Power [mW]	Time in use [s]	Contingency [%]	Power w. contingency [mW]	Energy w. contingency [J]	Battery
15101	Stepper motor	1	1000.000	14400	10.000	**1100.000**	**15840.000**	**Main**
15101	Motor controller	1	50.000	150	10.000	**55.000**	**8.250**	**Main**
Total						**1155.000**	**15848.250**	
System contingency						**10.000**	**10.000**	
Total w system contingency						**1270.500**	**17433.075**	

B. Test Reports

7. *Recovery systems testing*

A series of ground tests, drop tests and integrated tests were performed on both smaller and real scale modules. For each test a short description of the conditions in which it was performed is given, followed by the criteria table used to evaluate each repetition of those tests. In the case that a test was performed multiple times, only the most relevant criterions are shown in the tables, but a more detailed result table is given in the corresponding attached test procedure. Furthermore, each time a criterion failed, a conclusion was written to describe the lesson learned, and the conditions of the test were modified according to it.

a) Wind tunnel reefing proof of concept (POC)

The goal of this test is to prove that the required difference of drag between the phases of dual event recovery can be achieved with a single parachute by using reefing.

Table 26: Test 2 – wind tunnel reefing POC

Test 2	**Wind tunnel reefing POC**		
The test was done in EPFL wind tunnel, it is 2.38m large and 1.98m high. The wind speed can go up to 10m/s. The parachute used has a smaller scale canopy of 1m diameter. The reefing line's length is changed from the outside of the wind tunnel, there is no need to switch the wind off to change its length. Further details can be found in the annexed document: 2018_RE_TP_0002 _WIND_TUNNEL_REEFING_POC_R01			
Success criteria definition			
Sufficient drag ratio between maximum and minimum drag		PASSED	14 Fev. 2018
Correct position of upper vents		FAIL	14 Fev. 2018
Entanglements avoided thanks to reefing body		PASSED	14 Fev. 2018
System acceptance		YES	14 Fev. 2018

The general design of the canopy is correct. The upper vents resulted in a "flat" of the drag force according to the reefing line's length in a certain region. This will give stability to the falling speed. The next canopy design shall have its upper vent in a lower position in order to have the "flat" of the curve at a reefing line's length corresponding to a lower drag.

b) Small scale module integrated test

The idea of this test is to integrate the reefing as a dual event recovery technique in a smaller scale rocket.

Table 27: Test 3 – Integrated test – small scale

Test 3	**Integrated test - small scale**	
The following test was performed on a 3 inches rocket during a launch. The first event triggering the rocket separation was done thanks to the motor ejection piston. The second event, which normally corresponds to the deployment of the main parachute, but in our case is the release of the reefing mechanism, was triggered by a RAVEN avionic. Further details can be found in the annexed document: 2018_RE_TP_0003_SMALL_SCALE_MODULE_INTEGRATED_R01		
Success criteria definition		
1^{st} event – piston trigger	PASS	February 2018
1^{st} event – parachute out of rocket body	FAIL	February 2018
1^{st} event – accelerations during less than one second after deployment	FAIL	February 2018
1^{st} phase – parachute lines fully stretched	FAIL	February 2018
1^{st} phase – canopy not fully deployed	FAIL	February 2018
2^{nd} event – 1^{st} line cutter avionic trigger – RAVEN data review	FAIL	February 2018
2^{nd} event – 1^{st} igniter ignition	FAIL	February 2018
2^{nd} event – 2^{nd} line cutter avionic trigger – RAVEN data review	PASS	February 2018
2^{nd} event – 2^{nd} igniter ignition	FAIL	February 2018
2^{nd} event – reefing line cut	FAIL	February 2018
2^{nd} phase – canopy fully deployed	FAIL	February 2018
System acceptance	NO	February 2018

Firstly, let's discuss the failure of the ejection of the parachute. In was learned that the use of a deployment bag is necessary, it fixes the diameter used by the parachute in the rocket's tube and avoids the "earplug effect" which makes pulling the parachute out of the rocket body too hard. Furthermore, the use of a pilot parachute to extract the main parachute is necessary, it shall not be the ejection mechanism which fulfils this task.

Secondly, the 1^{st} line cutter avionic trigger failed since it didn't trigger at the right timing. Indeed, a pressure increase was detected when leaving the launching rail which simulated the apogee. A timer shall be used to unable any trigger during this first part of the flight.

Thirdly, the igniters failed to burn even if the trigger was sent. This will be discussed in the "small scale module ground test".

c) Small scale module ground test

The goal of this test was to familiarize ourselves with the Peregrine RAPTOR and the Archetype Rocketry AEROCON line cutter for the un-reefing. Furthermore, this test permitted to check that the SRAD recovery's electronic of the small-scale drop test module was functional.

Table 28: Ground test – small scale

Test 4	**Ground test – small scale**		
The diameter of the rocket part used was 4 inches. The avionic used was SRAD, a single push on a button launches a timer used to trigger the different event. The "parachute chain" used was the following: Rocket body – Electrical shock cord – Reefing body – Parachute – deployment bag – pilot. Further details can be found in the annexed document: 2018_RE_TP_0004_SMALL_SCALE_MODULE_GT_R03			
Success criteria definition			
1st Test: 2nd event – Both line cutters' igniter ignition		FAILED	31 Mars 2018
2nd Test: 2nd event – Reefing line cut		FAILED	1 April 2018
3rd Test: 1st event – RAPTOR igniter ignition		FAILED	3 April 2018
4th Test: 1st event – RAPTOR igniter ignition		FAILED	3 April 2018
5th Test: 1st event – RAPTOR CO_2 cartridge pierced		PASSED	3 April 2018
5th Test: 1st event – Nose cone ejection		PASSED	3 April 2018
5th Test: 1st event – Pilot parachute out of rocket body		PASSED	3 April 2018
5th Test: 1st event – No entanglement when pulling the drogue parachute		PASSED	3 April 2018
5th Test: 1st event – Main parachute comes out of the deployment bag		PASSED	3 April 2018
5th Test: 1st event – No entanglement observed in the parachute's line		PASSED	3 April 2018
5th Test: 2nd event – Reefing line cut		PASSED	3 April 2018
5th Test: 2nd event – Central line released		PASSED	3 April 2018
System acceptance		YES	3 April 2018

For the 1st test, the ignition of the line cutter's igniter failed. Indeed, both igniters were wired in parallel with a single current source delivering 0.8A. Therefore, only 0.4A passed in each igniter which is not sufficient to trigger the ignition. The redundancy shall be implemented with two independent electrical circuits, or both igniter could be wired in serial. The event prior to the second event all passed.

For the 2nd test, this time, even if the igniter and the black powder of the line cutter successfully burned, the line passing through the line cutter wasn't cut. The reason is that a gap was still there at igniter's exit. The solution is to add an O-ring around the igniter's head just before starting to pass the igniter through the cap.

For the 3rd test, due to an igniter failure, the CO2 cartridge wasn't pierced. Therefore, none of the subsystems were pushed out of the rocket body. This can happen statistically, and it helps to understand the importance of redundancies.

For the 4th test, once again, the igniter failed to burn even though the electronics worked nominally. Two solutions can be applied: increase the current in the igniter and increase the timing during the current is sent to the igniter. For the next test, using 2 seconds instead of one shall be the first correction to implement.

Finally, for the 5th test everything worked. The test is fully successful, and the module is ready for the drop test.

d) Small scale drop test

The objective of the test was to see how the small-scale parachute would deploy when pulled out of the deployment bag and how does the implementation of the reefing technique would work out. It permitted also to check that the folding procedure of the small-scale parachute was correct. The first test is a reefing test, so the parachute is already out of the module body. The second test is the 1st event testing, so the objective is to test the ejection of the parachute with the CO_2. The third test is a ConOps test, the objective is to test the ConOps of the drop test, so the pilot was already out of the module. The last test was performed from a 100m height, from which both events were tested.

Table 29. Drop test – small scale

Test 5	**Drop test – small scale**		
The diameter of the rocket part used was 4 inches. The height was 30m except for the last test performed from 100m height. The avionic used was SRAD, a single push on a button launches a timer used to trigger the different event. The "parachute chain" used was the following: Rocket body – Electrical shock cord – Reefing body – Parachute – deployment bag – pilot. Further details can be found in the annexed document: 2018_RE_TP_0005_SMALL_SCALE_MODULE_DT_R02			
Success criteria definition			
1st test: Reefing line cut		PASSED	7 April 2018
1st test: canopy fully deployed		PASSED	7 April 2018
2nd test: trigger sent by avionic to RAPTOR		FAILED	7 April 2018
2nd test: Nose cone ejection		FAILED	7 April 2018
3rd test: Main parachute comes out of the deployment bag		PASSED	7 April 2018
3rd test: Canopy fully deployed		PASSED	7 April 2018
4th test: 1st event – RAPTOR CO_2 cartridge pierced		PASSED	21 April 2018
4th test: 1st event – nose cone ejection		PASSED	21 April 2018
4th test: 1st event – pilot parachute out of rocket body		PASSED	21 April 2018
4th test: 1st event – no entanglement when the drogue parachute stretches the shock cord		PASSED	21 April 2018
4th test: 1st event – main parachute comes out of the deployment bag		PASSED	21 April 2018
4th test: 1st event – no entanglement observed in the parachute lines		PASSED	21 April 2018
4th test: 2nd event – reefing line cut		PASSED	21 April 2018
4th test: 2nd event – canopy fully deployed		PASSED	21 April 2018
System acceptance		YES	21 April 2018

The 1st test was fully successful. The reefing implementation, for this small-scale parachute, is operational. A more complete test can be performed.

For the 2nd test, the timing was wrong, the drop test was thrown 1 second too early compared to the required timer value. Therefore, the trigger was sent only after the module crashed on the ground. In conclusion, a buzzer was added to avoid future timing error.

For the 3rd test, the pilot parachute pulled the deployment bag out of the rocket body and the parachute out of the deployment bag. The parachute did fully deploy. The folding procedure seemed correct.

The 4th test was fully successful, dual event recovery using reefing has been successfully implemented on this small scale module.

e) Scale 1 module drop test

The aim of this test is to prove that the reefing system's implementation is functional considering that the rest of the subsystems are operational.

Table 30. Drop test – scale 1 module

Test 6	**Drop test – scale 1 module**		
The tests presented here are performed with a real scale rocket body. During Test 1, the pilot parachute and the payload were already out of the rocket body. The goal was to check that the parachute comes correctly out of the deployment bag and that the reefing is well implemented. During test 2 and test 3, no payload, no nose cone nor pilot parachute were integrated, the goal was to gather data on the reefing technology, such as the falling speeds and the acceleration at the unreefing. They also permitted to confirm the implementation of the reefing. Further details can be found in the annexed document: 2018_RE_TP_0006_DT_R01			
Success criteria definition			
1st test: 1st event – no entanglement when the drogue parachute stretches the shock cord		FAILED	7 April 2018
1st test: 1st event – main parachute comes out of the deployment bag		PASSED	7 April 2018
1st test: 2nd event – reefing line cut		FAILED	7 April 2018
1st test: 2nd event – canopy fully deployed		PASSED	7 April 2018
2nd test:1st event – no entanglement observed in the parachute lines		PASSED	20 May 2018
2nd test: 2nd event – reefing line cut		PASSED	20 May 2018
2nd test: 2nd event – canopy fully deployed		PASSED	20 May 2018
3rd test:1st event – no entanglement observed in the parachute lines		PASSED	20 May 2018
3rd test: 2nd event – reefing line cut		PASSED	21 May 2018
3rd test: 2nd event – canopy fully deployed		PASSED	21 May 2018
System acceptance		YES	21 May 2018

For the 1st test, the nose cone's shock cord got entangled with the upper part of the payload. From the parachute's point of view this didn't change its behavior. The deployment bag was pulled out successfully and the parachute could deploy in reefed position successfully. However, the sewing of the shock cord's loop at the parachute's quick link got stressed in the wrong direction and broke. Therefore, the shock cord slipped through the parachute's quick link in the direction of the nose cone, adding stress to the reefing electrical wires which broke the connection. This will be avoided by fixing the nose cone's shock cord at one end of the rocket body with Velcro strap and roll the shock cord with a strong elastic in order to force it to fall directly on the side and not entangle with the upperpart of the payload. Furthermore, the shock cord's loop will be sewed to support stress in both ways.

On the other hand, the reefing line was implemented using the wrong node. Therefore, it broke by itself and the parachute unreefed by itself. This will be corrected by using the fisherman's knot.

For the 2nd test, the reefing implementation was successful, but the reefed position was too close in term of descent rate to the fully deployed position. Therefore, the central line shall be shortened to reef more the parachute.

For the 3rd test, statistics are now very good for the reefing implementation. The reefing position seemed more correct, but a 100m fall is not sufficient to fully observe the different steps of the parachute inflation or the falling speed stabilization.

f) Matterhorn ground test

The aim of this test is to prove that the ejection system is functional for the rocket used during the competition and that the electrical wiring is correctly implemented.

Table 31. Ground test– Matterhorn

Test 7	**Ground test**		
The following tests were performed using the upper stage of the Matterhorn. The same configuration is used for the different tests. The latter is the same as the one used for the competition. The Test 1 was done to confirm that the CO2 cartridge size was right, so only the 1st event was tested. The test 1 and 2 were performed using only one RAPTOR mechanism. During Test 4, only one AEROCON line cutter was set. Further details can be found in the annexed document: 2018_RE_TP_0007_GT_R01			
Success criteria definition			
1st test: 1st event – nose cone ejection > 300 mm		PASSED	15 April 2018
2nd test: 1st event – nose cone ejection> 300 mm		PASSED	25 April 2018
2nd test: 1st event – Payload out of the rocket body		FAILED	25 April 2018
2nd test: 1st event – main parachute comes out of the deployment bag		FAILED	25 April 2018
3rd test: 1st event – Payload out of the rocket body		PASSED	26 April 2018
3rd test: 2nd event – trigger sent by avionic to line cutters		FAILED	26 April 2018
4th test: 1st event – Payload out of the rocket body		PASSED	27 April 2018
4th test: 1st event – main parachute comes out of the deployment bag		FAILED	27 April 2018
4th test: 2nd event – reefing line cut		PASSED	27 April 2018
System acceptance		PENDING	May 2018

During the 1st test, a single 25g CO2 cartridge is sufficient to eject nose cone, so the deployment system is truly fully redundant. The pilot parachute stays in the nose cone during ground test. However, with the drop tests: small module, similar conditions proved that during a drop test the pilot does leave the inside of the nose cone.

For the 2nd test, the airtightness of the recovery plate wasn't optimal enough, so the nose cone was ejected but not the payload. This would not be critical since the payload's drogue would have pulled the payload out. But better sealing of the recovery plate resulted in the ejection of the payload with a single CO2 cartridge.

Once the deployment bag was pulled out of the rocket body, it did not open itself and the lines stayed entangled in it. Indeed, the closing part is too loose which resulted in undesired stress once the shock cord was fully stretched. The position of the closing loop of the deployment bag has been adjusted to the right position.

For the 3rd test, when the SRAD avionic sent the current to the 4 igniters of the 1st event, it triggers an undesired voltage. A large capacitor was added to absorb this drop of voltage and deliver the required current.

For the 4th test, the deployment bag did release the parachutes lines but did not fully open and failed to let go the parachute. The loop closing the deployment bag still have too much lose and stay entangled as soon as stress is applied. The sewing of the loops shall be more adapted to avoid this entanglement.

g) Matterhorn integrated test

This test was performed during the last in-flight test. The rocket is mainly composed of the different subsystems used for the competition.

Table 32. Integrated – Matterhorn

Test 8	**Integrated**	
The aim of this test is to prove that the whole recovery system is functional during an in-flight-test and in similar conditions as the ones of the competition. Every recovery subsystem has already been tested. This test should validate the integration with the other section's systems in one rocket. The triggers were sent by two redundant RAVEN avionics. Further details can be found in the annexed document: 2018_RE_TP_0008_INTEGRATED_R01		
Success criteria definition		
1^{st} event – trigger sent by avionic to RAPTOR	PASS	1 May 2018
1^{st} event – RAPTOR igniters ignition	PASS	1 May 2018
1^{st} event – RAPTOR CO2 cartridges pierced	PASS	1 May 2018
1^{st} event – nose cone ejection	PASS	1 May 2018
1^{st} event – pilot parachute out of rocket body	PASS	1 May 2018
1^{st} event – payload out of rocket body	PASS	1 May 2018
1^{st} event – deployment bag out of rocket body	PASS	1 May 2018
1^{st} event – no entanglement when pulling the drogue parachute	PASS	1 May 2018
1^{st} event – main parachute comes out of the deployment bag	FAIL	1 May 2018
1^{st} event – no entanglement observed in the parachute lines	-	1 May 2018
2^{nd} event – trigger sent by avionic to line cutter	PASS	1 May 2018
2^{nd} event – line cutter igniter ignition	PASS	1 May 2018
2^{nd} event – reefing line cut	PASS	1 May 2018
2^{nd} event – central line released	PASS	1 May 2018
2^{nd} event – canopy fully deployed	FAIL	1 May 2018
System acceptance	YES	20 May 2018

The different electronic subsystems worked successfully. The nosecone was correctly opened, and the payload was separated and recovered.

Unfortunately, the shock due to the inflation of the pilot parachute led to the tear of the strap located on top of the deployment bag. As such, no forces were exerted to pull the main parachute out of the bag and the rocket started to descent in pseudo-freefall.

A new deployment bag will be made, using different textile. Once the latter will be tested and accepted, the recovery system will be accepted.

h) Deployment bag acceptance test

After the result of the 2018_RE_TP_0008_INTEGRATED, a new deployment bag was manufactured, using a more rigid textile and stronger attach. Some features shall be tested for acceptance regarding the next flight.

Table 33. Acceptance – Deployment bag

Test 9	**Deployment bag acceptance**		
The deployment bag with the parachute inside is attached through a short strap to a small bridge. A 10kg mass is attached to the bottom part of the parachutes line. The mass is thrown and once the parachute's lines are stretched the latter is pulled out of the deployment bag. The control is done visually. Further details can be found in the annexed document: 2018_RE_TP_0009_DEPLOYMENT_BAG_R01			
Success criteria definition			
1st elastic opened		PASS	20 May 2018
2nd elastics opened x 2		PASS	20 May 2018
3rd elastics opened x 2		PASS	20 May 2018
Upper attach intact		PASS	20 May 2018
Parachute out of DB		PASS	20 May 2018
System acceptance		YES	20 May 2018

The deployment bag did withstand the pulling shock, the parachute did correctly leave the deployment bag. The system is accepted.

8. SRAD Propulsion System Testing

THIS PAGE INTENTIONALLY LEFT BLANK (as per section 2.6.2.7 of SA Cup IREC Rules and requirements document).

9. SRAD Pressure Vessel Testing

THIS PAGE INTENTIONALLY LEFT BLANK (as per section 2.6.2.7 of SA Cup IREC Rules and requirements document).

10. Avionic System Testing

The avionics must undergo a lengthy test process to make sure the boards were well designed and the components soldered correctly. Errors can easily occur, and delays accumulate. In its current state, not all sensors function properly and the most general tests were either canceled, post-poned or could only be done with a partially completed avionic resulting in failure of the test. For example, the flight test failed because telemetry communication was lost at 1200m from the ground-station. On the other hand, for legal reasons, the used module is 100 times less powerful than the one that will be used in the US, so such an outcome was expected. The shake test was canceled after discussion at the CDR because too little is known on the shock spectrum and it was too dangerous to risk the avionics for a test with so many unknowns. The rest of the tests should be completed in the weeks following the submission of the document and the competition.

11. Aero-structure System Testing

The structure team has spared many structural tests through thorough simulation of the load bearing components and a flight test with an identical structure to the one that will fly at the competition. The description of the well-known "spaghetti test" (grasp the assembled rocket from both ends and shake it) is not included here because no procedure or measures were done on it, but the fully loaded rocket qualitatively passes the test by showing no sign of flexion whatsoever.

Table 34. Avionics test summary

Test AV	**Description of the conducted test**		
Criteria 1 to 4 are board performance tests. Then for the next criteria, the software is uploaded to the STM32. The Outputs are checked with the interfacial systems to be sure these systems are operational using the Avionics. The telemetry is tested on the ground with a range up to 5 km. The connections both serial and wireless between the nosecone and the central body are tested with maximum package rate of 10Hz (limited by the GPS updates). To check the autonomy, the avionics are run 5h without interruption, with the sensors always recording, and the data stored. The temperature test for the batteries are conducted with a specialist at EPFL. Finally, a shake test and flight test validate the system.			
Success criteria definition			
Criteria 1: Power Potential and GND connections check		PASSED	29 March 2018
Criteria 2: Regulators and Boost check		PASSED	31 March 2018
Criteria 3: STM32 boot check		PASSED	04 April 2018
Criteria 4: Sensors check		PENDING	April 2018
Criteria 5: Outputs (Airbrakes and Recovery) check		PASSED	April 2018
Criteria 6: Telemetry check-up to maximum range		PENDING	April 2018
Criteria 7: Data transmission between Central Body and Nosecone		PASSED	April 2018
Criteria 8: Data saving check		PENDING	April 2018
Criteria 9: Batteries consumption 3 h at 60 °C check		PENDING	April 2018
Criteria 10: Mission ground test		PENDING	April 2018
Criteria 11: Vibration test		CANCELED	April 2018
Criteria 12: Flight test		FAILED	1 May 2018
System acceptance		PENDING	15 April 2018

Concerning the recorded tests, the structure team was worried the heat in the desert and long exposure in direct sunlight would compromise glued joints. The most heat resistant structural epoxy was used and cured according to the data-sheet. If cured correctly, it conserves its mechanical properties up to 80°C. For the wet layup of the cone, the used resin is graded up to 120°C. The carbon frame and fins are resistant up to their curing temperature of 180°C. The heating test was thus designed to check if these parts would exceed these temperatures when exposed to direct sunlight. Color changing thermal patches were used to measure surface temperature.

At the end of the design phase, a test was carried out to make sure the structure team was able to manufacture a composite glass fiber nosecone by themselves. Having learned the basics of composite lamination while manufacturing the airframe tubes at RUAG, members set out to build their own mold for the nosecone. The outcome of the test demonstrated that a SRAAD nosecone could be manufactured allowing us to keep the structure design as it was. In fact, no COTS noecone of 120mm in diameter can be bought because they only exit in inches.

Table 36. Results of structure heating test

Test 1	**Structure Heating**	
This test allows us to check if the complete structure can sustain an increase in temperature once the rocket stays for hours in the desert. High temperature, high sun radiation and low wind may be critical. All the epoxies, resin and glue, are tested with a thermal static test in Switzerland which must confirm the thermal model (Convection, Radiation, Emission, Absorption, etc). More details are available in appendix 2018_SE_TP_0005_STRUCTURE_HEATING_R01.		
Success criteria definition		
Fins T<180°C	PASSED	April 2018
Fins module T<120°C	PASSED	April 2018
Coupling system T<80°C	PASSED	April 2018
Central upper airframe T<80°C	PASSED	April 2018
Nose Cone T<120°C	PASSED	April 2018
System acceptance	YES	April 2018

Table 35. Results of nose cone mold test

Test 2	**Nose Cone mold**	
The process of manufacturing is evaluated as well as the result quality. The test allows us to choose if the nose cone will be SRAD or COTS. It must show that it can be easily manufactured and that the price is not excessive. Also, 120mm nosecones can't be bought so a COTS nosecone would require a significant design change. More details are available in appendix 2018_ST_TP_0006_NOSE_CONE_MOLD_R01		
Success criteria definition		
Surface	PASSED	January 2018
Nose Cone fits	PASSED	January 2018
Mold is feasible	PASSED	January 2018
Nose Cone doesn't break	PASSED	January 2018
Price lower than market	PASSED	January 2018
System acceptance	YES	January 2018

12. Payload System Testing

Table 4. Experimental and scientific tests.

Test 1	**Description of the conducted test**	
These tests have to ascertain that the payload is able to carry out its scientific endeavor. The first test has to confirm or infirm that the payload is capable to detect and record an event. The second test has to prove the efficiency of the detector. The third test has to determine if our active management of the current supply to the SiPM effectively counteracts their gain loss due to temperature rises. The fourth series of tests has to show that the events correspond to muons, and that the detector can filter out luminous noise.		
Success criteria definition		
Detection of an event and proper recording of said event on the onboard memory.	PASSED	April 2018
Detection rate above 7 events per second	PASSED	April 2018
Acceptable gain depletion management	PASSED	May 2018
Confirmation that events are muons	PASSED	April 2018
System acceptance	YES	May 2018

Table 5. Overall electronic tests.

Test 2	**Description of the conducted test**	
These tests ascertain that all our onboard electronics are fully functional and operational to ensure that the payload can carry out its mission. The first test validates that the onboard avionics of the payload is working using it is custom PCB board i.e. all the sensors are working, and the Teensy code can read data from them. The second test proves that the payload is able to easily get a GPS fix without struggles and with a good enough accuracy. The third test proves the ability of the payload to communicate its position to the ground station without hiccups. The fourth test is the temperature test for the battery in an oven at 60°C. The fifth test shows that the payload's overall electrical consumption can be sustained for >5 hours at >45C°.		
Success criteria definition		
Electronics are fully functional	PASSED	27 April 2018
GPS fix under 10 seconds and accurate position readings	PASSED	April 2018
Ground station has to be able to get a steady signal in a 3km range	PASSED	27 April 2018
The batteries didn't rupture under thermal load and the discharge rate is manageable	PASSED	May 2018
With a variation between idle and active state, the payload's battery powers it for 5 hours	PASSED	30 April 2018
System acceptance	YES	May 2018

Table 6. Structural tests.

Test 3	**Description of the conducted test**	
These tests have to ascertain the structural stability and robustness of the payload's frame. The first test is a drop.-test that has to show the robustness of the frame. The second is a more brutal drop test of the frame to ensure that rocks or other features will not damage it upon landing		
Success criteria definition		
The payload is recoverable and the experiment and avionic are still fully functional	PASSED	27 April 2018
The payload frame can sustain drops at high speed without any damage	PASSED	April 2018
System acceptance	YES	May 2018

13. Ground Station System Testing

Table 37. Ground station tests

Test 1	**Description of the conducted test**		
The ground station was brought to the launch tests to check its functionalities.			
Success criteria definition			
Ground station powers up, the software starts and the RF data link with the rocket is correctly established.		PASSED	27 April 2018
The ground station autonomy is 5 hours or more.		PASSED	11 April 2018
System acceptance		YES	27 April 2018

C. Hazard Analysis

With a RSPS, two type of hazardous elements are encountered: the igniter and the propellant cartridges.

The manipulation of the igniter should be done carefully as it contains explosive substances capable of harming the user and/or any surrounding people. Indeed, it can cause burns and/or injuries due to high velocity dispersed particles.

For propellant cartridges, they are composed of highly reactive and flammable compact solid fuel. Similarly, to the igniter, they can cause injuries if the manipulation or storage is not done properly. As a result, these elements should always be stored and transported in a hermetic specific package and placed away from any source of fire or heat.

The manipulations of the igniters and propellant should only be done by the trained propulsion team members, who already have experience in launching solid propellant rockets. Applicable procedures for safe operation of the igniters and propellant are in 2018_PP_SP_0001_RELOAD_INGNITER_MANIPULATION_R01 included in appendix G.

Since the recovery deployment systems will use CO_2 cartridges, some procedures need to be followed to avoid accidents. These procedures are explained in detail in 2018_RE_SP_0001_CO2_SAFETY_PROCEDURE_R02, included in appendix G.

Furthermore, the RAPTOR mechanism and the line cutters use black powder. This product must be used with extreme precaution and only under the conditions explained in 2018_RE_SP_0002_BLACK_POWDER_SAFETY_PROCEDURE_R01, included in appendix G.

D. Risk Assessment

Table 38. General risks

ID	PHASE	RISK	CAUSES	PROBABILITY	CONSEQUENCES	SEVERITY	MITIGATION
R_GE_01	Pre Competition	Failure to complete tasks due to time conflicts with other tasks relating to university & works etc.	Lack of comunication between team-leads and between general members and team-leads. The task might also be too ambitions	4	5	20	Communicate with everyone and take in consideration the available time of each member of the team; clearly split the tasks and assign the hard deadlines; constantly verify that the task is being performed; try to find additional skillful people to help if needed; asses the difficulty of the task and consider spending time on finding an easier solution.
R_GE_02	Pre Competition	Mistakes on subsystem level due to misscommunication	Unadequate leadership of the team-leader. Sub-team members are either divided by a geographical or language barrier.	4	4	16	During the weekly lead-meetings discuss and verify the work on subsystems; have one responsible person for each issue. Peer review as much as possible. Insure that most of the team members speak french and are located on the university grounds most of the week.
R_GE_03	Pre Competition	Complete damage on a testlaunch	Double failure on a critical system (eg. recovery).	4	4	16	Thorough static tests, Have a backup (spare), respect GoNoGo's discussed with team.
R_GE_04	Pre Competition	Team not ready for test launch	Part deliveries are late. There are more integration problems than expected. Team members lack time to complete all the basic tasks.	4	4	16	Complete launch & assembly checklists at least one week in advance; all tests to be completed up until one week prior to the launch; general team meeting 2 weeks prior to identify all possible issues; assign part of the team to focus completely on test-rocket.
R_GE_05	Assembling	Loose wires prevent smooth assembly	Many wires have to be connected internally and space is limited.	4	4	16	Wires can get tangled with other parts -> proper assembly checklist needed; make additional incisions for easier removal and wiring; inspect wiring upon every usage, and before storing. Taylor design to avoid such problems. Use good quality connectors.
R_GE_06	Pre Competition	Team split between tasks	Team member's ambition to achieve the perfect rocket.	3	4	12	Prioritize the tasks; assign the team members to focus completely on the highest priority ones; terminate infeasible objectives; discuss compromised objectives at team meetings.
R_GE_07	Pre Competition	Mistakes at interfaces due to miscommunication	Unadequate leadership of the system-engineering team.	3	4	12	Interfaces are under the responsibility of a single member of the system-engineering team. Critical interfaces are discussed weekly with the team leaders.
R_GE_08	Global	Team conflicts due to the organization decisions	Chain of command not well established. Decisions were taken without considering all stakeholders. Lack of good leadership.	4	3	12	Clear structure; identify and communicate the priority tasks clearly; Tasks that concern competition rocket receive the highest priority; the team's primary focus is to make a successfull rocket for the competition
R_GE_09	Pre Competition	Lack of money to complete the objectives	Too little effort put into publicizing the project or too little interest on the industrie's side in our activities.	2	5	10	Concentrate more efforts in sponsoring and PR by establishing a strong sponsoring team with reliable members. Profit from EVS's help in this domain.

R_GE_10	Pre Competition	Person injuries during fabrication, launch, testing	Lack of adequate procedures and non-compliance with local legislations or safety regulations.	2	5	10	Ensure compliance with safety regulations, keeping safe distance, having checklist to prevent improper handling.
R_GE_11	Pre Competition	Unexpected environmental conditions afect simulation results.	Wind, temperature or atmospheric pressure exceed the range ofexpected values in the simulations.	3	3	9	Determine the apogee for large range of values; Experiment with different trim weights to compensate. Determine range of atmospheric values that insure apogee can be reached with adequate control.
R_GE_12	Pre Competition	Exceeding the mass margin for the selected engine	Another engine has to be used than the one initially selected.	3	3	9	Weighing each component to precisly determine its mass; Take a system and subsystem level margins to account for uncertanty; Have a plan where a mass could be decreased if necessary
R_GE_13	Launch	Instability due to un-symetric mass distribution.	Inner systems were designed un-symetrically to accomodate heavy/bulky elements (eg. Batteries).	3	3	9	Design such that the weight distribution is as symetrical as possible. Design an interchangeable fin system so the stability margin can be taylored late in the rocket construction. Check stability through simulation.
R_GE_14	Pre Competition	Key members can't come to the US or are injured during the competition.	Exams couldn't be postponed, a key member is badly sick or injured, an accident happens at the competition.	3	3	9	Make sure other members (coming to the USA) know how to execute the work; Establish a list of competition operations responsibles and their backups.
R_GE_15	Pre Competition	People leaving project unexpectedly	Personnal lack of time or lack of interest.	2	4	8	Clearly identify reliable members based on their availabilities, demonstration of personal investment and initiative. Exclude unreliable people.
R_GE_16	Pre Competition	Inadequate working force (in any SS)	Too little effort was invested into finding the adequate people. The objectives are too ambitious. Team member's experience is inadequate.	2	4	8	Clearly prioritize the tasks and make sure that mission critical ones have enough people working on them; Try to recruite additional working force for the remaining (second-order) tasks; identify the infeasible objectives and terminate or relax them
R_GE_17	Pre Competition	Exceeding the budget contingencies taken on subsystem level	Unexpected system features in multiple systems were implemented after the budgets were establieshed. Some features were much more complex than expected.	2	4	8	Designing the subsystems with allocated weight and power consumption in mind; Weighing and verifying the weight for as many components as possible as well as maintaining rigourous budgets for mass, power and money.
R_GE_18	Shipping	Forgetting tools and spare components for the launch	Incomplete check-lists were established.	2	4	8	Create additonal checklists outlining the tools and spare parts needed for each subsystem; Locating the possible ways of obtaining the parts once in the USA
R_GE_19	Pre Competition	Minor damage on a test launch	Rocket behaves differently than expected (eg. Descent speed). Some functions didn't work properly (eg. Un-reefing),	4	2	8	Analyse and identify most probable things that can fail, plan the repairment accordingly. Fins and boattail are the most likely to fail, make them interchangeable.

R_GE_20	Shipping	Danger of damage during shipping and not having the required tools for reparations etc.	Shipping shock envelope wasn't considered in the design of the launch veicle.	2	3	6	Ship as many tools as possible to the US; try to determine shock envelope with transport company. Do as many shake tests as possible.
R_GE_21	Pre Competition	Stability: Bad CP from simulation	Error in rocket definition in commercial rocket smulation program (OR or RS).	1	5	5	Check by hand using Barrwoman method
R_GE_22	Pre Competition	Stability: Bad CM from desgin	Error in rocket definition in commercial rocket smulation program (OR or RS) or because of incomplete CAD.	1	5	5	If weight margins allow for it, plan locations for trim weights.

Table 39. Operation risks

ID	PHASE	RISK	CAUSES	PROBABILITY	CONSEQUENCES	SEVERITY	MITIGATION
R_OP_01	Assembly	Not enough time	A part is broken shortly before the assembly period. Team members aren't coordinated. Stress induces errors.	4	5	20	Assembly checklists; assign duties for each team member to avoid confusion
R_OP_02	Recovery	Parachute entangles	The folding of the parachute wasn't done according to procedures. Shock cords and lines get tangles in the rocket.	4	5	20	Assess risk during drop test. Write standard folding procedure. Always have parachute folded by the same person. Put parachute in deployment bag.
R_OP_03	Seperation	No seperation	Cone is too tightly fitted to airframe. Ejection charge is not strong enough or pressure leaks through recovery bulkhead.	4	5	20	Several seperation tests in different rocket positions, including shake test and test flight.
R_OP_04	Seperation	No deployment of parachute	Parachute is stuck in the rocket by protruding structural elements. It is tangled with it's own cord or the payload.	4	5	20	Several deployment tests in different rocket positions, including shake test and test flight. Use an ejection ConOps which reduces the risk of payload entanglement to a minimum. Do ejection tests with payload.
R_OP_05	Primary recovery	Reefed parachute not opening	It can occur that a reefed parachutes turns itself inside out when unreefed.	4	5	20	Several opening tests, test flight, advice of professionals
R_OP_06	Secondary recovery	Unreefing not working	Line-cutters didn't opperate nominaly. The parachute is tangled with the payload or its own shock cord.	4	5	20	Several opening tests, test flight, advice of professionals
R_OP_07	Altitude control	Braking too much	Phyical model on which the controller is based is inaccurate. The mechanism fails while it is fully open.	4	4	16	Avoid braking too fast, prefer braking over longer period with continous apogee reevaluation. Correct aerodynamic model with windtunnel data.
R_OP_08	Altitude control	Not braking enough	Phyical model on which the controller is based is inaccurate. The mechanism fails while it is fully closed.	4	4	16	Test beforehand how much breaking is possible. Dont go to the limits.
R_OP_09	Flight	Signal lost - Rocket untraceable	Rocket runs out of power during flight, lands behind a terrain feature which obstructs the signal or crashes.	3	4	12	Design choice: use of redundant signals (900MHz and 433MHz), also implement secondary system. (Beacons) Implement easy integration of rocket attitude in simulator to predict landing location and have GPS data logging to have the latest registered position of the rocket.

R_OP_10	Payload recovery	Signal lost - payload untraceable	Payload runs out of power during flight, lands behind a terrain feature which obstructs the signal or crashes.	3	4	12	Design choice: use of redundant signals (900MHz and 433MHz), also implement secondary system. (Beacons)
R_OP_11	Assembly	Shipping - Rocket not in US for launch	Accident during transport.	2	5	10	Ship with enough time margin. Ship through professionals
R_OP_12	Arming	Not enough battery power to launch after wait time on pad.	Weather is not optimal. Electrical issues with igniters. Another rocket has problems which delay the countdown.	2	5	10	Dedicate more masse budget to batteries in order to last for 3(+) hours. Implement standby or hibernation modes in sub-systems such that they drain less power before launch.
R_OP_13	Seperation	No deployment of payload	Payload is stuck in rocket. Pilot chute fails to deploy.	2	5	10	Several deployment tests in different rocket positions, including vibrational test, test flight.
R_OP_14	Payload recovery	Landing in white sands	Payload descent rate is too slow to allow for enough muon detections.	3	3	9	Tailor descent rate to minimize risk of landing in restricted area. Have budget reserves to permit recovery in costly area. (military missile range).
R_OP_15	Flight	Unstable flight	The stability margin is smaller than expected. Elements detach in rocket (bouncing)	2	4	8	Check CP/CM through different calculations + people
R_OP_16	Seperation	Entangling of payload in parachute	Payload "falls" into parachute.	2	4	8	Make Design/Operation choices rendering this impossible.
R_OP_17	Payload descent	System unable to take measures due to shocks/acceleratio ns	Structure is too rigid. Sensing parts aren't damped enough.	2	4	8	Design choice for shock resistance as much as possible, shake tests, test flight
R_OP_18	Disassembl y	Impossible due to jammed subsystems	Following a rocket crash, parts are deformed or temperature variations warp the parts such that they get stuck.	2	3	6	Bring adapted (incl destructive) tools for this case. Design such that assembly and dissassembly are easy and not influenced by temperature variations.
R_OP_19	Ground arrival	Damage on landing	Non nominal operation of parachute and recovery or underestimated parachute size.	3	2	6	Design choice of parachute size, also avoid to have fragile parts exposed
R_OP_20	Firing	Misfire	It happens…	3	1	3	Use two igniters from the beginning, (ask for) recycle.

E. Assembly, Preflight and Launch Checklists

Since the EPFL Rocket Team is coming from abroad, the checklists were compiled into two documents, one detailing all the components to be packed in the shipping box, called "Shipping Procedure", the other, called "Launch Procedures" includes tasks to be done at arrival in New Mexico such as unpacking and checking all the parts for transportation damage, tasks to be done during the launch preparation day such as assembling the rocket, finally the document includes the arming procedure to be done when the rocket is on the Launchpad and the after launch procedure to thoroughly evaluate the state of the rocket and disassemble the rocket. To ease the COO's task of managing the team during packing, assembling, launching and recovering the rocket, a summary of the main points is compiled in the "General Procedures" checklist The two checklists are included in the following documents:

- `2018_SE_OP_0000_GENERAL_PROCEDURES_R01`
- `2018_SE_OP_0001_SHIPPING_PROCEDURE_R01`
- `2018_SE_OP_0002_LAUNCH_PROCEDURES_R01`

OPERATION PROCEDURES

Title:	**General procedures**	Procedure validated (Date):
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_SE_OP_0000_GENERAL_PROCEDURES_R01	
Prepared by:	Maxime Eckstein	
Checked by:	Héloïse Boross	
Approved by:		Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This document describes the general procedures of the COO. It helps the COO to better distribute and verify task during critical moments such as the packing before shipping and the assembly before launch.

People involved and responsibilities

CHIEF OPERATION OFFICER:	Maxime Eckstein
CHECKLIST RESPONSIBLE:	Héloïse Boross
PACKING RESPONSIBLE:	Emilien Mingard
General:	Maxime Eckstein
Logistics:	Benjamin Arnoult
Structure:	Emilien Mingard
Recovery:	Malo Goury du Roslan
Avionic and Ground station:	Clément Nussbaumer
Airbrakes:	Christian Cardinaux
Propulsion:	Alexandre Looten
Payload:	Loup Cordey

2 ITEM CHECKLISTS

NOTE: each sub -teams shall maintain a complete, hardcopy set of these checklist procedures with their flight hardware during all range activities. Competition officials will verify teams are following their checklists during all operations.

☐ Shipping procedure
☐ Launch procedures

2.1 Procedures

☐ Parachute folding procedures and tangling prevention
☐ Avionic testing procedure
☐ Ground Station testing procedure
☐ AEROCON line cutter procedure
☐ Peregrine RAPTOR procedure
☐ Airbrakes testing procedure

2.2 Hardware

☐ Toolbox 1: General
☐ Toolbox 2: Structure
☐ Toolbox 3: Recovery
☐ Toolbox 4: Avionic
☐ Toolbox 5: Ground Station
☐ Toolbox 6: Airbrakes
☐ Toolbox 7: Propulsion
☐ Toolbox 8: Payload

3 PROCEDURES ON SITE

3.1 Launch preparation

3.1.1 Location: At hotel

TIMEFRAME: 17th to 19th of June

STEP BY STEP:

	ID	Task Name	Description
☐	GE_P-01	Handle checklists	Handle checklists to each subteam
☐	GE_P-02	Briefing	Check briefing to the team
☐	GE_P-03	Structure check	Structural integrity checked Module and part chosen
☐	GE_P-04	Avionic check	Verify all circuits and connexion in both avionic, check ground station connexion and data acquisition
☐	GE_P-05	Recovery check and preparation	Verify connectors and prepare Raptors and line cutters

☐	GE_P-06	Parachute folding	Fold the main parachute following the corresponding procedure
☐	GE_P-07	Payload check	Verify electrical circuit and total weight
☐	GE_P-08	Airbrakes check	Check structure integrity,

3.1.2 Location: Camping site

TIMEFRAME: 20^{th} of June

STEP BY STEP:

	ID	Task Name	Description
☐	GE_P-09	Handle checklists	Handle checklists to each sub team
☐	GE_P-10	Briefing	Launch preparation briefing to the team
☐	GE_P-11	Structure bottom assembly	All bottom structure parts below airbrakes are assembled.
☐	GE_P-12	Recovery plate assembly	Fix the connectors Connect the igniter board following the procedure Mount the raptors, verify they are full. Attach and connect the shock cord.
☐	GE_P-13	Avionic structure assembly	Fix the bottom avionic to the recovery plate, insert everything inside the rocket and connect properly the batteries. Check the recovery plate airtightness. Test arming of the recovery.
☐	GE_P-14	Airbrakes assembly	Connect the airbrakes to the avionic and fix them to the upper tube
☐	GE_P-15	Parachute assembly	Shock cord, parachute and payload correctly linked together. Insert inside the rocket
☐	GE_P-16	Collect RBF	The two RBF of the main parachute are removed The RBF of the payload parachute is removed
☐	GE_P-17	Airframe assembly	Connect upper and lower tubes Thrust plate is fixed inside the bottom tube
☐	GE_P-18	Motor assembly	Insert motor inside the rocket and fix boat tail.
☐	GE_P-019	Igniter verification	Check igniter resistance: _________Ω and ________Ω
☐	GE_P-20	Nose cone assembly	Nose cone structure and avionic are assembled. Avionic is turned on, transmitting data. Nose cone closed with the shock cord attached. External connexion to power up the avionic. Connexion established with the ground station. Shock cord attached

3.2 Launch time

3.2.1 Location: On pad

TIMEFRAME: 9AM 21th of June

TASKS DISTRIBUTION:

	ID	Task Name	Description
☐	GE_P-21	Rocket is on the launch pad	Install rocket, set the launchpad angle
☐	GE_P-22	Avionic turn on	Nose and boy avionic turned on. Telemetry link with ground station established. Three RBF to collect. One for each battery.
☐	GE_P-23	Recovery arming	Recovery SRAD and COTS are armed. Two RBF to collect, one for each system
☐	GE_P-24	Igniter installed	Rocket is ready to flight. Last RBF to collect
☐	GE_P-25	LAUNCH	Get battery state from GS and decision to launch.

3.3 After launch

TIMEFRAME: 9AM-5PM 21th of June

TASKS DISTRIBUTION:

	ID	Task Name	Description
☐	GE_P-26	Briefing	Not over yet, we need to recover the rocket and clean everything.
☐	GE_P-27	Locate and find the rocket	Go to the landing zone to prepare for recovery.
☐	GE_P-28	Structure check	Structural integrity checked.
☐	GE_P-29	Avionic disarming and data saving	Turn off the avionic Recover SD card and store safely data.
☐	GE_P-30	Recovery disarming	Disarm all recovery systems.
☐	GE_P-31	Parachute folding	Fold the main parachute to protect it against external damage.
☐	GE_P-32	Payload recovery	Locate and find the payload, disarm all electronics, recover and store the data.
☐	GE_P-33	Airbrakes disarming and closing	Disarm the airbrakes and close them if they are open to prevent for any damage.
	GE_P-34	Motor clean up	Clean the used motor casing from all remaining parts. Check temperature sensor Max Temp: _________
	GE_P-35	Clean camping site	Clean camping site, bring back to the hotel all what is unnecessary.

OPERATION PROCEDURES

Title:	**Shipping procedures**	Procedure validated (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_SE_OP_0001_SHIPPING_PROCEDURES_R01	
Prepared by:	Maxime Eckstein	
Checked by:	Héloïse Boross	
Approved by:		Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This document goes through all the steps needed to ensure to have everything well prepared on the field at the competition and to recover them back.

2 PEOPLE INVOLVED AND RESPONSABILITIES

CHIEF OPERATION OFFICER: Maxime Eckstein
CHECKLIST RESPONSIBLE: Héloïse Boross
PACKING RESPONSIBLE: Emilien Mingard
General: Maxime Eckstein
Structure: Emilien Mingard
Recovery: Malo Goury du Roslan
Avionic and Groundstation: Clément Nussbaumer
Airbrakes: Christian Cardinal
Propulsion: Alexandre Looten
Payload: Loup Cordey

3 ITEM CHECKLISTS

3.1 Checklists

NOTE: teams shall maintain a complete, hardcopy set of these checklist procedures with their flight hardware during all range activities. Competition officials will verify teams are following their checklists during all operations.

- ☐ Packing procedures
- ☐ Launch procedures
- ☐ General procedures

3.2 Procedures

- ☐ Parachute folding procedures and tangling prevention
- ☐ Avionic testing procedure
- ☐ Ground Station testing procedure
- ☐ AEROCON line cutter
- ☐ Peregrine RAPTOR
- ☐ Airbrakes testing procedure

3.3 Documentation

- ☐ Stability analysis documentation paper version
- ☐ Ground station user manual

3.4 Toolbox 1: General

	ID	Name	Amount	Description
☐	GE-01	Laminated version of checklists	2	Size A3, will be posted inside the tents for better visualization
☐	GE-02	Pens to write on laminated paper	2	Whiteboard pens
☐	GE-03	Multiple plugs	1	
☐	GE-04	Tables	4	3 flat foldable table for rocket assembly 1 Table for electronic work
☐	GE-05	Trash bag	1	1 roll for wastes related to the rocket assembly
☐	GE-06	Scale	1	Precisely determine weight of the rocket
☐	GE-07	Safety googles	10	Bought onsite
☐	GE-08	Rubber gloves	1	1 box size L
☐	GE-09	Safety signs	4	No smoking area
☐	GE-10	Duct tape, safety tape, sealing tape	3	1 roll of each to secure perimeter and final adjustments
☐	GE-11	Zip ties	1	One pack of small size Zip ties

☐	GE-12	Pencil, scissor, paper	Xx	Enough “School material”
☐	GE-13	Backup tools		**List TBD**
☐	GE-14	Backup screws and nuts		**List TBD**
☐	GE-15	Drilling hand machine	1	
☐	GE-16	Drilling tools	1	1 box of drilling tools
☐	GE-17	Remove before flight	9	1 nose cone avionic 1 payload 2 main parachute 1 payload parachute 1 airbrake 2 recovery electronics 1 motor igniters installation
☐	GE-18	Bubble wrap for transportation of the rocket	1	1 roll

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.5 Toolbox 2: Structure

	ID	BOM name	Amount	Description
☐	ST-01	11100 Nose Cone	2	Assemblage: 11101,11102
☐	ST-02	11103 Hole Tip	2	Pièce Seule
☐	ST-03	11600 Upper Airframe Assembly	2	Assemblage: 11601-11606
☐	ST-04	11607 Ecrou Locking M8	4	Pièce Seule
☐	ST-05	11608 Ecrou M8	8	Pièce Seule
☐	ST-06	11609 Rondelles Ressort M8	4	Pièce Seule
☐	ST-07	11302 Bague Interne	7	Pièce Seule
☐	ST-08	11303 Bague	7	Pièce Seule (1 Bague = 8 Morceaux)
☐	ST-09	11304 Vis M4x20 Tête Fraisée	48	Pièce Seule
☐	ST-10	11400 Fins Module	2	Assemblage: 11401-11403,11405,11408-11413,11415
☐	ST-11	11404 Aft Enclosure	2	Pièce Seule
☐	ST-12	11406 Motor Tube	3	Pièce Seule
☐	ST-13	11414 Boat Tail	2	Pièce Seule
☐	ST-14	11416 Vis M3x15 6p Creux	6	Pièce Seule
☐	ST-15	11500 Lower Airframe Assembly	2	Assemblage: 11501-11503
☐	ST-16	11606 Recovery Attach	2	Pièce Seule
Tools needed for assembly				
☐	ST-20	Clé Imbus 2.5mm	2	
☐	ST-21	Clé Imbus 3mm	2	
☐	ST-22	Clé Imbus 6mm	2	
☐	ST-23	Clé Mixte 13mm	2	
☐	ST-24	Clé Mixte 7mm	2	
☐	ST-25	Perçeuse à main, américaine	1	
☐	ST-26	Jeu de mèche métal	1	
☐	ST-27	Boite outils taraudage	1	
☐	ST-28	Clé dynamométrique	1	
☐	ST-29	Jeu de douilles	1	
☐	ST-30	Jeu de tournevis	1	
☐	ST-31	Epoxy 120min Alu	1	
☐	ST-32	Epoxy 10min All	1	
☐	ST-33	Scotch Ajustage Moteur	1	
☐	ST-34	Scotch Carrosier	1	
☐	ST-35	Sharp Cutter	2	

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.6 Toolbox 3: Recovery

	ID	BOM name	Amount	Description
☐	RE-01	12101 Recovery Plate	1	Assembly: 12101 - Recovery plate 12407 - system cap 12411 - M3x10 screws 12407 - System Cap O-Ring
☐	RE-02	12102 M8 Structural Shaft	2	Single piece
☐	RE-03	12103 M8 Eyelet	3	Single piece
☐	RE-04	12104 M8 Upper Nut	4	Single piece
☐	RE-05	12105 Connector	2	Assembly: 12105 - Male Connector 12106 - Female Connector
☐	RE-06	12107 Bottom Long Spacer	4	Single piece
☐	RE-07	12108 Top Short Spacer	4	Single piece
☐	RE-08	12109 Security Wash	4	Single piece
☐	RE-09	12201 Parachute	1	Assembly: 12201 - Parachute 12202 - Quick Link 12306 - Reefing Body
☐	RE-10	12203 Electrical shock cord	1	Single piece
☐	RE-11	12204 Harness	1	Assembly: 12204 – Harness 12202 - Quick Link
☐	RE-12	12205 Kevlar Strap	1	Replaced by 12203 Electrical shock cord
☐	RE-13	12206 Deployment Bag	1	Assembly: 12202 - Quick Link 12206 - Deployment Bag
☐	RE-14	12207 Swivel	2	Assembly: 12207 Swivel 12208 Short Strap
☐	RE-15	12306 Line Cutter Body	2	Assembly: 12303 - Line Cutter Cap 12305 - Line Cutter Spike 12306 - Line Cutter Body
☐	RE-16	12304 Line Cutter O-Ring	8	Single piece
☐	RE-17	12306 Reefing Line	2	Single piece
☐	RE-18	12401 - Charge Cup	2	Assembly: 12401 - Charge Cup 12402 - Charge Cup O-Ring
☐	RE-19	12403 - Pyro Housing	2	Single piece
☐	RE-20	12405 - Puncture Piston	2	Assembly: 12404 - Puncture Spring 12405 - Puncture Piston 12406 - Puncture Piston O-Ring

☐	RE-21	12409 - CO2 Cartridge	2	Assembly: 12410 - CO2 Cartridge 25g 12409 - CO2 Cartridge Adapter
☐	RE-22	12412 - Scotch Cap Red	4	Single piece
Tools needed for assembly				
☐	RE-23	Igniter	12	6 igniters needed, 6 as back up
☐	RE-24	Grease		for RAPTOR charge cup and Pyro housing
☐	RE-25	Screw Terminal Connector	10	Domino/Sucre Connector
☐	RE-26	Multimeter	1	
☐	RE-27	Fibered Tape	1	1 roll for parachute repair
☐	RE-28	Mesh Elastic	3	Useful to contain lines or shock cords
☐	RE-29	Parachute line		Back up
☐	RE-30	cordon		Reefing line supply
☐	RE-31	Quick Link	2	Back up
☐	RE-32	Short Strap	2	Back up
☐	RE-33	Electrician Tape	1	1 rouleau scotch electricien
☐	RE-34	Paper Tape	1	1 rouleau scotch papier / peintre
☐	RE-35	Screwdriver flat 3mm	1	Pour vis connecteurs domino
☐	RE-36	Wrench 13 dynamometer	1	pour ecrou M8
☐	RE-37	Pliers	1	Fils igniters
☐	RE-38	Cutter	1	Denudage fil and other
☐	RE-39	Lighter	1	
☐	RE-40	Q-tip	10	RAPTOR Nettoyage
☐	RE-41	Degreasing		Netoyage recovery systems
☐	RE-42	Needles	20	Ressortir piston line cutter
☐	RE-43	Paper Towel		
☐	RE-44	Cleaning tissues		

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.7 Toolbox 4: Avionic

	ID	BOM name	Amount	Description
☐	AV-01	14102 - PCB	1	Central body avionics
☐	AV-02	14301 - Raven	1	COTS avionics
☐	AV-03	14502 - Battery	2	Central body batteries
☐	AV-04	14401 - Control Panel PCB	1	
☐	AV-05	14111 – Central microSD card	1	
☐	AV-06	14201 - PCB	1	Nosecone avionics
☐	AV-07	14220 – Nosecone microSD card		
☐	AV-08	14801 - Ignition board	1	Passive Recovery protection circuit
☐	AV-09	14701 - Interconnection wire	1	
☐	AV-10	14702 -Interconnection to nosecone wire	1	soldered with 14201
☐	AV-11	14703 -Interconnection to Central wire	1	soldered with 14102
☐	AV-12	14705 - Central to Airbrakes connector wire	1	soldered with 14102
☐	AV-13	14706 - Airbrakes to Airbrakes connector wire	1	soldered with Airbrakes motor cable
☐	AV-14	14707 - Central to debugger port wire	1	
☐	AV-15	14709 -Central to Control panel signal wire	1	soldered with 14102 and 14401 with Molex between them
☐	AV-16	14710 - Recovery to Central via Control panel wire	1	attached with a "sucre" to 14801
☐	AV-17	14711 - Central to COTS wire	1	soldered with 14102
☐	AV-18	14712 - COTS to ignition board wire	1	
☐	AV-19	14713 - Central to Ignition board wire	1	soldered with 14102
☐	AV-20	14714 - BAT to Control Panel wire	2	
☐	AV-21	14715 - Control Panel to Central power wire	2	
☐	AV-22	14716 - Ignition board to Recovery 1st wire	1	
☐	AV-23	14717 - Ignition board to Recovery 2nd wire	1	
☐	AV-24	14718 - Recovery 1st to C6H12O6 wire	1	
☐	AV-25	14719 - Recovery 2nd to Parachute wire	1	to be cut by Recovery

☐	AV-26	14720 - Central 900MHz antenna wire	1	with UFL M - F soldered
☐	AV-27	14721 - BAT3 to nosecone wire	1	
☐	AV-28	14722 - Nosecone 900MHz antenna wire	1	with UFL M - F soldered
☐	AV-29	14723 - Pitot Tube nosecone	1	
Tools needed for assembly				
☐	AV-30	Status LED peripheral	1	
☐	AV-31	LiPo charger	2	The small one and the multicharger
☐	AV-32	Scotch	1	
☐	AV-33	Elastics	20	
☐	AV-34	Soldering iron	1	With small head
☐	AV-35	Multimeters	2	At least 1 high current proof
☐	AV-36	Scissors	1	Long enough to cut elastics inside of the rocket
☐	AV-37	Flat pliers	1	
☐	AV-38	Screwers hexa 2.5	1	
☐	AV-39	Screwers flat 2.5	1	
☐	AV-40	Third hand	1	
☐	AV-42	Wire stripper	1	
☐	AV-43	Cutting pliers	1	
☐	AV-44	Tin	2	Fine and large

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.8 Toolbox 5: Ground station

	ID	BOM name	Amount	Description
☐	GS-01	16100	1	Ground station
☐	GS-02	16101	1	Battery (LFP 12V / 20Ah)
☐	GS-03	16300	1	Ground station battery charger
☐				
☐				
Tools needed for assembly				
☐		Shared with avionic		

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.9 Toolbox 6: Airbrakes

	ID	BOM name	Amount	Description
☐	AB-01	Shuriken Module	1	Module already fully assembled
☐	AB-02	Flaps Module	1	Module already fully assembled
☐	AB-03	15711 Spare Flaps	2	
☐	AB-05	15800 Test station Shuriken	1	
☐	AB-06	15900 Test station Flaps	1	
Tools needed for assembly				
☐	AB-07	Set de clefs IMBUS	1	
☐	AB-08	Pince à circlip 3.2 mm	1	

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.10 Toolbox 7: Propulsion

	ID	BOM name	Amount	Description
☐	PR-01	13201-Casing	1	Competition casing (comes with aft closure, forward closure, seal disk and case)
☐	PR-02	13202-Reload	1	Competition reloads, USA purchase
☐	PR-03	13203-Igniters	10	Igniters, USA purchase
Tools needed for assembly				
☐	PR-04	Snyco/Super Lube or other grease	1	
☐	PR-05	Hobby knife	1	
☐	PR-06	Spray Dégraissant (for disassembling)	1	
☐	PR-07	Electric match	1	
☐	PR-08	Masking tape	1	
☐	PR-09	Wet pipes or damp paper towels	1	
☐	PR-10	Disposable rubber gloves	1	
☐	PR-11	Headlight	1	
☐	PR-12	Safe-box with a key for reloads and igniters	1	USA purchase
☐	PR-13	Colour tape (red and blue)	1	
☐	PR-14	Pince multiprise	1	
☐	PR-15	Water Extinguisher!! NOT CO2 or Foam	1	USA purchase
☐	PR-16	Araldite glue tube	1	

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

3.11 Toolbox 8: Payload

	ID	BOM name	Amount	Description
☐	PL-01	17111 Central glued plate with scintillating plastics on it	1	assemblage 17111,17301
☐	PL-02	17304 Bias DC-DC Alimentation PCB	1	pièce seule
☐	PL-03	17300 SiPM+Amp PCB	2	assemblage 17302,17304
☐	PL-04	17110 Support PCB SiPM+Amp	2	pièce seule
☐	PL-05	17200 Avionic	1	assemblage 17201-17209
☐	PL-06	17119 parachute	1	pièce seule
☐	PL-07	17120 shock cord	1	pièce seule
☐	PL-08	17114 M4x20 socket head screw hex drive	10	pièce seule
☐	PL-09	17115 M4x10 socket head screw hex drive	10	pièce seule
☐	PL-10	17116 M3x8 flat head screw hex drive	20	pièce seule
☐	PL-11	17117 M3x6 flat head screw hex drive	40	pièce seule
☐	PL-12	17118 M4 locknuts	10	pièce seule
☐	PL-13	17121 Masking fabric	2	pièce seule
☐	PL-14	17122 Masking Tape	1	pièce seule
☐	PL-15	17210 Short power cables	2	pièce seule
☐	PL-16	17211 Long power cables	2	pièce seule
☐	PL-17	17305 Short data cables	1	micro usb to usb cable
☐	PL-18	17306 Long data cables	1	micro usb to usb cable
☐	PL-19	17208 NiMH 1800 mAh battery	8	pièce seule
Tools needed for assembly				
☐	PL-20	Programming/Debug device for AtMega	1	pièce seule
☐	PL-21	Multimeter	1	TP Phys
☐	PL-22	Laboratory power supply	1	TP Phys
☐	PL-23	Solder iron	1	Fine tip
☐	PL-24	Soldering lead	1	Fine size
☐	PL-25	Oscilloscope	1	If possible
☐	PL-26	M4 hex drive screwdriver	1	pièce seule
☐	PL-27	M3 hex drive screwdriver	1	pièce seule
☐	PL-28	digital weighing scale capable of measuring >4kg	1	pièce seule
☐	PL-29	M4 wrench	1	pièce seule
☐	PL-30	Battery charger	1	Pièce seule
☐	PL-31	Metal scissors	1	Pièce seule

Checked before packing (CH)	(Date and Responsible signature)
Checked before packing (USA)	(Date and Responsible signature)

4 PACKING STEPS

4.1 At Home

TIMEFRAME: 26th - 27th of May

SITUATION: **TBD**

STEPS: **TBD**

4.2 In the USA

TIMEFRAME: After launch – 20th June

SITUATION: **TBD**

STEPS: **TBD**

OPERATION PROCEDURES

Title:	**Launch procedures**	Procedure validated (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_SE_OP_0002_LAUNCH_PROCEDURES_R01	
Prepared by:	Maxime Eckstein	
Checked by:	Héloïse Boross	
Approved by:		Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This document describes the launch procedures, assigns tasks to people and responsibilities.

People involved and responsibilities
CHIEF OPERATION OFFICER: Maxime Eckstein

CHECKLIST RESPONSIBLE: Héloïse Boross

PACKING RESPONSIBLE: Emilien Mingard

General: Maxime Eckstein

Logistics: Benjamin Arnoult

Structure: Emilien Mingard

Recovery: Malo Goury du Roslan

Avionic and Ground station: Clément Nussbaumer

Airbrakes: Christian Cardinaux

Propulsion: Alexandre Looten

Payload: Loup Cordey

2 ITEM CHECKLISTS

NOTE: teams shall maintain a complete, hardcopy set of these checklist procedures with their flight hardware during all range activities. Competition officials will verify teams are following their checklists during all operations.

☐ Shipping procedure
☐ Launch procedures

2.1 Procedures

☐ Parachute folding procedures and tangling prevention
☐ Avionic testing procedure
☐ Ground Station testing procedure
☐ AEROCON line cutter
☐ Peregrine RAPTOR
☐ Airbrakes testing procedure

2.2 Documentation

☐ Stability analysis documentation paper version
☐ Ground station user manual

2.3 Hardware

☐ Toolbox 1: General
☐ Toolbox 2: Structure
☐ Toolbox 3: Recovery
☐ Toolbox 4: Avionic
☐ Toolbox 5: Ground Station
☐ Toolbox 6: Airbrakes
☐ Toolbox 7: Propulsion
☐ Toolbox 8: Payload

3 PROCEDURES ON SITE

3.1 Launch preparation

3.1.1 Location: At hotel

TIMEFRAME: 17^{th} to 19^{th} of June

TASKS DISTRIBUTION: After travel and pre-assembly checks/procedures

Clement Nussbaumer	Check avionic and Ground station
Emilien Mingard	Structure check, rocket observation and parts selection

Malo Goury du Roslan	Folding parachute, recovery preparation
Loup Cordey	Payload verification and assembly
Christian Cardinaux	Check airbrakes assembly and test bench

STEP BY STEP:

	ID	Task Name	Description	Requirements
Structure				
☐	ST_P-01	Delivery Check: Parts List	Check if any part is missing once the box is opened.	Document needed: Structure_Mass_Budget 2018_SE_OP_0001_SHIPPING_PROCEDURE
☐	ST_P-02	Delivery Check: Upper Airframe Assembly	Check if glued parts are unglued, broken or damaged. Following parts are supposed to be glued: 2x11604 Thin List 2x11605 Thick List 1x11301 Tube Ring 1x11602 Bague Renfort 1x11603 Rail Triangle 1x14403 Control Panel Support 2x14501 Battery Mount 1x14601 Central Debug Port Support 3x11611 Recovery Etancheity Following parts are supposed to be assembled: 1x11610 Launch Lug	Spare Parts Needed: 1xST-03
☐	ST_P-03	Delivery Check: Lower Airframe Assembly	Check if glued parts are unglued, broken or damaged. Thrust plate should be screwed: Following parts are supposed to be glued: 2x11409 Sandwich Centering Ring 2x11301 Tube Ring Following parts are supposed to be assembled: 2x11502 Thrust Plate 6x11503 Vis M6x14 6p Creux 3x11415 Insert M3	Spare Parts Needed: 1xST-15
☐	ST_P-04	Delivery Check: Fins Module	Check fins module assembly Following parts are supposed to be assembled: 1x11401 Upper Ring 1x11402 Middle Ring 1x11403 Lower Ring 3x11405 Fins	Spare Parts Needed: 1xST-10

			3x11408 Third of Panel 27x11411 Vis M4x8 Tête Ronde 9x11412 Vis M4x20 6p Creux 9x11413 Ecrou Locking M4 3x11415 Insert M3 1x11417 Launch Lug	
☐	ST_P-05	Delivery Check: Nose Cone	Check the glued tip Following part is supposed to be glued: 1x11102 Insert Tip 1x11104 Avionic Structure Following parts are supposed to be assembled 2x11105 6mm Thread Rods 2x11106 Ecrou M6	Spare part needed: 1xST-01
Recovery				
☐	RE_P-01	RAPTOR preparation	Charge RAPTOR External Procedure: Peregrine RAPTOR Attention: igniter must stay short-circuited	Spare Part Needed: 2xRE-18 2xRE-19 2xRE-20 2xRE-22 Tools needed: RE-23 RE-24 RE-37 RE-38
☐	RE_P-02	AEROCON line cutter preparation	Charge line cutter and prepare reefing line External Procedure: AEROCON line cutter Attention: igniters must stay short-circuited	Spare Part Needed: 2xRE-15 4xRE-16 1xRE-17 Tools needed RE-23 RE-24 RE-37 RE-38
☐	RE_P-03	Prepare Parachute	Fold the parachute, finish reefing assembly External Procedure: 2018_SE_OP_0005_PARACHUTE_PROCEDURE_R01	Required: RE_P02 Spare Part Needed: RE-09 RE-13 RE_P02 Tools needed: RE-35 RE-38 RE-39

Avionic				
☐	AV_P-01	Nosecone avionic check	Verify all connexions in the nosecone avionic after the travel. External procedure: 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01	Section 2.3.1
☐	AV_P-02	Central body avionic check	Verify all connexions in the central body avionic. External procedure: 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01	Section 2.3.2
☐	AV_P-03	Control panel avionic check	Verify all connexion in the control panel avionic. External procedure: 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01	Section 2.3.3
☐	AV_P-04	Common checks	Verify all connexion inside the rocket, and between the subsystems External procedure: 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01	Section 2.3.4

Ground Station				
☐	GS_P-01	General check	Verify all connexion and hardware External procedure: 2018_SE_OP_0007_GROUNDSTATION_PROCEDURES_R01	
☐	GS_P-02	fuse check	Check that the installed fuse is correctly rated	
☐	GS_P-03	boot check	Power the ground station up, and check that the UpBoards boot up (Ubuntu login screen must appear)	
☐	GS_P-04	software check	Verify that the ground station software starts with the correct settings (location, ...)	
☐	GS_P-05	Charge batteries	Charge all the batteries for avionic and ground station	

Airbrakes				
☐	AB_P-01	Assembly check	External procedure: 2018_SE_OP_0008_AIRBRAKES_PROCEDURES_R01	Section 2.3.1
☐	AB_P-02	Working and pre-flight check	External procedure: 2018_SE_OP_0008_AIRBRAKES_PROCEDURES_R01	Section 2.3.2

Payload				
☐	PL_P-01	Weighing	Ascertain that the payload meets its weight criteria for the competition.	Tools needed PL-28
☐	PL_P-02	Powered	Check that there is +5V between +5V and Ground pins	Tools needed PL-21
☐	PL_P-03	Vbias	Check that there is between +55V and +59V on Vbias	Tools needed PL-21
☐	PL_P-04	Power cables	Power cables are connected (2x)	Visual inspection
☐	PL_P-05	Data cables	Data cables are connected	Visual inspection
☐	PL_P-06	Vbias	Vbias is same as on previous point when checked on SiPM PCB	Tools needed PL-21
☐	PL_P-07	Data reading	Via computer, read the event rate.	Tools needed PL-17 PL-18
☐	PL_P-08	Screws	Check if the screws are holding correctly the PCB and the PCB Holder. No loose parts.	Visual inspection
☐	PL_P-09	Charge batteries	Charge batteries	Tools needed PL-30

3.1.2 Location: Camping site

TIMEFRAME: 20th of June

TASKS DISTRIBUTION:

Benjamin Arnoult	Installing camp and infrastructures
Emilien Mingard	Structure assembly
Eric Brunner	Simulation of launch and airbrakes controller
Malo Goury du Roslan	Recovery plate connexion and parachute insertion
Loup Cordey	Payload assembly and launch
Christian Cardinaux	Airbrakes assembly and final checks
Clément Nussbaumer	Avionic connexion, insertion and configuration
Ludovic Gizendaner	Ground station verification and connexion
Alexandre Looten	Motor assembly

STEP BY STEP:

	ID	Task Name	Description	Requirements
Logistic				
☐	LO_P-01	Materials	Bring all the materials from the Hotel to the launch site	Everything
☐	LO_P-02	Tent	Install the tent and table to allow the team to work in the best conditions	Tent and table
☐	LO_P-03	Generator	Install the generator and check that everything works	Generator

Simulations				
☐	SE_P-01	Data gathering	Determine exact lift-off weight of the rocket Predict weather conditions and environment parameters	Weather forecast Rocket fully assembled
☐	SE_P-02	Airbrakes table	Run the simulations to generate the breaking table regarding the actual weather conditions Load the table in the rocket avionic	Data SE_P-01
☐	SE_P-03	Prediction	Apogee prediction Splash zone prediction	Data SE_P-01

Structure				
☐	ST_P-06	Check launch lug	Verify if the launch lug fits inside the rail and are perfectly adjusted	1x11610 Launch Lug
☐	ST_P-07	Fins Module to Lower Airframe Assembly	ST-10 and ST-15 are coupled. The general coupling system is used. One person is needed to fulfil this procedure. Help may be asked to a second person. Inside ring is first placed between the couplers, while one person keep the correct alignment, the second screw the external rings, following a cross linking to ensure co-centricity.	Spare Parts Needed: 1xST-07 1xST-08 8xST-09 Tool Needed: 1xST-20 1xST-28
☐	ST_P-08	Motor tube	Motor tube is inserted from the aft. If it doesn't fit, tape must be removed until it fits and cut using sharp cutter (1). If space is seen between the fins module and the tube, tape (2) can be added. The motor tube should touch the thrust plates.	Spare Parts Needed: 1xST-12 Possible Tool: (1) ST-35 (2) ST-33 Required Procedure: ST_P-06
☐	ST_P-09	Motor Retainer	Motor retainer is screwed. Once propulsion team inserted the loaded motor inside the motor tube, it needs to be fixed using the motor retainer. The motor retainer should be screwed until contact is made. A small pre-load is necessary in case initial acceleration, it helps coupling system to set in place.	Required Procedure: PR_P-05 ST_P-07 Spare Parts Needed: ST-11
☐	ST_P-10	Boat Tail	Assembly of ST-13 at the back of ST-10.	Spare Parts Needed: 1xST-13 3xST-14 Tool Needed: ST-20
☐	ST_P-11	Recovery Attach	Preparation of electronic made by recovery team and avionics. Once ready, electronic and recovery plate are inserted from top of Upper Airframe to their final position. Structure team take care of control panel adjustment and assembly. Serial connector, debug connector and air-breaks connector	Spare Parts Needed: 2xST-04 4xST-05 2xST-06 2xST-16 Tool Needed:

			are engaged. Finally, the batteries are connected. Recovery attach are adjusted and fixed. The spring rings are placed beforehand.	1xST-29 1xST-23 1xST-36 Equivalent Procedure: RE_P-09
☐	ST_P-12	Airbrakes to Upper Airframe Assembly	Coupling between Lower Airframe Assembly and Airbrake assembly. The general coupling system is used. One person can fulfil this procedure. Help may be asked to a second person. Inside ring is first place between the couplers, while a person keep the correct alignment, the second screw the external rings, following a cross linking to ensure co-centricity.	Spare Parts Needed: 1xST-07 1xST-08 8xST-09 Tool Needed: 1xST-20 1xST-28 Required Procedure: ST_P-10
☐	ST_P-13	Nose Cone	The nose cone tip is assembled on top of the nose cone shell, in provided thread. If pitot tube is used, it must be inserted through the tip. The upper avionic is slided along the 6mm rods and fixed using PVC entretoise and M6 nuts. The nose cone is finally closed using wood plate (Connected to shock cord)	Spare Parts Needed: 1xST-01 1xST-02 2xST-17 2xST-18 Required Procedure: RE_P-08
☐	ST_P-14	Upper Airframe to Lower Airframe	Coupling of Upper Assembly and Lower Assembly+Airbrakes. The coupling system is used. One person is required to fulfil this procedure but help can be asked. Inside ring is first place between the couplers, while a person keep the correct alignment, the second screw the external rings, following a cross linking to ensure co-centricity.	Spare Parts Needed: 1xST-07 1xST-08 8xST-09 Tool Needed: 1xST-20 1xST-28 Required Procedure: ST_P-10 ST_P-11

Recovery				
☐	RE_P-04	Attach Nose Cone	Attach the Kevlar strap to the nose cone via the swivel Required: Nose cone ready	Spare Part Needed: RE-12 RE-03 RE-14 Nose cone assembly
	RE_P-05	Prepare Recovery Structure	Fasten together the recovery plate and the applicable structural components. Verify that the CO_2 cartridge are full. Tight strongly the upper M8 nut. Required: Avionic ready RE_P-03	Spare Part Needed: 1xRE-01 2xRE-02 2xRE-03 2xRE-04 2xRE-05 2xRE-06 2xRE-07 2xRE-08 2xRE-21

				Tools needed RE-36
☐	RE_P-06	Connect RAPTOR	Electrically connect the RAPTORS Required: RE_P-01 RE_P-04	Spare Part Needed: RE_P-01 RE_P-04 Tools needed: RE-35
☐	RE_P-07	Attach Shock Cord	Join Electrical Shock Cord, Kevlar strap and Harness to Recovery structure.	Spare Part Needed: 2xRE-03 2xRE-05 RE-10 RE-11 RE-12 Tools needed: RE-35
☐	RE_P-08	Integrate Recovery structure	Slide the recovery structure in the rocket tube and attach it to the coupler Required: Structure Team ready RE_P-04	Spare Part Needed: RE_P-04
☐	RE_P-09	Integrate Parachute	Connect deployment bag to the payload, connect line cutters and parachute to the electrical shock cord Required: RE_P-05	Spare Part Needed: RE-10 RE_P-05 Tools needed: RE-35
☐	RE_P-10	Integrate Shock cords	Put the rocket vertically, integrate the Electrical shock cord near the Raptors. Integrate and fix the nose cone shock cord to the Velcro strip. Required: Structure Team ready RE_P-04	Spare Part Needed: RE_P-04
☐	RE_P-11	Integrate Parachute Chain in the Rocket	Integrate the parachute, the payload and the Kevlar strap. Carefully tie the nose cone shock cord to prevent entanglement.	Required: RE_P-07 RE_P-09

Avionic				
☐	AV_P-05	Autonomy check	Verify the batteries are fully charged	
☐	AV_P-06	Nosecone avionics start up	Plug the battery to the nosecone PCB. check that LEDs turn on	
☐	AV_P-07	Telemetry link	Check with ground station that the redundant	

		check	telemetry data link is established	
☐	AV_P-08	Data saving check	Verify the SD cards are well formatted and data is saving	
☐	AV_P-09	Nosecone avionics insertion	Verify that the tube pass through the hole at the top of the nosecone	
☐	AV_P-10	Pitot fixation	Fix the tube into the Pitot structure element and screw it at the top of the nosecone	
☐	AV_P-11	Nosecone interconnection	Fix the LEMO connector on the nosecone structure	
☐	AV_P-12	Nosecone avionics fixation	Fix the avionics with the nosecone structure	
☐	AV_P-13	interconnection insertion	Slide the interconnection wire into the "Gothard"	
☐	AV_P-14	Avionics mounting before insertion in the rocket	Plug the 14710 into Central and CP and screw it into the ignition board screw the 14712 into the RAVEN and the ignition board plug the 14715 into the CP and the Central Mount the 14716 on the Recovery plate and screw it into the ignition board Mount the 14717 on the Recovery plate and screw it into the ignition board Plug the 14718 to the 14716 (Ignition) Plug the 14719 to the 14717 (Ignition)	
☐	AV_P-15	Rocket avionics insertion	Insert the Recovery/Avionics in the rocket passing through the Recovery side Plug the 14701 to the 14703 (Interconnection) Plug the Batteries to the CP Take the 14720, pass it through the little hole on the debugger structure and scotch it outside on the tube Mount the 14707 on the debugger structure in the rocket Plug the 14705 to the 14706 (Airbrakes)	
☐	AV_P-16	Avionics start up	When the rocket is fully mounted, pursue with the start up procedure 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01	Section 3.1

Ground Station				
☐	GS_P-06	telemetry check	Verify that both telemetry link are acquired with a good level	
☐	GS_P-07	logging check	10 min before the flight, check that the recording of the data is enabled	

Airbrakes				
☐	AB_P-03	Pre-flight check	External procedure: 2018_SE_OP_0008_AIRBRAKES_PROCEDURES_R01	Section 2.3.2
☐	AB_P-04	Launch check	External procedure: 2018_SE_OP_0008_AIRBRAKES_PROCEDURES_R01	Section 2.3.3

Payload				
☐	PL_P-11	Chute folding and assembly	Correct chute folding procedure and proper double checking. Done with Recovery.	
☐	PL_P-12	Triggers for data acquisition test	Test if all the triggers for the data acquisition are working as intended: accelerometer trigger, jumper cable trigger. the first is tested via a simulated acceleration reading injected into the program and the second is physically pulled. Both trigger must wake up the payload's electronic and must trigger the data acquisition of the experiment. readout on the serial monitor.	
☐	PL_P-13	Battery check	Check if the battery are fully charged using a multimeter. also check the battery health for any potential defects and change them if any doubt occurs.	Tools needed: PL-21
☐	PL_P-14	Payload Telemetry check	Check if the telemetry of the payload is working as intended. Setting the pressure reading for the day to calibrate the pressure sensors.	Tools needed: PL-17 PL-18
☐	PL_P-15	Payload insertion	Installation of the payload in the rocket. check if everything slides smoothly, as intended.	
Propulsion				
☐	PR_P-01	Motor Assembly Camping	Wear protective glasses and gloves along all the assembly Follow the instructions from the Aerotech assembly Guidelines.	Required Procedure: RMS75/7680-1850W_Assembly-instructions.pdf Tool Needed: 1x Disposable gloves 1x Protective glasses Check above procedure
☐	PR_P-02	Double igniter assembly camping	Assemble two FirstFire igniter with tape and attach the two ends of wires in separate colour (red, blue) Check the igniters internal resistance: Should be around 3Ω	Tool Needed: 1x Colour tape
☐	PR_P-03	Motor loading in the rocket	Apply temperature sensor on the casing surface Slide slowly the motor in the insulator phenolic tube Screw manually the rear retainer (Aft) ring	Tool Needed: 1x Temperature Sensor
☐	PR_P-04	Igniter arming on launch pad	Change protective gloves Insert the double igniter system in the motor by the nozzle Connect the igniter wires with the corresponding colour to the corresponding connector of the pad	Tool Needed: 1x (Eventually) Disposable gloves

3.2 Launch time

3.2.1 Location: On pad

TIMEFRAME: 9AM 21th of June
TASKS DISTRIBUTION:

Emilien Mingard	Install rocket on the launch pad
Clement Nussbaumer	Arming Recovery, turn the igniters board switch on
Alexandre Looten	Igniter installation and arming

3.2.2 Location: At the Ground Station

TIMEFRAME: 9AM 21th of June
TASKS DISTRIBUTION:

Ludovic Gizendaner	Confirm signal reception, give the final GO after battery parameters check.

3.3 After launch

TIMEFRAME: 9AM-5PM 21th of June
TASKS DISTRIBUTION:

Emilien Mingard	Structure disassembly and integrity check
Malo Goury du Roslan	Recovery cleaning and parachute folding
Loup Cordey	Payload recovery
Christian Cardinaux	Airbrake check
Clément Nussbaumer	Avionic shutdown and check
Ludovic Gizendaner	Ground station shut down
Alexandre Looten	Motor disassembly and cleaning

	ID	Task Name	Description	Requirements
Structure				
☐	ST_P-15	After Launch Check: Upper Airframe Assembly	Check if glued parts are unglued, broken or damaged. Look for sign of internal delamination. Check for plastic deformation or fractured parts Spare Parts Needed: 1xST-03	Following parts are supposed to be glued: 2x11604 Thin List 2x11605 Thick List 1x11301 Tube Ring 1x11602 Bague Renfort 1x11603 Rail Triangle Following parts are supposed to be assembled: 1x11610 Launch Lug Following parts are subjected to possible delamination: 1x11601 Upper Airframe Following parts are subjected to possible failure or deformation: 2x11604 Thin List 2x11605 Thick List 1x11301 Tube Ring 1x11602 Bague Renfort 1x11603 Rail Triangle
☐	ST_P-16	After Launch Check: Lower Airframe Assembly	Check if glued parts are unglued, broken or damaged. Thrust plates should be screwed. Check for sign of delamination or failure mode. Spare Parts Needed: 1xST-15	Following parts are supposed to be glued: 2x11409 Sandwich Centering Ring 2x11301 Tube Ring Following parts are supposed to be assembled: 2x11502 Thrust Plate 6x11503 Vis M6x14 6p Creux Following parts are subjected to possible delamination: 1x11501 Lower Airframe 2x11409 Sandwich Centering Ring Following part are subjected to possible failure: 2x11301 Tube Ring 2x11502 Thrust Plate
☐	ST_P-17	After Launch Check: Fins Module	Check about fins module assembly. Look for sign of delamination or mechanical failure. The boat tail can be broken. Spare Parts Needed: 1xST-10	Following parts are supposed to be assembled: 1x11401 Upper Ring 1x11402 Middle Ring 1x11403 Lower Ring 3x11405 Fins 3x11408 Third of Panel 27x11411 Vis M4x8 Tête Ronde 9x11412 Vis M4x20 6p Creux

				9x11413 Ecrou Locking M4 3x11415 Insert M3 1x11417 Launch Lug Following part are subjected to possible delamination: 3x11405 Fins 3x11408 Third of Panel Following part are subjected to mechanical failure: 1x11401 Upper Ring 1x11402 Middle Ring 1x11403 Lower Ring 3x11415 Insert M3 1x11417 Launch Lug
☐	ST_P-18	After Launch: Nose Cone	Check the glued tip. Look for sign of delamination	Following part is supposed to be glued: 1x11102 Insert Tip Following part is subjected to possible delamination: 1x11101 Nose Cone Shell 120x500

Recovery				
☐	RE_P-11	Disconnect Parachute Chain	Disconnect Nose cone from Kevlar Strap, Parachute from Electrical Shock cord	Tools needed: RE-35
☐	RE_P-12	Disassemble Reefing Assembly	Take the line cutters out of the reefing body	Tools needed: RE-38
☐	RE_P-13	Fold parachute	Fold the parachute back in the deployment bag	
☐	RE_P-14	Disassemble Recovery structure	Disassemble the connectors, the eyelets, the harness	Tools needed: RE-36 RE-35
☐	RE_P-15	Clean RAPTOR	Disassemble and clean RAPTORS	Tools needed: RE-35 RE-37 RE-40 RE-41 RE-43 RE-44
☐	RE_P-16	Clean AEROCON line cutter	Disassemble and clean the line cutters	Tools needed: RE-35 RE-37 RE-40 RE-41 RE-42 RE-43 RE-44

Avionic				
☐	AV_P-17	Unarming	Turn the arming switches off.	
☐	AV_P-18	Power off	Disconnect the batteries	
☐	AV_P-19	Data recovery	Take both SD cards and place them in their box. Make a copy on a computer in a clean environment.	
☐	AV_P-20	Visual inspection	Visually check the PCB for any mechanical failure or electrical	If anything seems wrong, apply pre-flight checks and verify wiring 2018_SE_OP_0006_AVIONIC_PROCEDURES_R01

Ground Station				
☐	GS_P-05	Stop reception	Stop logging, close program and save flight data	
☐	GS_P-06	Shut down	Power the ground station off	

Airbrakes				
☐	AB_P-05	Post-flight check	External procedure: 2018_SE_OP_0008_AIRBRAKES_PROCEDURES_R01	Section 2.3.4

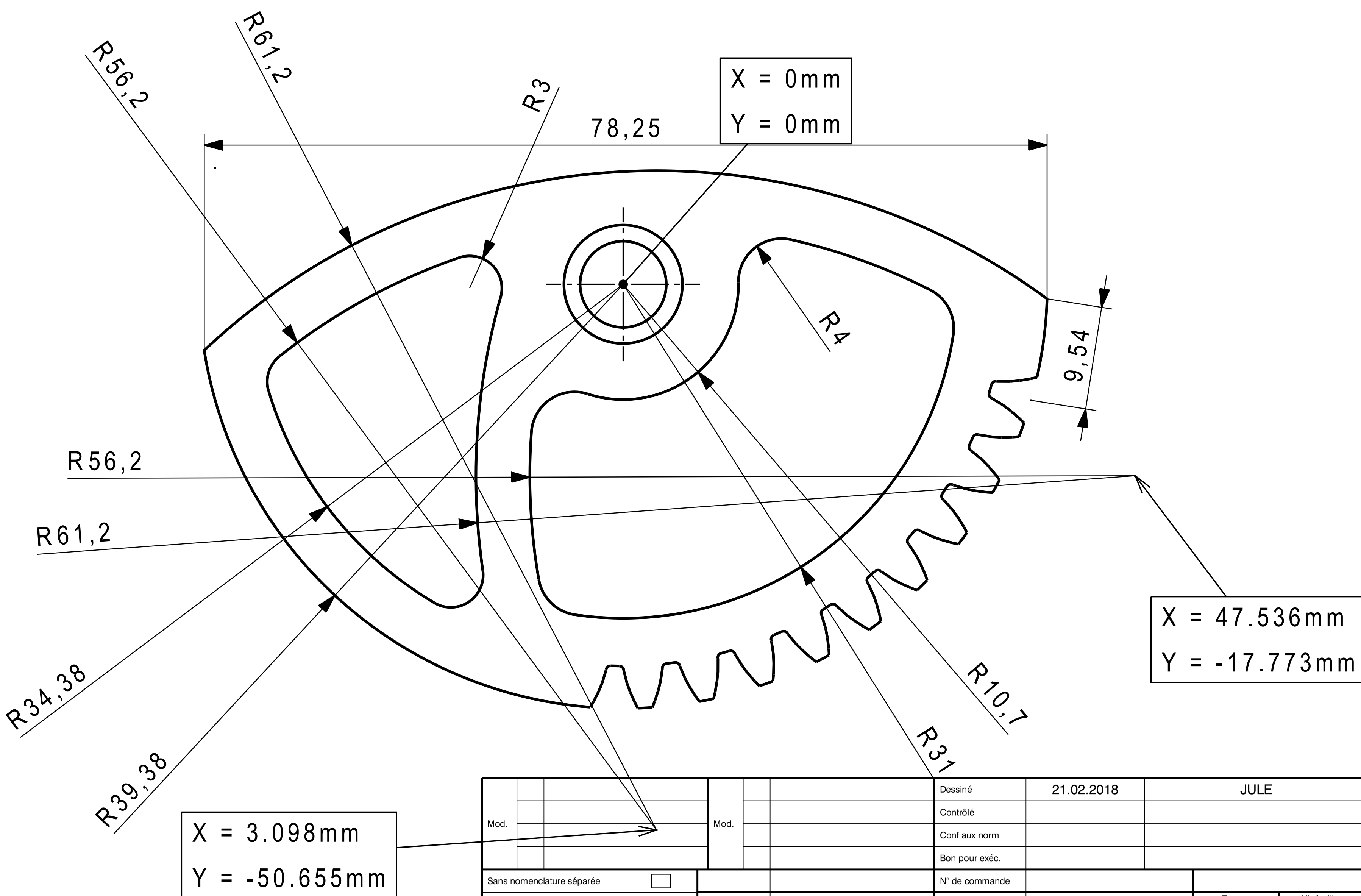
Payload				
☐	PL_P-15	Payload retrieval	Check if no part are loosened up after landing, check if any of the battery have been punctured before handling of the payload.	
☐	PL_P-16	Payload data retrieval	Disconnect the battery and store safely the data.	

Propulsion				
☐	PR_P-05	Motor disassembly & cleaning	Forewarning: Motor casing temperature might be high! Disassemble the motor in reverse order of assembly using the document provided by Aerotech which includes disassembly guidelines as well. Remember to use the grease and pipe wrench, and to clean with wet wipes all the hardware and sort out consumed parts.	
☐	PR_P-06	Waste management	Wait around 30 minutes for the motor to cool down. Wear protective glasses and gloves. Withdraw, neutralize and sort out consumables from re-usable using the procedure (do not leave any leftover propellant in the	Required Procedure: 2018_PP_SP_0001_Reload-Igniter_Manipulation Tool Needed: 1x Protective glasses or sunglasses 1x Disposable gloves

			casing).	
Logistic				
☐	LO_P-04	Materials	Bring all the technical materials back to the hotel	Everything
☐	LO_P-05	Tent	Unstall the tent and table at the end of the event.	Tent and table

F. Engineering Drawings

1. Airbrakes Subsystem



Dessiné	21.02.2018	JULE	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Matiere	EN AC-AlSi7Mg0.3 T6	Origine	
Masse	0.023 kg	Remplace	

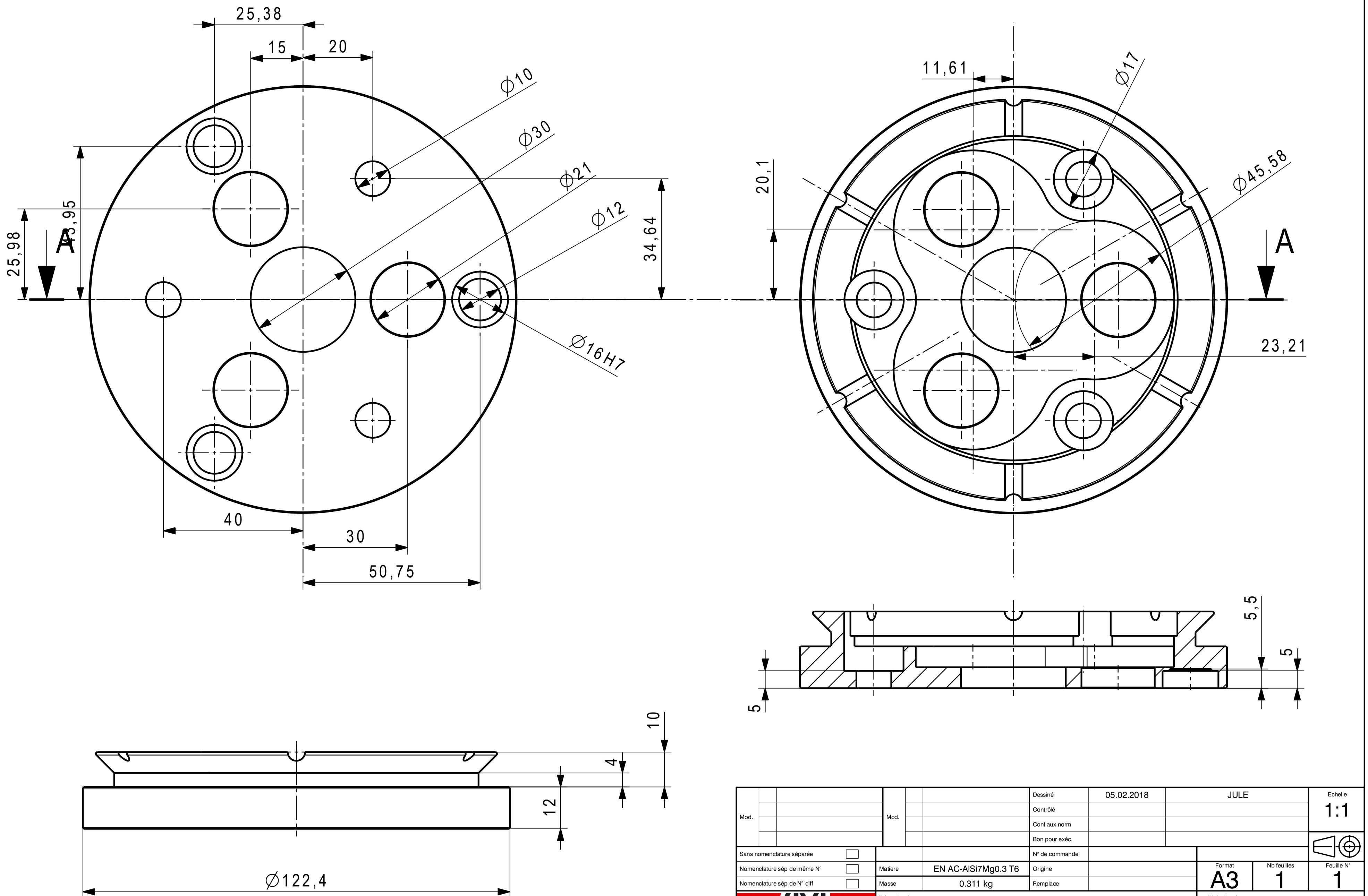
Sans nomenclature séparée		
Nomenclature sép de même N°		
Nomenclature sép de N° diff		

Format	Nb feuilles	Feuille N°
A4	1	1

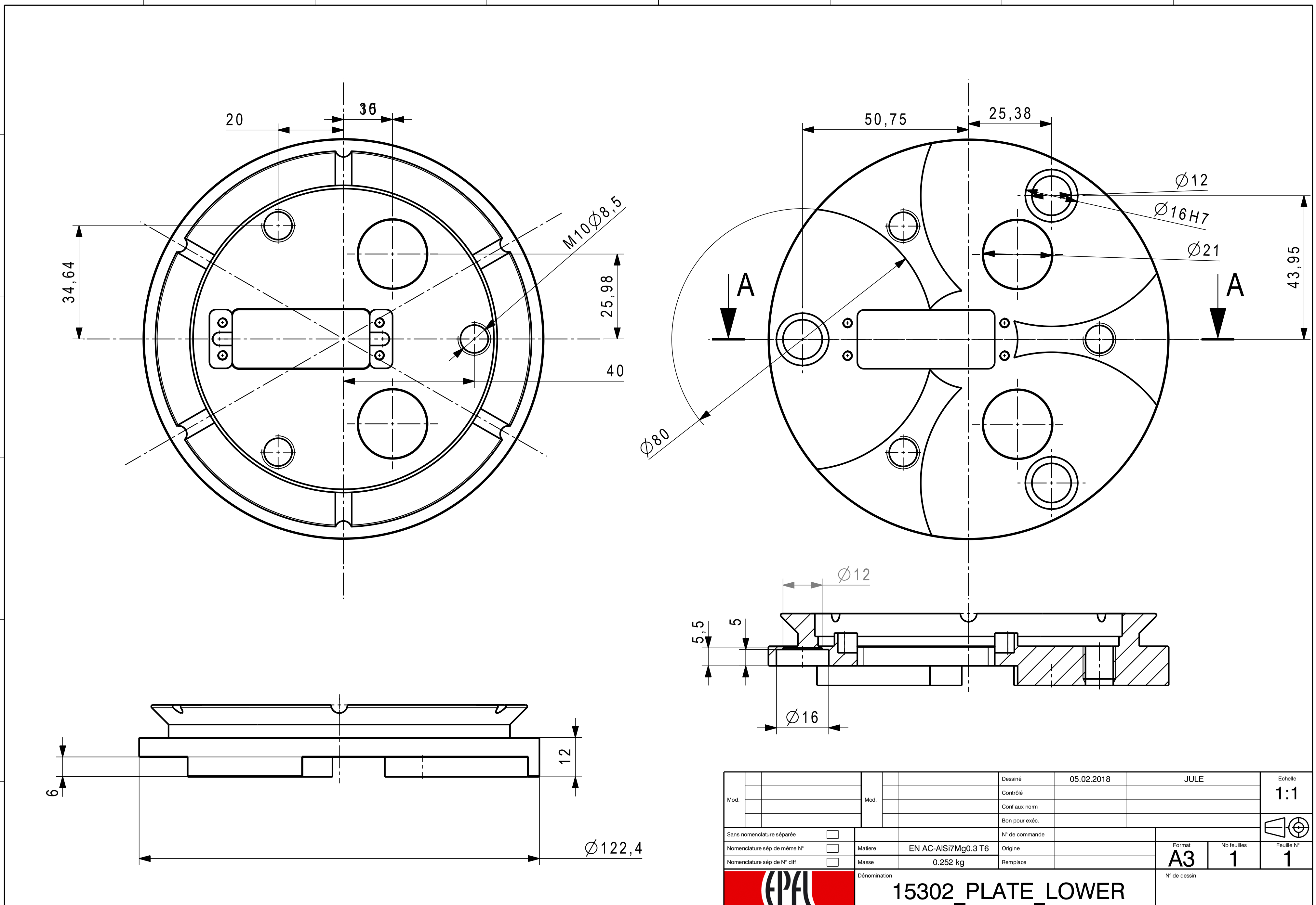
Dénomination

15202_GEARED_WING_T43

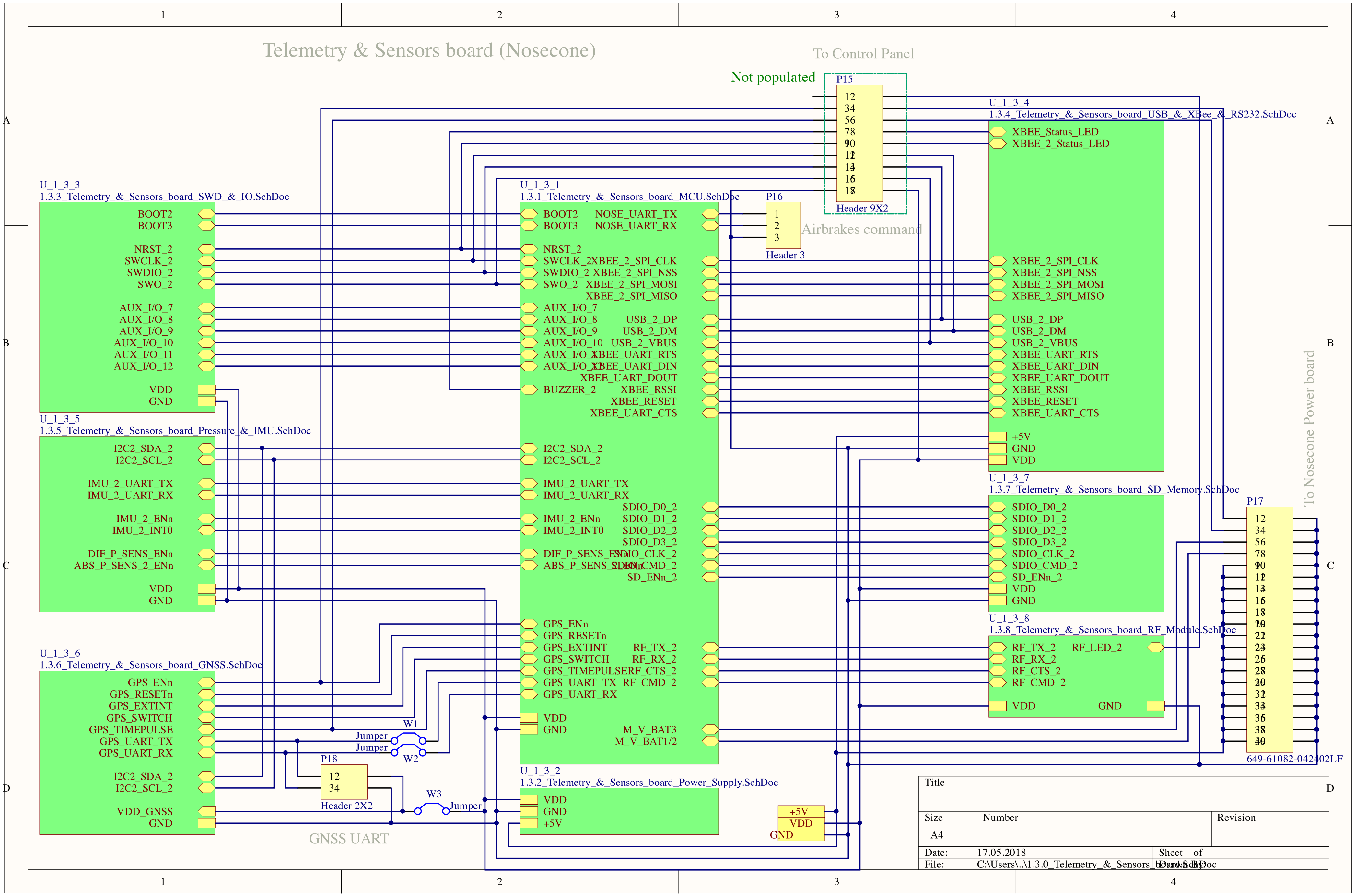
N° de dessin

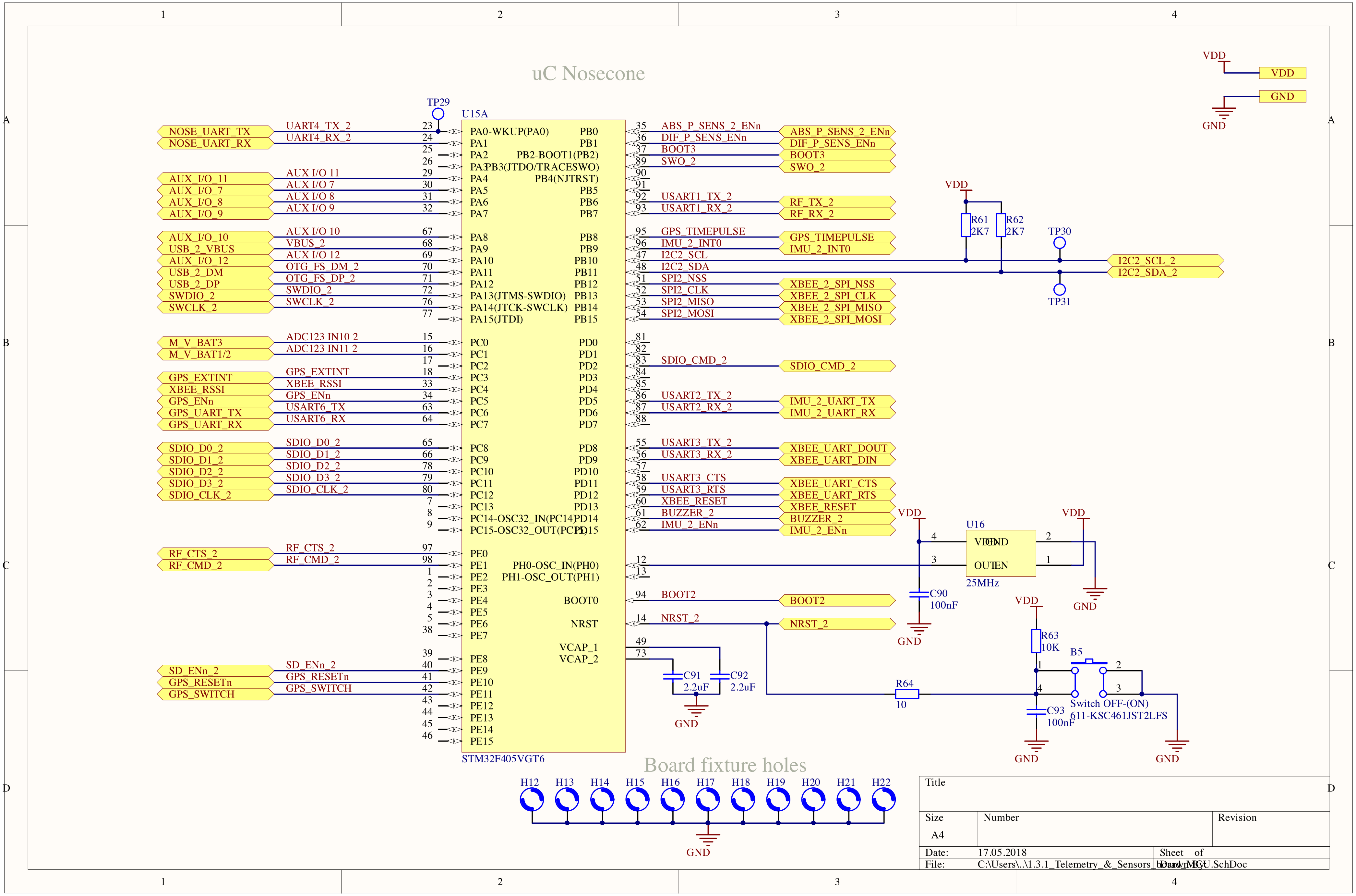


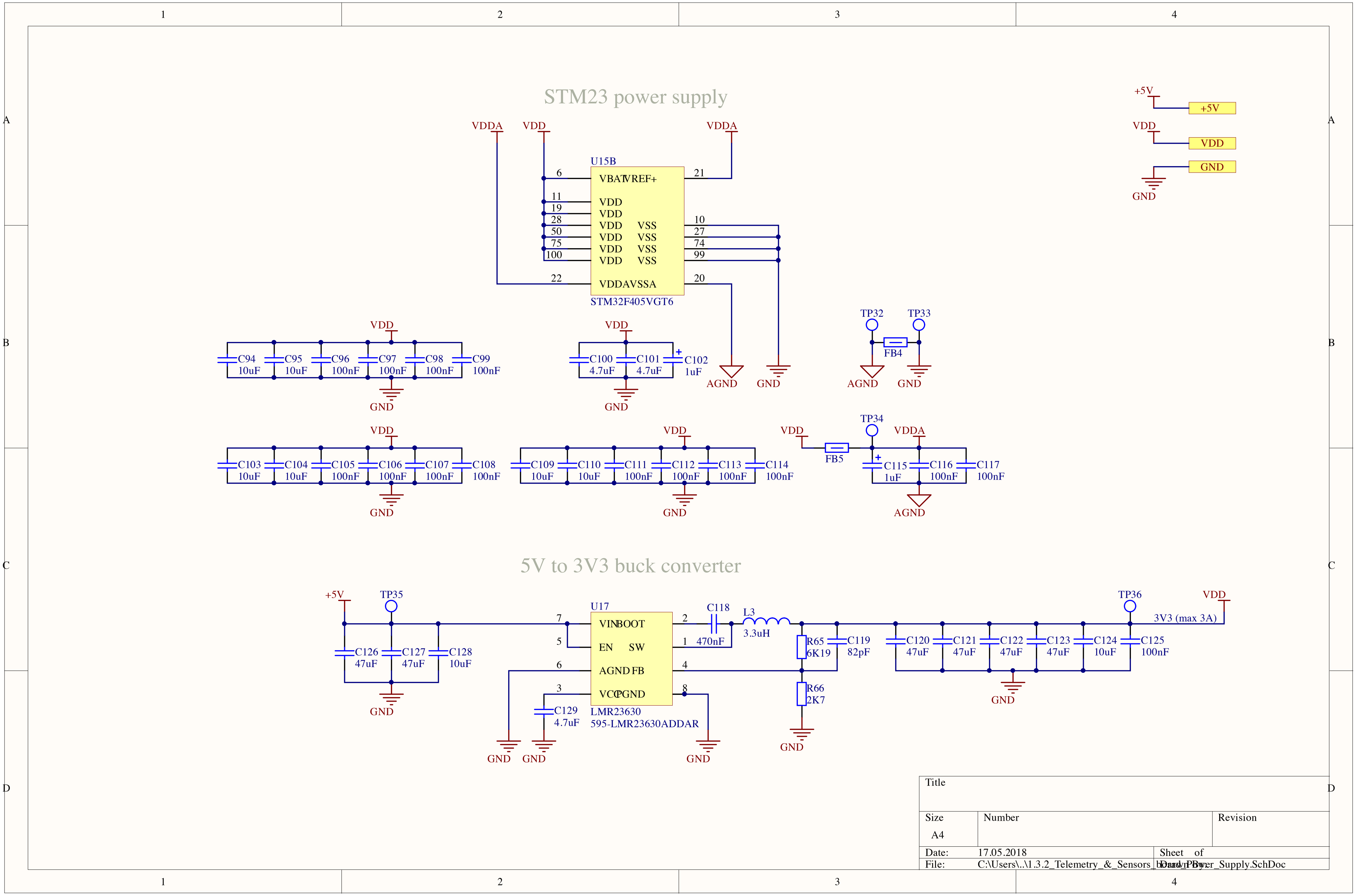
Mod.	Mod.	Dessiné	05.02.2018	JULE	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: EN AC-AlSi7Mg0.3 T6	Origine		Format A3	Nb feuilles 1 / Feuille N° 1
Nomenclature sép de N° diff	Masse: 0.311 kg	Remplace			
EPFL	Dénomination: 15301_PLATE_UPPER			N° de dessin	

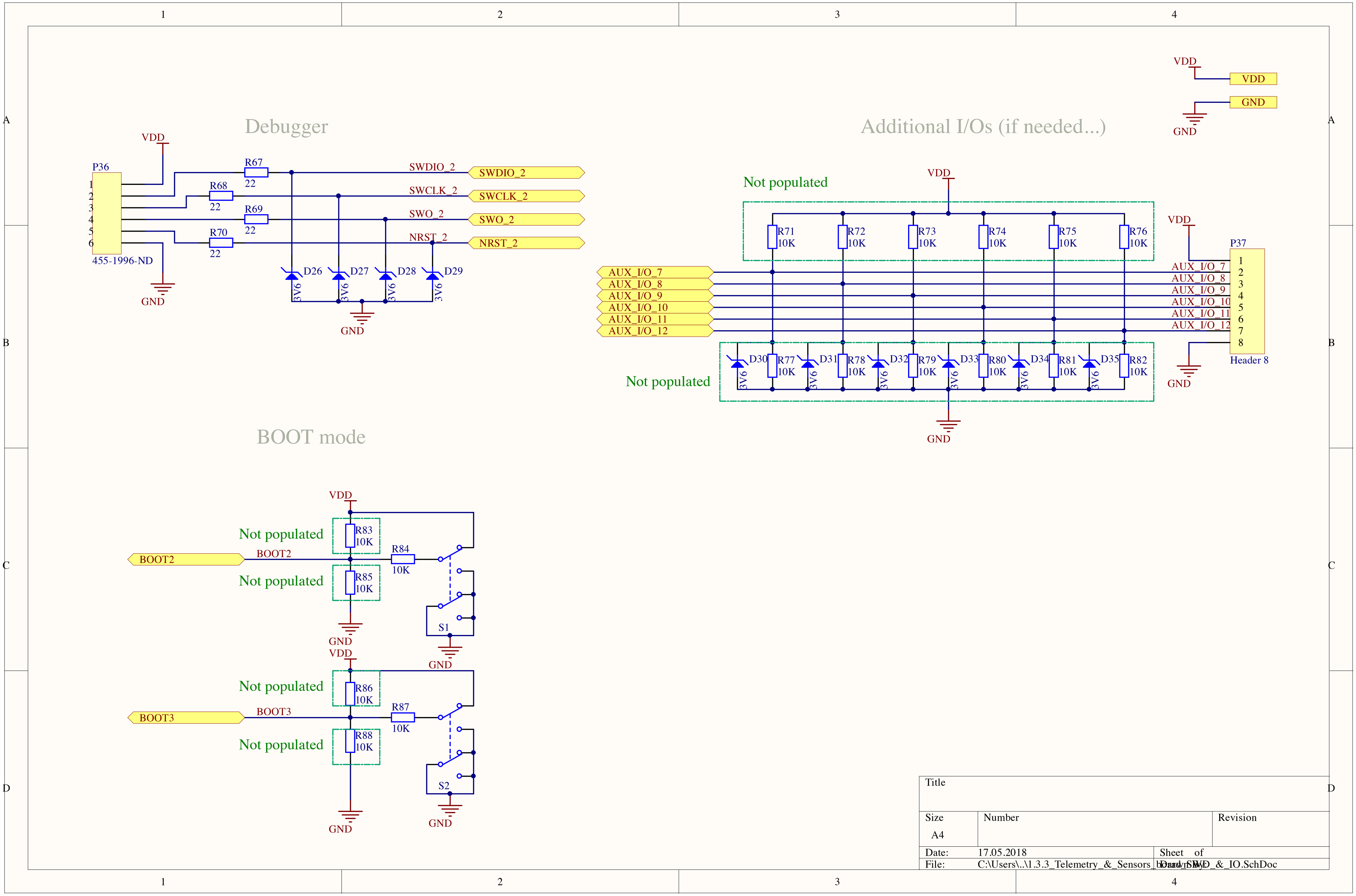

20
36
34,64
25,98
40
M10∅8,5
50,75
25,38
∅12
∅16H7
∅21
43,95
A
A
∅80
∅12
5,5
5
∅16
12
6
∅122,4
Mod.
Mod.
Dessiné
05.02.2018
JULE
Contrôlé
Conf aux norm
Bon pour exéc.
N° de commande
Echelle
1:1
Sans nomenclature séparée
Nomenclature sép de même N°
Nomenclature sép de N° diff
Matiere
EN AC-AlSi7Mg0.3 T6
Masse
0.252 kg
Origine
Remplace
Format
A3
Nb feuilles
1
Feuille N°
1
Dénomination
15302_PLATE_LOWER
N° de dessin

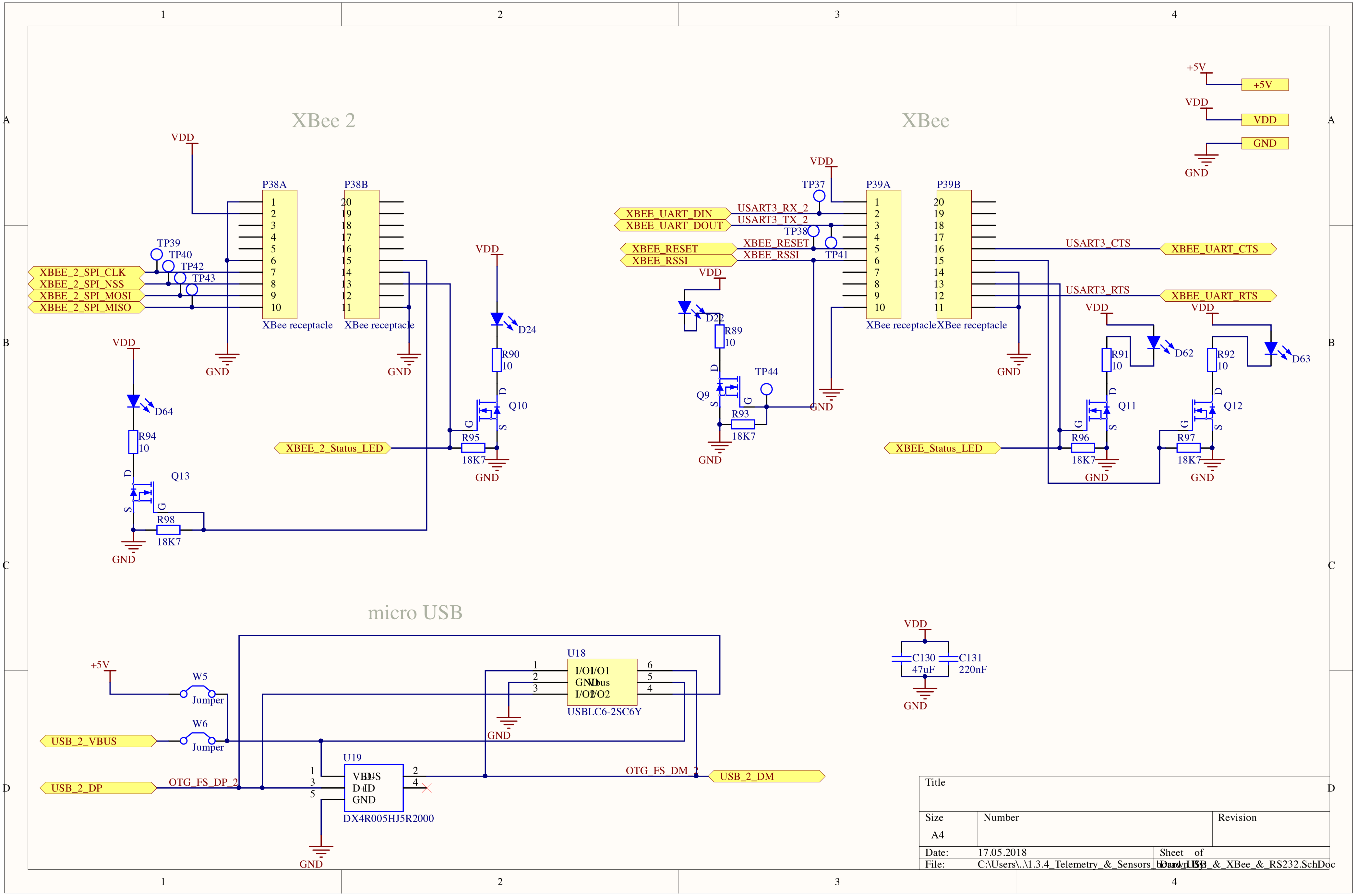
1. Avionics Subsystem

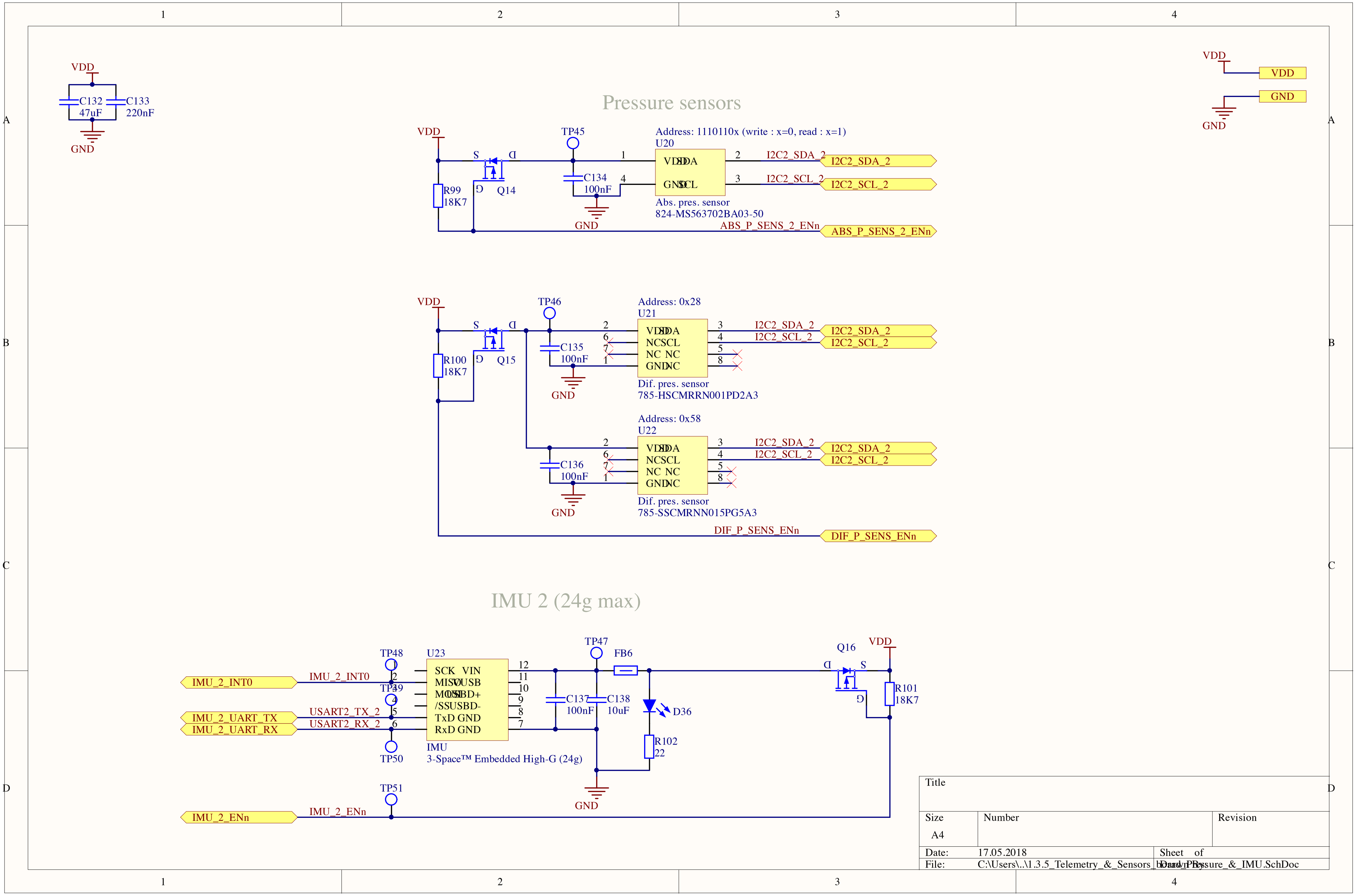

Telemetry & Sensors board (Nosecone)
To Control Panel
Not populated
P15
Header 9X2
P16
Header 3
Airbrakes command
U_1_3_3
1.3.3_Telemetry_&_Sensors_board_SWD_&_IO.SchDoc
U_1_3_1
1.3.1_Telemetry_&_Sensors_board_MCU.SchDoc
U_1_3_4
1.3.4_Telemetry_&_Sensors_board_USB_&_XBee_&_RS232.SchDoc
U_1_3_5
1.3.5_Telemetry_&_Sensors_board_Pressure_&_IMU.SchDoc
U_1_3_7
1.3.7_Telemetry_&_Sensors_board_SD_Memory.SchDoc
U_1_3_8
1.3.8_Telemetry_&_Sensors_board_RF_Module.SchDoc
U_1_3_6
1.3.6_Telemetry_&_Sensors_board_GNSS.SchDoc
U_1_3_2
1.3.2_Telemetry_&_Sensors_board_Power_Supply.SchDoc
To Nosecone Power board
P17
649-61082-042402LF
W1
W2
W3
Jumper
P18
Header 2X2
GNSS UART
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.0_Telemetry_&_Sensors_board.SchDoc


uC Nosecone
U15A
STM32F405VGT6
TP29
NOSE_UART_TX
NOSE_UART_RX
UART4_TX_2
UART4_RX_2
AUX_I/O_11
AUX_I/O_7
AUX_I/O_8
AUX_I/O_9
AUX_I/O_10
USB_2_VBUS
AUX_I/O_12
USB_2_DM
USB_2_DP
SWDIO_2
SWCLK_2
VBUS_2
OTG_FS_DM_2
OTG_FS_DP_2
M_V_BAT3
M_V_BAT1/2
ADC123 IN10 2
ADC123 IN11 2
GPS_EXTINT
XBEE_RSSI
GPS_ENn
GPS_UART_TX
GPS_UART_RX
USART6_TX
USART6_RX
SDIO_D0_2
SDIO_D1_2
SDIO_D2_2
SDIO_D3_2
SDIO_CLK_2
RF_CTS_2
RF_CMD_2
SD_ENn_2
GPS_RESETn
GPS_SWITCH
PA0-WKUP(PA0)
PA1
PA2
PA3
PB3(JTDO/TRACESWO)
PB2-BOOT1(PB2)
PB4(NJTRST)
PA4
PA5
PA6
PA7
PA8
PA9
PA10
PA11
PA12
PA13(JTMS-SWDIO)
PA14(JTCK-SWCLK)
PA15(JTDI)
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
PC8
PC9
PC10
PC11
PC12
PC13
PC14-OSC32_IN(PC14)
PC15-OSC32_OUT(PC15)
PE0
PE1
PE2
PE3
PE4
PE5
PE6
PE7
PE8
PE9
PE10
PE11
PE12
PE13
PE14
PE15
PH0-OSC_IN(PH0)
PH1-OSC_OUT(PH1)
BOOT0
NRST
VCAP_1
VCAP_2
PB0
PB1
PB5
PB6
PB7
PB8
PB9
PB10
PB11
PB12
PB13
PB14
PB15
PD0
PD1
PD2
PD3
PD4
PD5
PD6
PD7
PD8
PD9
PD10
PD11
PD12
PD13
PD14
PD15
ABS_P_SENS_2_ENn
DIF_P_SENS_ENn
BOOT3
SWO_2
USART1_TX_2
USART1_RX_2
RF_TX_2
RF_RX_2
GPS_TIMEPULSE
IMU_2_INT0
I2C2_SCL
I2C2_SDA
SPI2_NSS
SPI2_CLK
SPI2_MISO
SPI2_MOSI
XBEE_2_SPI_NSS
XBEE_2_SPI_CLK
XBEE_2_SPI_MISO
XBEE_2_SPI_MOSI
SDIO_CMD_2
USART2_TX_2
USART2_RX_2
IMU_2_UART_TX
IMU_2_UART_RX
USART3_TX_2
USART3_RX_2
USART3_CTS
USART3_RTS
XBEE_UART_DOUT
XBEE_UART_DIN
XBEE_UART_CTS
XBEE_UART_RTS
XBEE_RESET
BUZZER_2
IMU_2_ENn
BOOT2
NRST_2
VDD
GND
R61
2K7
R62
2K7
TP30
TP31
I2C2_SCL_2
I2C2_SDA_2
U16
VDD
GND
OUT
EN
25MHz
C90
100nF
C91
2.2uF
C92
2.2uF
R63
10K
R64
10
B5
Switch OFF-(ON)
611-KSC461JST2LFS
C93
100nF
Board fixture holes
H12
H13
H14
H15
H16
H17
H18
H19
H20
H21
H22
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.1_Telemetry_&_Sensors_board_MCU.SchDoc

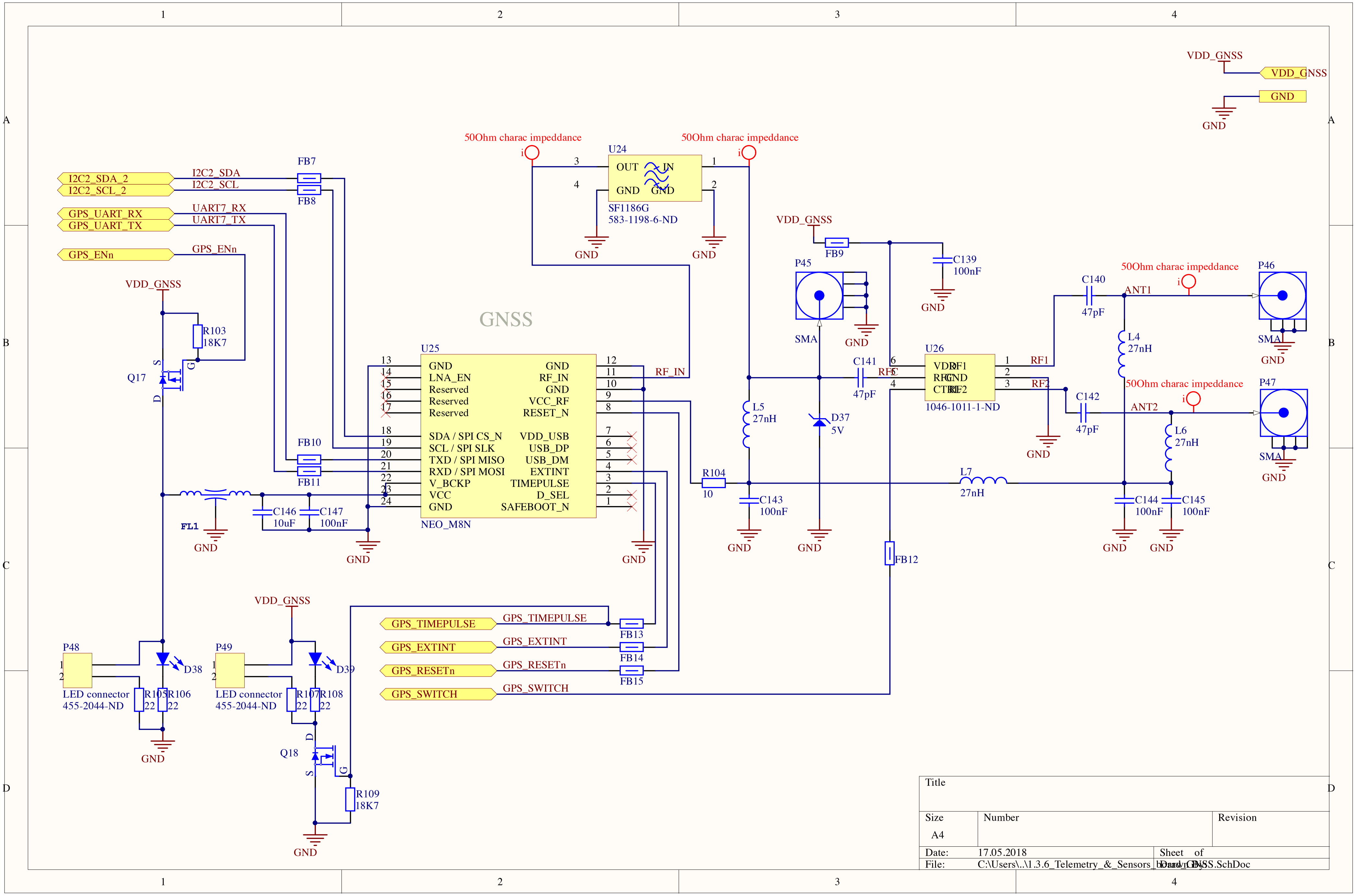

STM23 power supply
U15B
VBAT
VREF+
VDD
VSS
VDDA
VSSA
STM32F405VGT6
VDDA
VDD
GND
AGND
C94 10uF
C95 10uF
C96 100nF
C97 100nF
C98 100nF
C99 100nF
C100 4.7uF
C101 4.7uF
C102 1uF
C103 10uF
C104 10uF
C105 100nF
C106 100nF
C107 100nF
C108 100nF
C109 10uF
C110 10uF
C111 100nF
C112 100nF
C113 100nF
C114 100nF
C115 1uF
C116 100nF
C117 100nF
TP32
TP33
TP34
FB4
FB5
+5V
5V to 3V3 buck converter
TP35
TP36
U17
VIN
BOOT
EN
SW
AGND
FB
VCC
PGND
LMR23630
595-LMR23630ADDAR
C118 470nF
L3 3.3uH
R65 6K19
R66 2K7
C119 82pF
C120 47uF
C121 47uF
C122 47uF
C123 47uF
C124 10uF
C125 100nF
C126 47uF
C127 47uF
C128 10uF
C129 4.7uF
3V3 (max 3A)
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.2_Telemetry_&_Sensors_board_Power_Supply.SchDoc


Debugger
Additional I/Os (if needed...)
BOOT mode
Not populated
P36
455-1996-ND
R67 22
R68 22
R69 22
R70 22
SWDIO_2
SWCLK_2
SWO_2
NRST_2
D26 D27 D28 D29
3V6
VDD
GND
P37
Header 8
AUX_I/O_7
AUX_I/O_8
AUX_I/O_9
AUX_I/O_10
AUX_I/O_11
AUX_I/O_12
R71 R72 R73 R74 R75 R76 10K
R77 R78 R79 R80 R81 R82 10K
D30 D31 D32 D33 D34 D35
BOOT2
BOOT3
R83 10K
R84 10K
R85 10K
R86 10K
R87 10K
R88 10K
S1
S2
Title
Size A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.3_Telemetry_&_Sensors_board_SWD_&_IO.SchDoc
Drawn By:

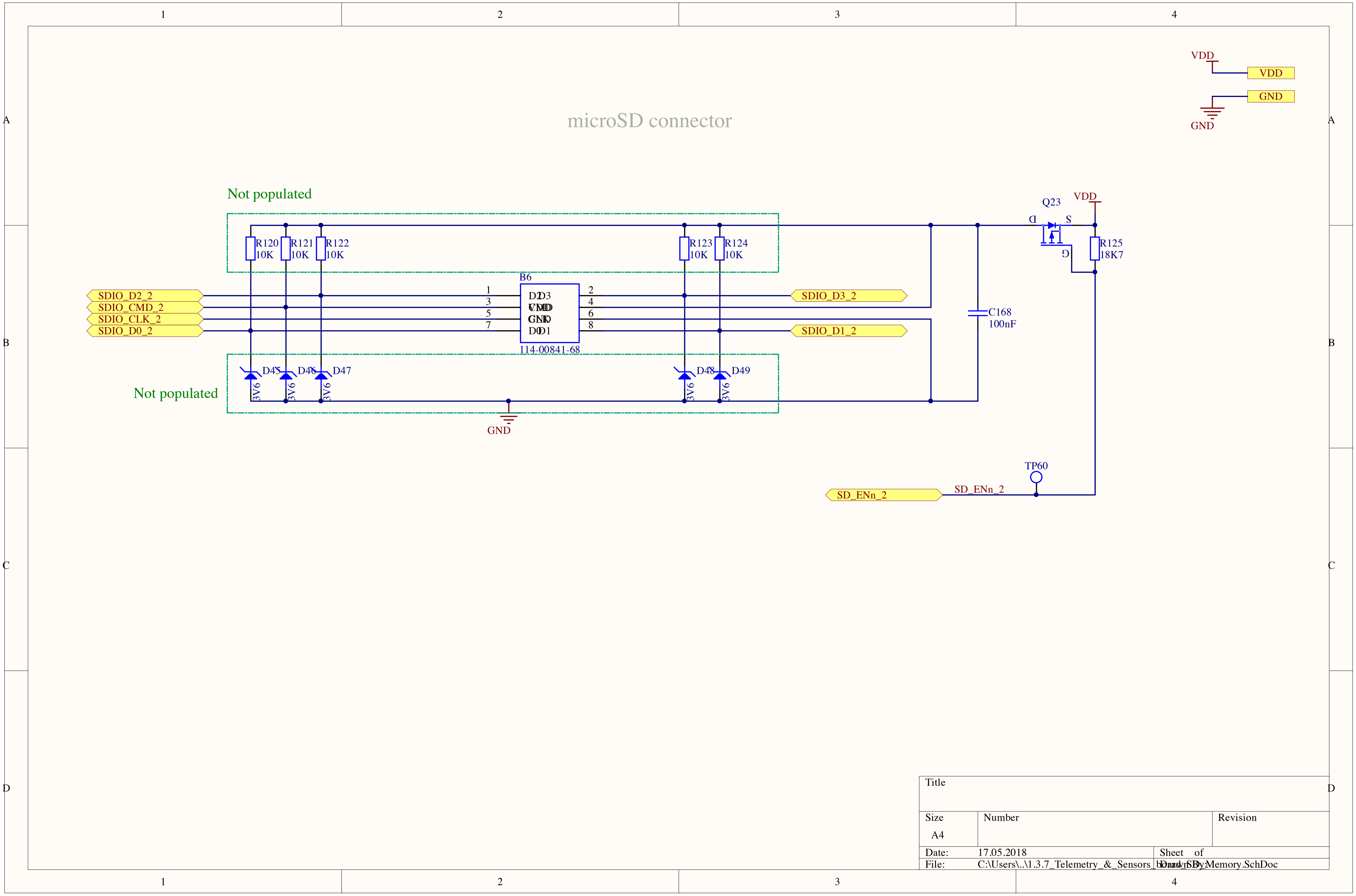

XBee 2
XBee
micro USB
+5V
VDD
GND
P38A
P38B
P39A
P39B
XBee receptacle
XBEE_2_SPI_CLK
XBEE_2_SPI_NSS
XBEE_2_SPI_MOSI
XBEE_2_SPI_MISO
TP39
TP40
TP42
TP43
XBEE_2_Status_LED
D24
R90
10
Q10
R95
18K7
D64
R94
Q13
R98
XBEE_UART_DIN
XBEE_UART_DOUT
XBEE_RESET
XBEE_RSSI
USART3_RX_2
USART3_TX_2
TP37
TP38
TP41
TP44
D22
R89
Q9
R93
USART3_CTS
USART3_RTS
XBEE_UART_CTS
XBEE_UART_RTS
XBEE_Status_LED
D62
D63
R91
R92
Q11
Q12
R96
R97
C130
47uF
C131
220nF
W5
W6
Jumper
USB_2_VBUS
USB_2_DP
USB_2_DM
OTG_FS_DP_2
OTG_FS_DM_2
U18
USBLC6-2SC6Y
I/O1
GND
Vbus
I/O2
U19
DX4R005HJ5R2000
VBUS
D+
D-
ID
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.4_Telemetry_&_Sensors_board\USB_&_XBee_&_RS232.SchDoc



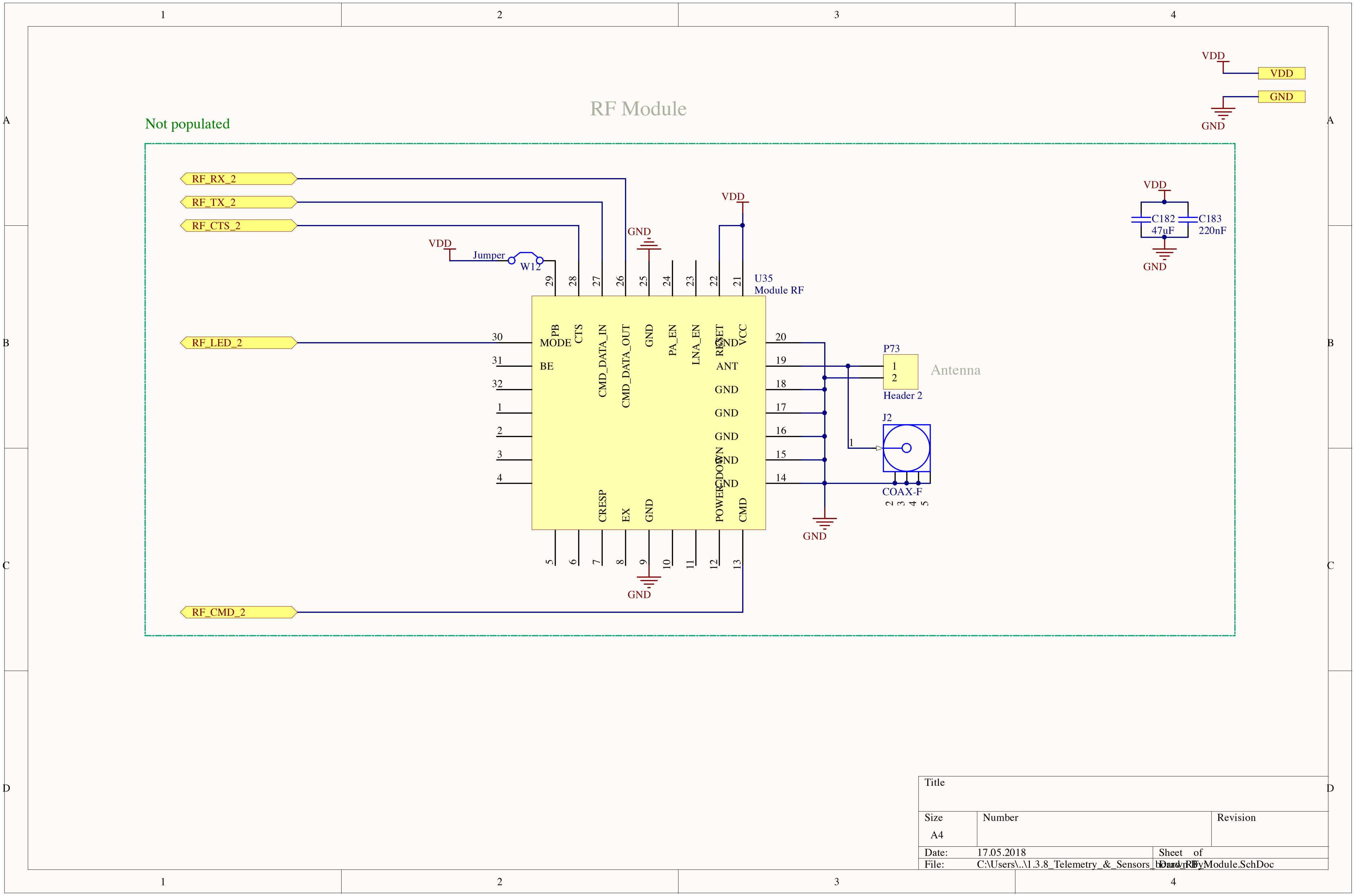
Pressure sensors
Address: 1110110x (write : x=0, read : x=1)
U20
Abs. pres. sensor
824-MS563702BA03-50
Address: 0x28
U21
Dif. pres. sensor
785-HSCMRRN001PD2A3
Address: 0x58
U22
Dif. pres. sensor
785-SSCMRNN015PG5A3
I2C2_SDA_2
I2C2_SCL_2
ABS_P_SENS_2_ENn
DIF_P_SENS_ENn
VDD
GND
C132 47uF
C133 220nF
C134 100nF
C135 100nF
C136 100nF
R99 18K7
R100 18K7
Q14
Q15
TP45
TP46
IMU 2 (24g max)
U23
IMU
3-Space™ Embedded High-G (24g)
IMU_2_INT0
IMU_2_UART_TX
IMU_2_UART_RX
USART2_TX_2
USART2_RX_2
IMU_2_ENn
TP47
TP48
TP49
TP50
TP51
FB6
C137 100nF
C138 10uF
D36
R102 22
Q16
R101 18K7
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.5_Telemetry_&_Sensors_board\Pressure_&_IMU.SchDoc

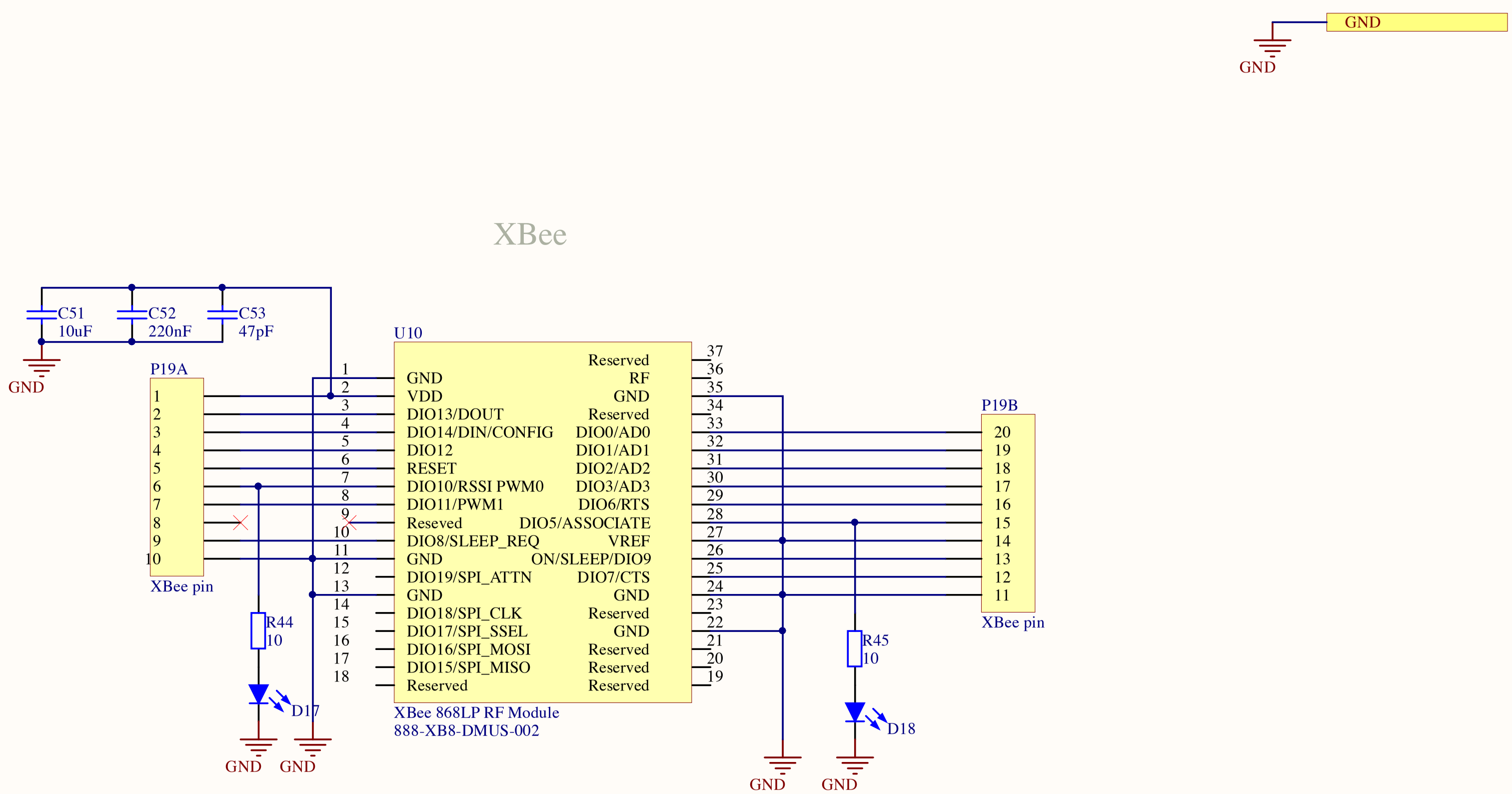


GNSS
U25
NEO_M8N
GND
LNA_EN
Reserved
Reserved
Reserved
SDA / SPI CS_N
SCL / SPI SLK
TXD / SPI MISO
RXD / SPI MOSI
V_BCKP
VCC
GND
RF_IN
VCC_RF
RESET_N
VDD_USB
USB_DP
USB_DM
EXTINT
TIMEPULSE
D_SEL
SAFEBOOT_N
U24
SF1186G
583-1198-6-ND
OUT
IN
50Ohm charac impeddance
U26
1046-1011-1-ND
VDD
RFC
CTRL
RF1
RF2
ANT1
ANT2
RF1
RF2
RFC
RF_IN
P45
P46
P47
SMA
C139 100nF
C140 47pF
C141 47pF
C142 47pF
C143 100nF
C144 100nF
C145 100nF
C146 10uF
C147 100nF
L4 27nH
L5 27nH
L6 27nH
L7 27nH
D37 5V
R104 10
FB7
FB8
FB9
FB10
FB11
FB12
FB13
FB14
FB15
FL1
VDD_GNSS
GND
I2C2_SDA_2
I2C2_SCL_2
I2C2_SDA
I2C2_SCL
GPS_UART_RX
GPS_UART_TX
UART7_RX
UART7_TX
GPS_ENn
Q17
R103 18K7
Q18
R109 18K7
S
G
D
P48
P49
LED connector
455-2044-ND
D38
D39
R105 22
R106 22
R107 22
R108 22
GPS_TIMEPULSE
GPS_EXTINT
GPS_RESETn
GPS_SWITCH
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.6_Telemetry_&_Sensors_board\GNSS.SchDoc
Drawn By:

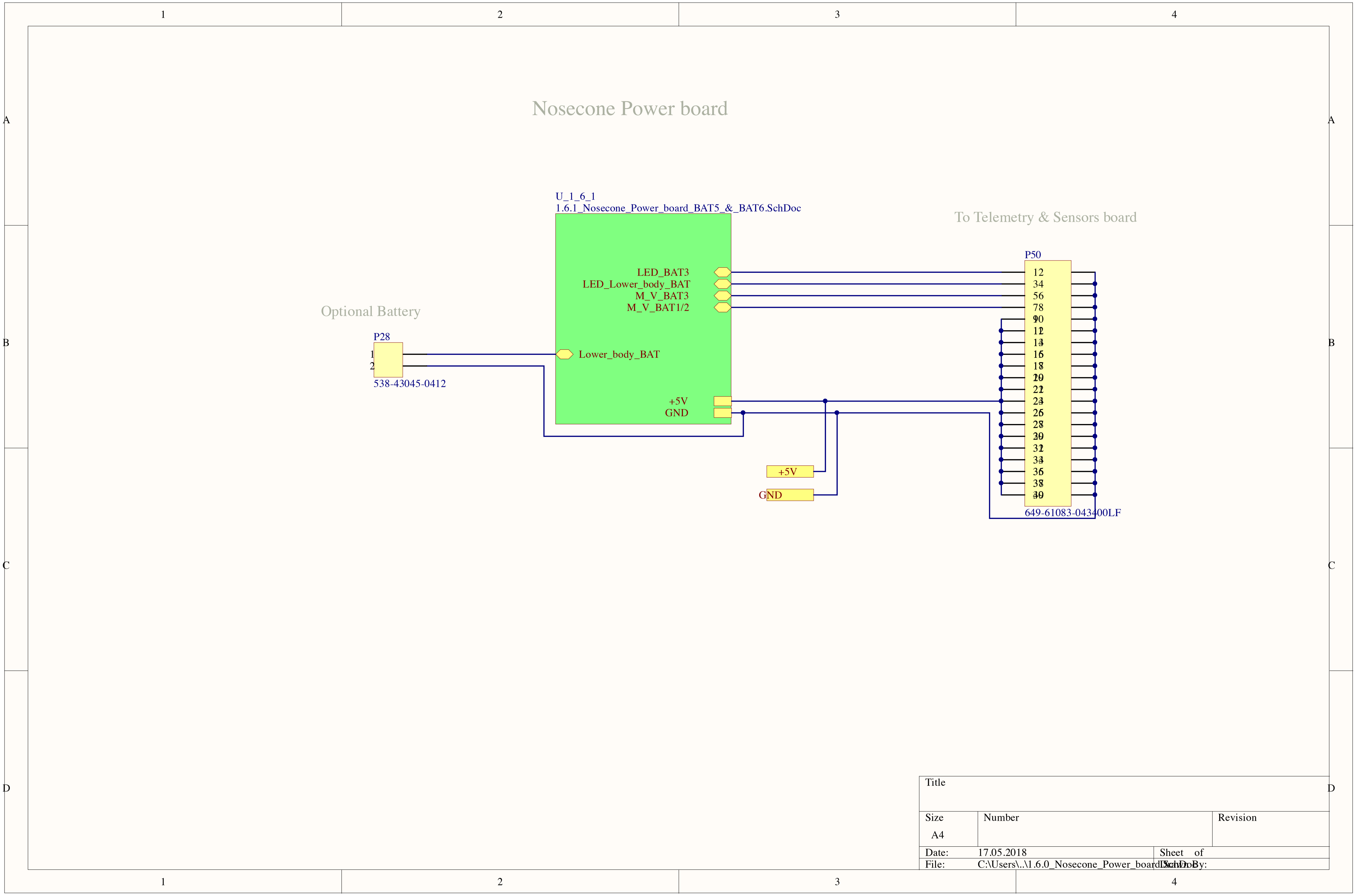


microSD connector
Not populated
Not populated
VDD
GND
R120 10K
R121 10K
R122 10K
R123 10K
R124 10K
R125 18K7
B6
114-00841-68
SDIO_D2_2
SDIO_CMD_2
SDIO_CLK_2
SDIO_D0_2
SDIO_D3_2
SDIO_D1_2
D45 3V6
D46 3V6
D47 3V6
D48 3V6
D49 3V6
Q23
D S G
C168 100nF
TP60
SD_ENn_2
Title
Size A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.7_Telemetry_&_Sensors_board_SD_Memory.SchDoc
Drawn By:

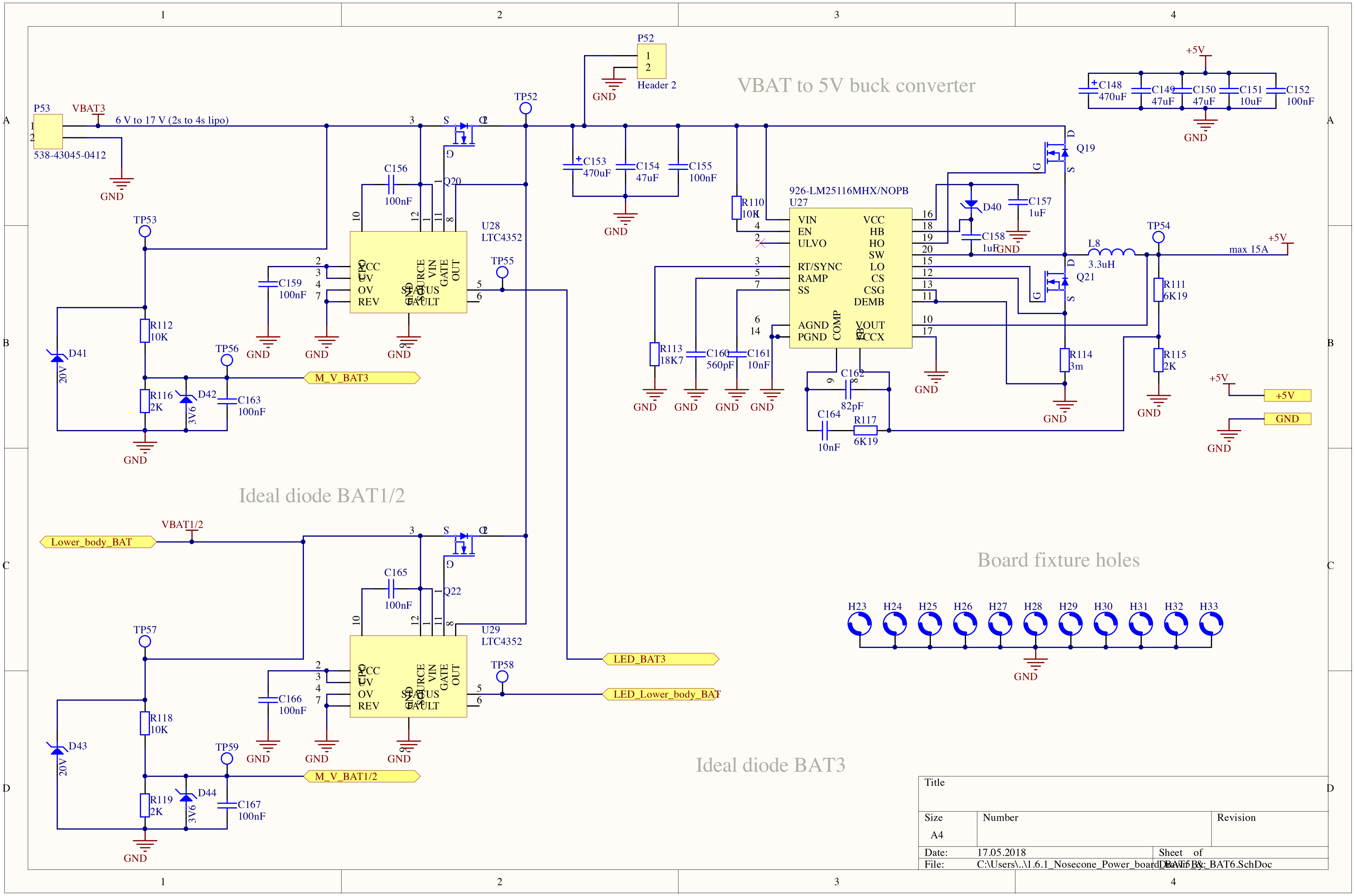

RF Module
Not populated
VDD
GND
RF_RX_2
RF_TX_2
RF_CTS_2
RF_LED_2
RF_CMD_2
Jumper
W12
U35
Module RF
PB
MODE
CTS
CMD_DATA_IN
CMD_DATA_OUT
GND
PA_EN
LNA_EN
RESET
VCC
BE
ANT
POWERDOWN
CRESP
EX
CMD
P73
Header 2
Antenna
J2
COAX-F
C182
47uF
C183
220nF
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.3.8_Telemetry_&_Sensors_board\RF_Module.SchDoc



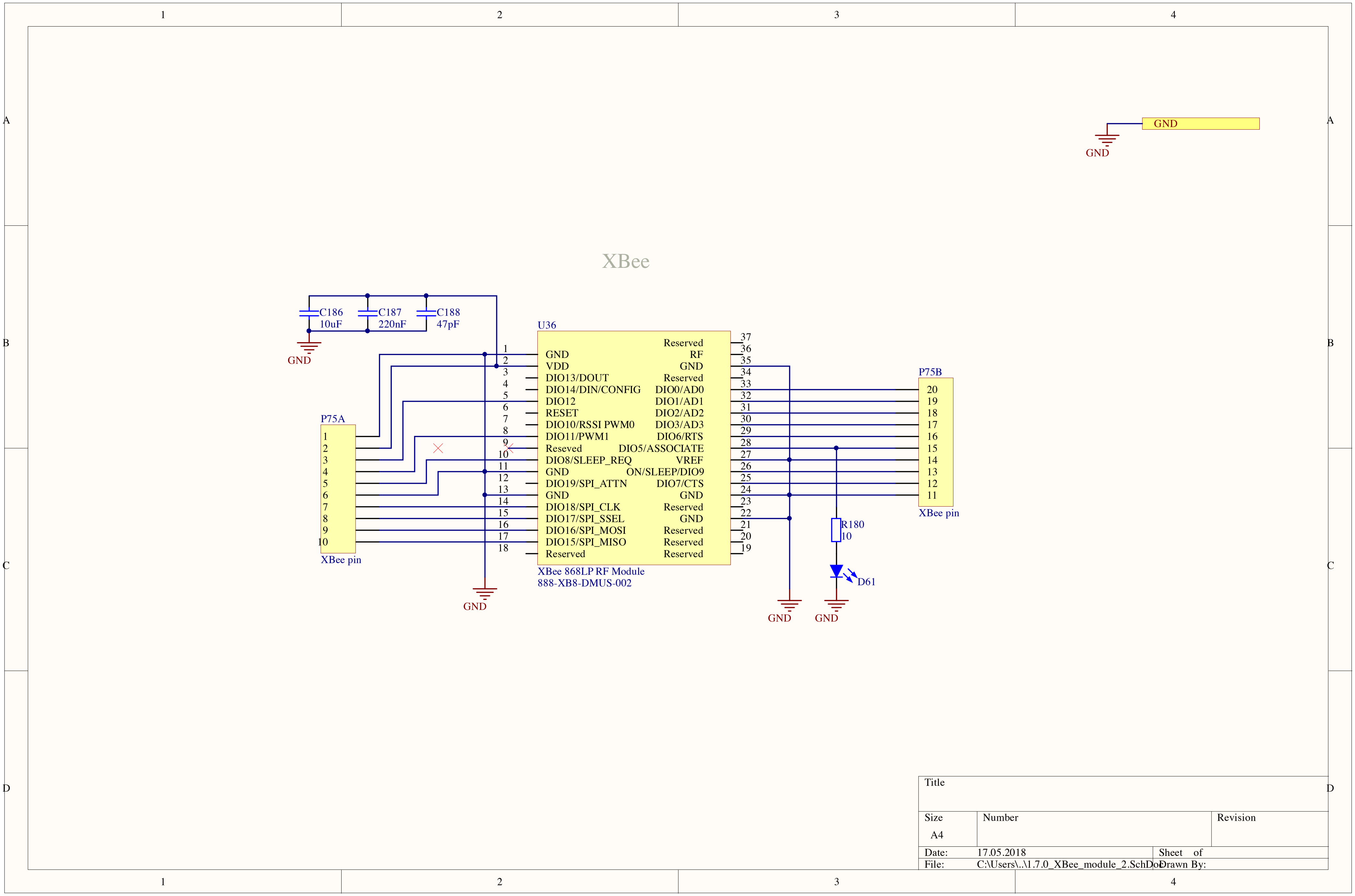
Title		
Size	Number	Revision
A4		
Date:	17.05.2018	Sheet of
File:	C:\Users\..\1.4.0_Xbee_module.SchDoc	Drawn By:

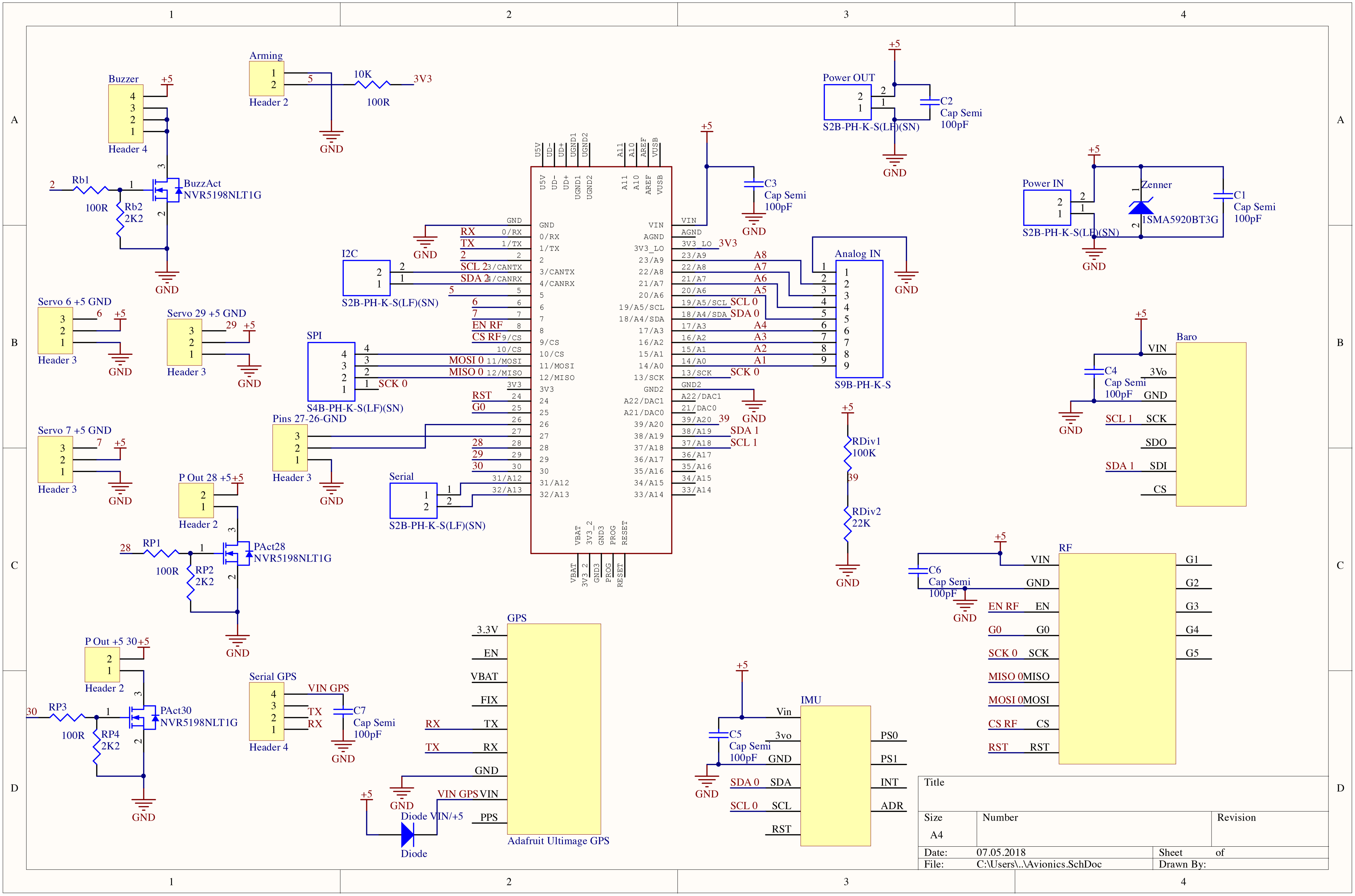


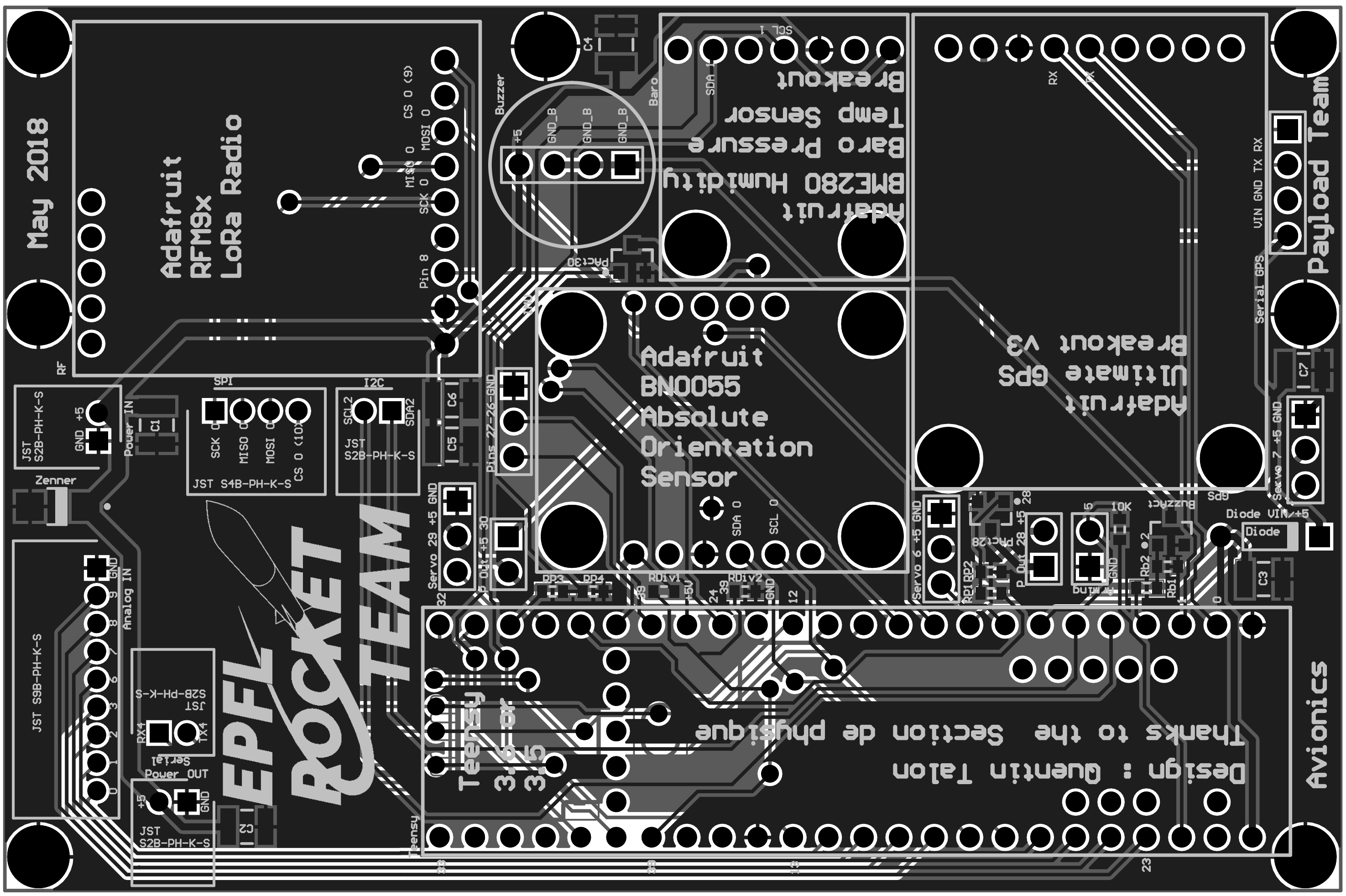
Nosecone Power board
U_1_6_1
1.6.1_Nosecone_Power_board_BAT5_&_BAT6.SchDoc
LED_BAT3
LED_Lower_body_BAT
M_V_BAT3
M_V_BAT1/2
Lower_body_BAT
+5V
GND
Optional Battery
P28
538-43045-0412
To Telemetry & Sensors board
P50
649-61083-043400LF
+5V
GND
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.6.0_Nosecone_Power_board.SchDoc
Drawn By:



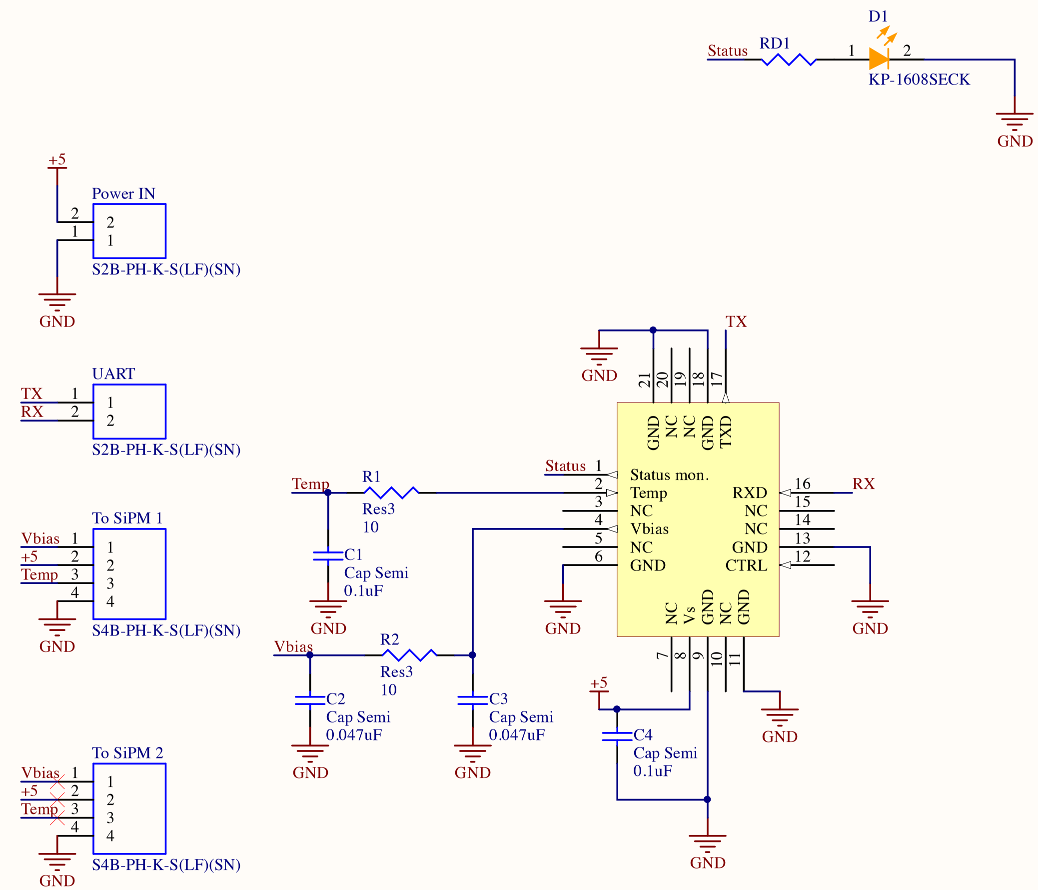
VBAT to 5V buck converter
Ideal diode BAT1/2
Ideal diode BAT3
Board fixture holes
P53
538-43045-0412
VBAT3
6 V to 17 V (2s to 4s lipo)
P52
Header 2
U28
LTC4352
U29
LTC4352
926-LM25116MHX/NOPB
U27
max 15A
L8
3.3uH
M_V_BAT3
M_V_BAT1/2
Lower_body_BAT
VBAT1/2
LED_BAT3
LED_Lower_body_BAT
+5V
GND
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.6.1_Nosecone_Power_board\BAT5 & BAT6.SchDoc


XBee
GND
C186 10uF
C187 220nF
C188 47pF
U36
GND
VDD
DIO13/DOUT
DIO14/DIN/CONFIG
DIO12
RESET
DIO10/RSSI PWM0
DIO11/PWM1
Reseved
DIO8/SLEEP_REQ
GND
DIO19/SPI_ATTN
GND
DIO18/SPI_CLK
DIO17/SPI_SSEL
DIO16/SPI_MOSI
DIO15/SPI_MISO
Reserved
Reserved
RF
GND
Reserved
DIO0/AD0
DIO1/AD1
DIO2/AD2
DIO3/AD3
DIO6/RTS
DIO5/ASSOCIATE
VREF
ON/SLEEP/DIO9
DIO7/CTS
GND
Reserved
GND
Reserved
Reserved
Reserved
XBee 868LP RF Module
888-XB8-DMUS-002
P75A
XBee pin
P75B
XBee pin
R180
10
D61
Title
Size
A4
Number
Revision
Date: 17.05.2018
Sheet of
File: C:\Users\..\1.7.0_XBee_module_2.SchDoc
Drawn By:

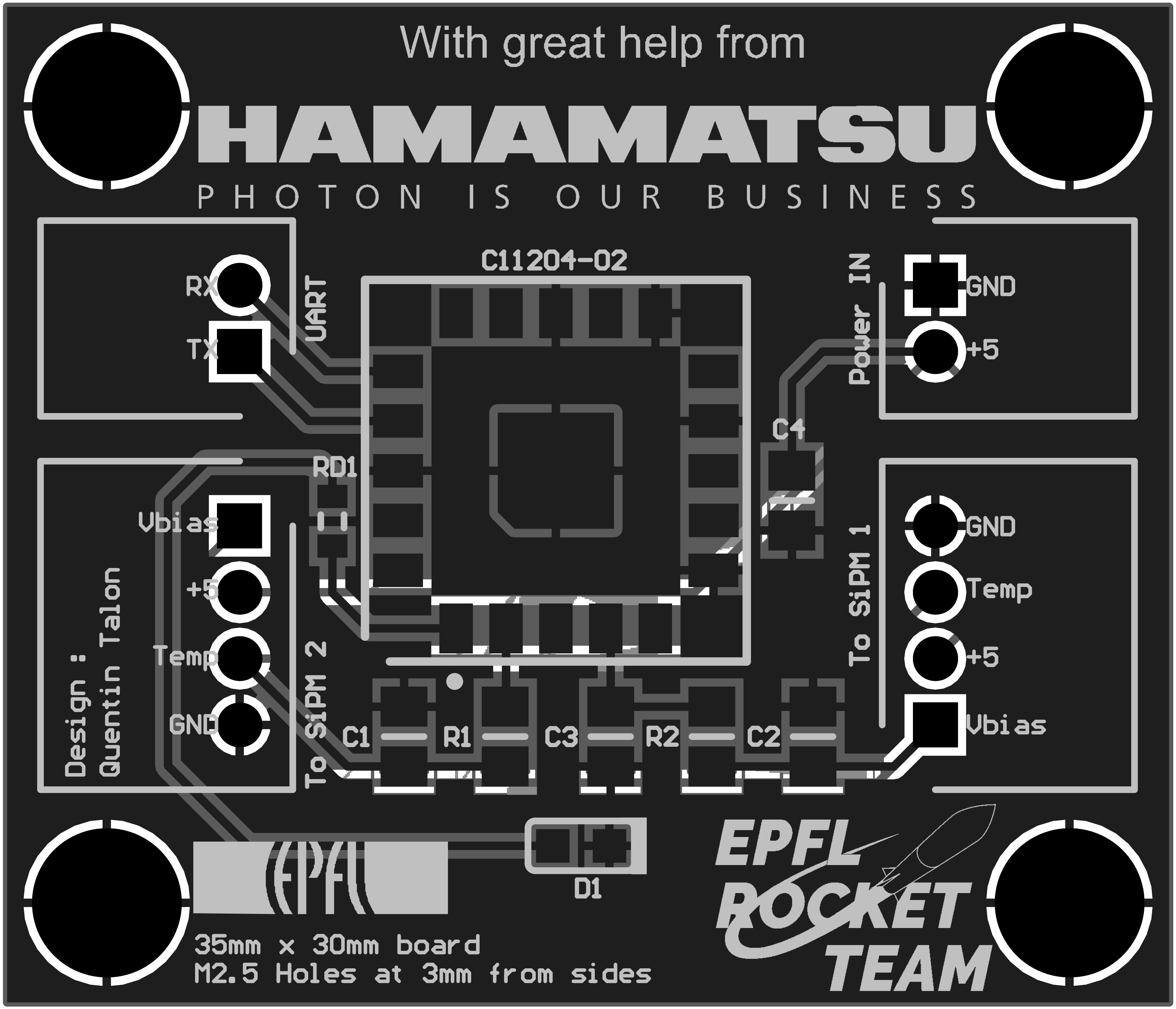

Buzzer
BuzzAct
NVR5198NLT1G
Arming
Power OUT
Power IN
Zenner
1SMA5920BT3G
I2C
SPI
Serial
Analog IN
S9B-PH-K-S
Baro
RF
IMU
GPS
Adafruit Ultimage GPS
Serial GPS
Servo 6 +5 GND
Servo 29 +5 GND
Servo 7 +5 GND
Pins 27-26-GND
P Out 28 +5+5
PAct28
P Out +5 30+5
PAct30
RDiv1
100K
RDiv2
22K
Diode VIN/+5
Diode
Title
Size
A4
Number
Revision
Date:
07.05.2018
Sheet
of
File:
C:\Users\..\Avionics.SchDoc
Drawn By:

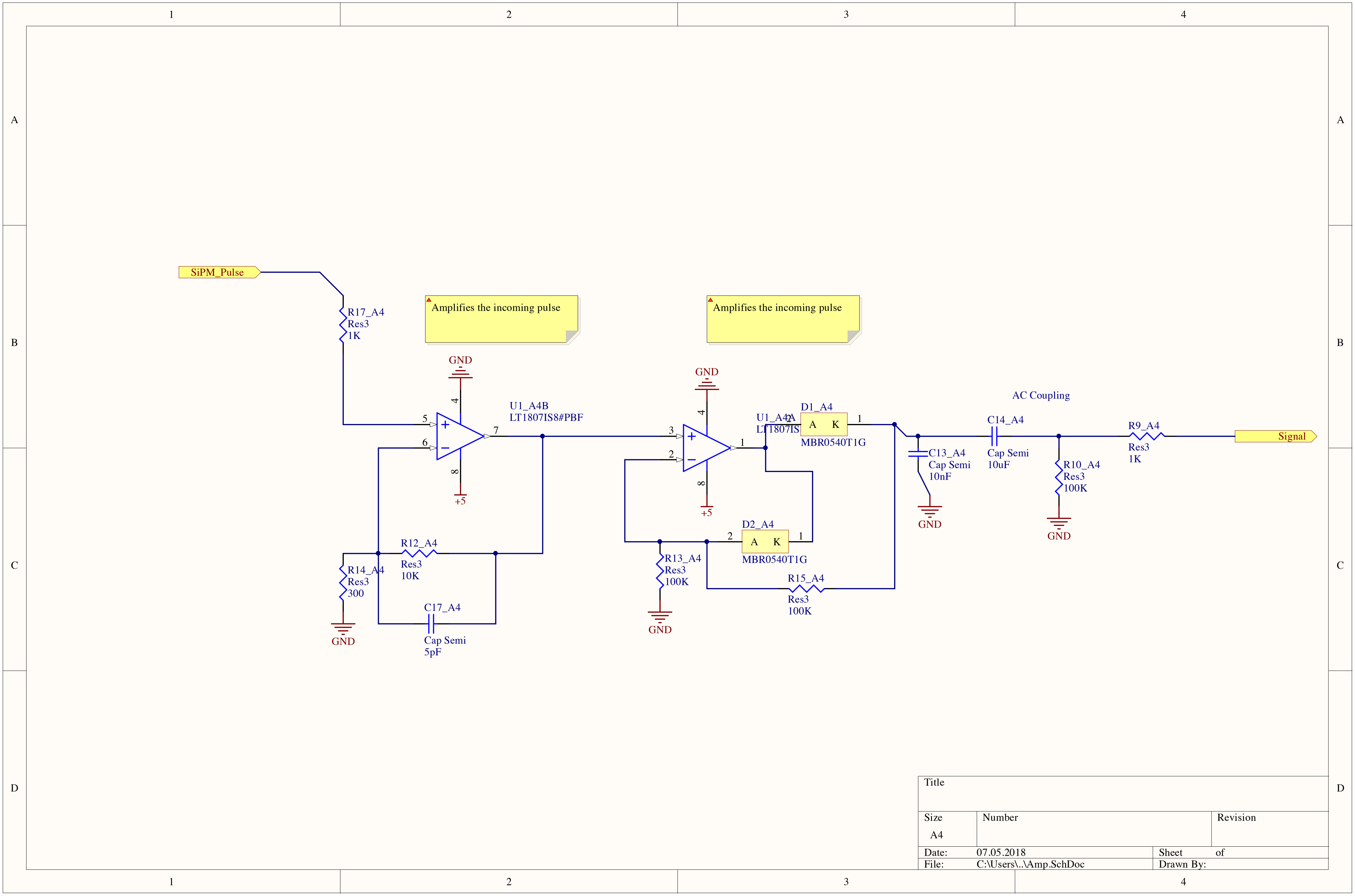


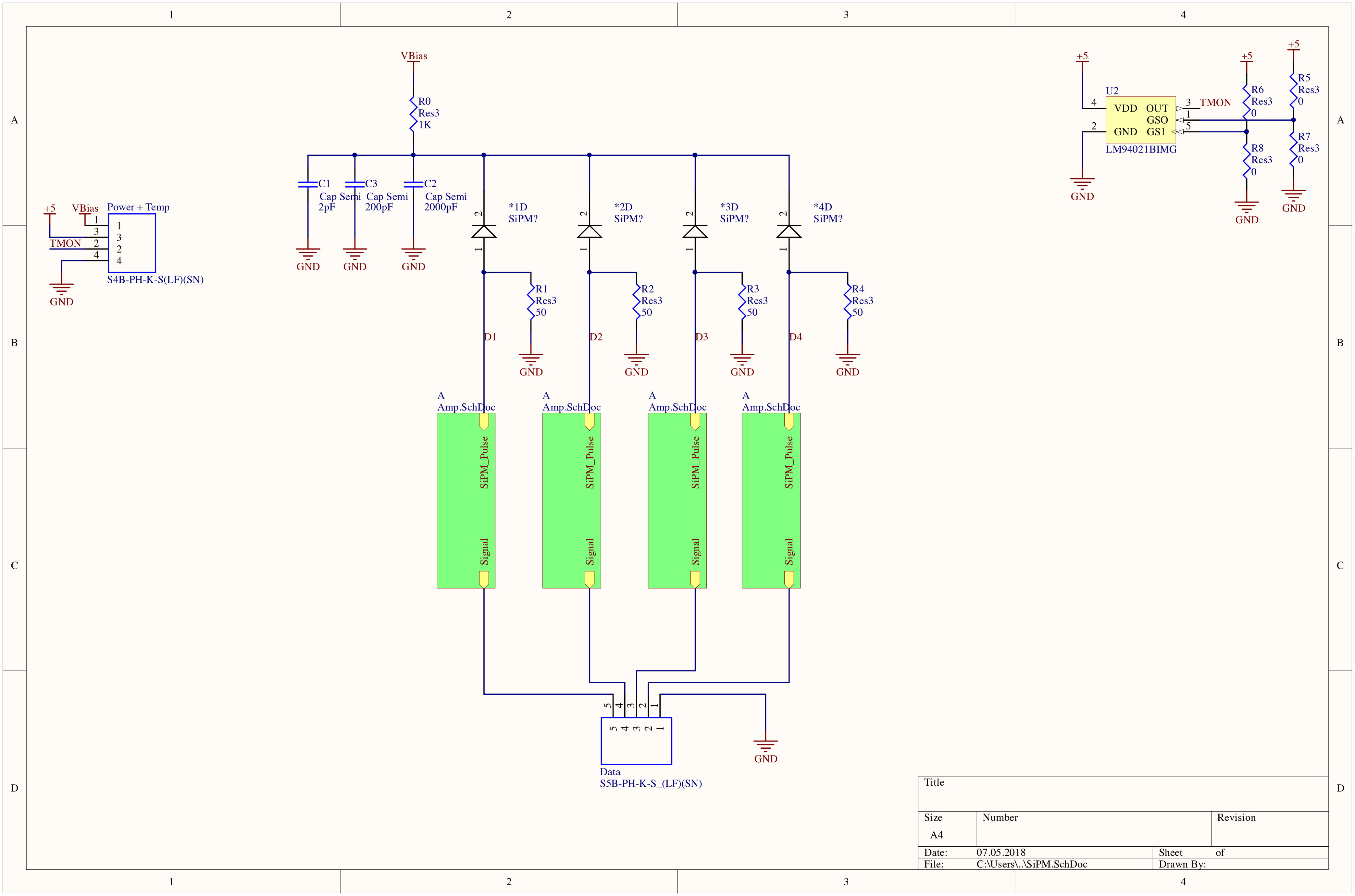
May 2018
Adafruit
RFM9x
LoRa Radio
Adafruit
BME280 Humidity
Baro Pressure
Temp Sensor
Breakout
Adafruit
BNO055
Absolute
Orientation
Sensor
Adafruit
Ultimate GPS
Breakout v3
Payload Team
Avionics
EPFL
ROCKET
TEAM
Thanks to the Section de physique
Design : Quentin Talon



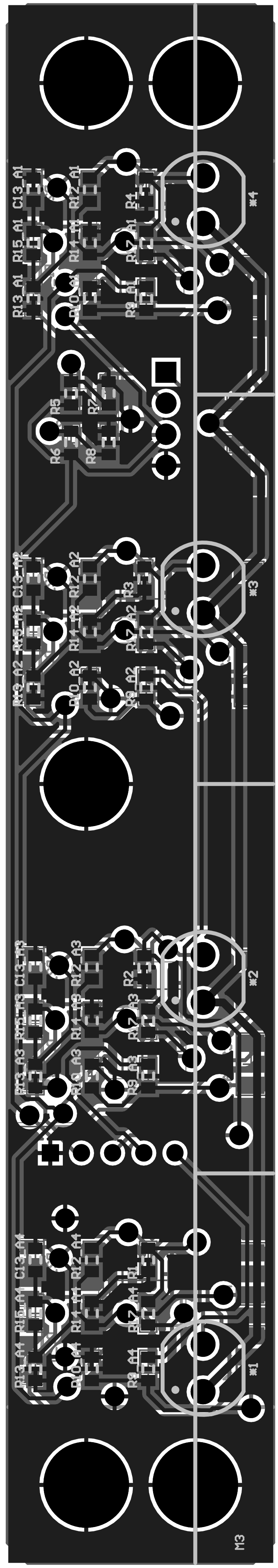
Title			
Size	Number		Revision
A4			
Date:	07.05.2018	Sheet	of
File:	C:\Users\..\Sheet1.SchDoc	Drawn By:	

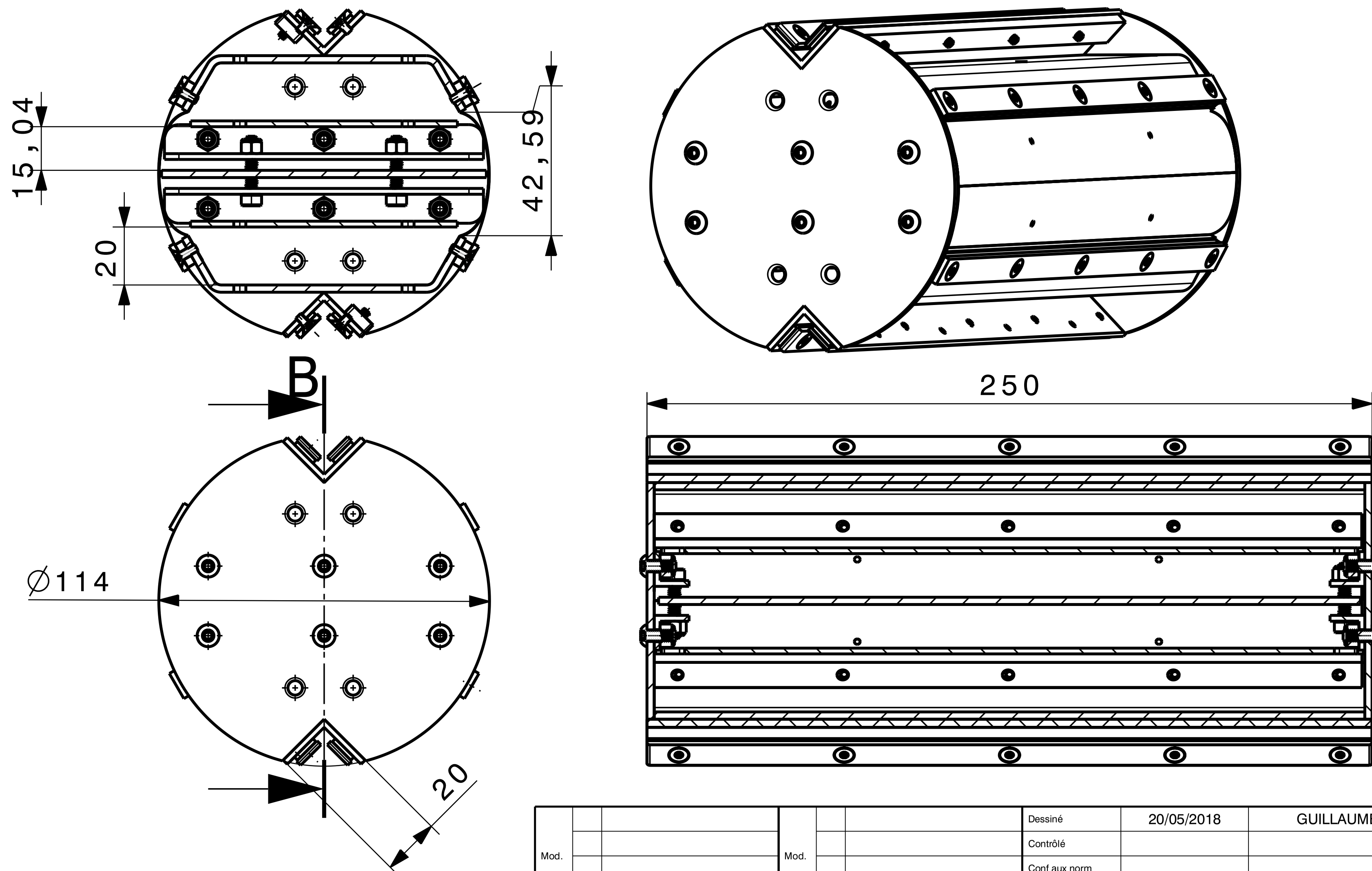

With great help from
HAMAMATSU
PHOTON IS OUR BUSINESS
C11204-02
RX
TX
UART
Power IN
GND
+5
C4
RD1
Vbias
+5
Temp
GND
To SiPM 2
Design :
Quentin Talon
To SiPM 1
GND
Temp
+5
Vbias
C1
R1
C3
R2
C2
D1
EPFL
35mm x 30mm board
M2.5 Holes at 3mm from sides
EPFL ROCKET TEAM


SiPM_Pulse
R17_A4
Res3
1K
Amplifies the incoming pulse
Amplifies the incoming pulse
GND
U1_A4B
LT1807IS8#PBF
+5
R12_A4
Res3
10K
R14_A4
Res3
300
GND
C17_A4
Cap Semi
5pF
GND
U1_A4A
LT1807IS
D1_A4
A K
MBR0540T1G
+5
D2_A4
A K
MBR0540T1G
R13_A4
Res3
100K
GND
R15_A4
Res3
100K
AC Coupling
C14_A4
Cap Semi
10uF
C13_A4
Cap Semi
10nF
GND
R10_A4
Res3
100K
GND
R9_A4
Res3
1K
Signal
Title
Size
A4
Number
Revision
Date: 07.05.2018
Sheet of
File: C:\Users\..\Amp.SchDoc
Drawn By:



Title			
Size A4	Number		Revision
Date:	07.05.2018	Sheet	of
File:	C:\Users\..\SiPM.SchDoc	Drawn By:	


C13_A1
R12_A1
R15_A1
R14_A1
R13_A1
R10_A1
R9_A1
R4
R5
R6
R7
R8
R3
R2
R1
M3



Dessiné	20/05/2018	GUILLAUME LOCHER
Contrôlé		
Conf aux norm		
Bon pour exéc.		
N° de commande		
Origine		
Remplace		

Mod.

Mod.

Sans nomenclature séparée ☐
Nomenclature sép de même N° ☐
Nomenclature sép de N° diff ☐

Echelle 1:1

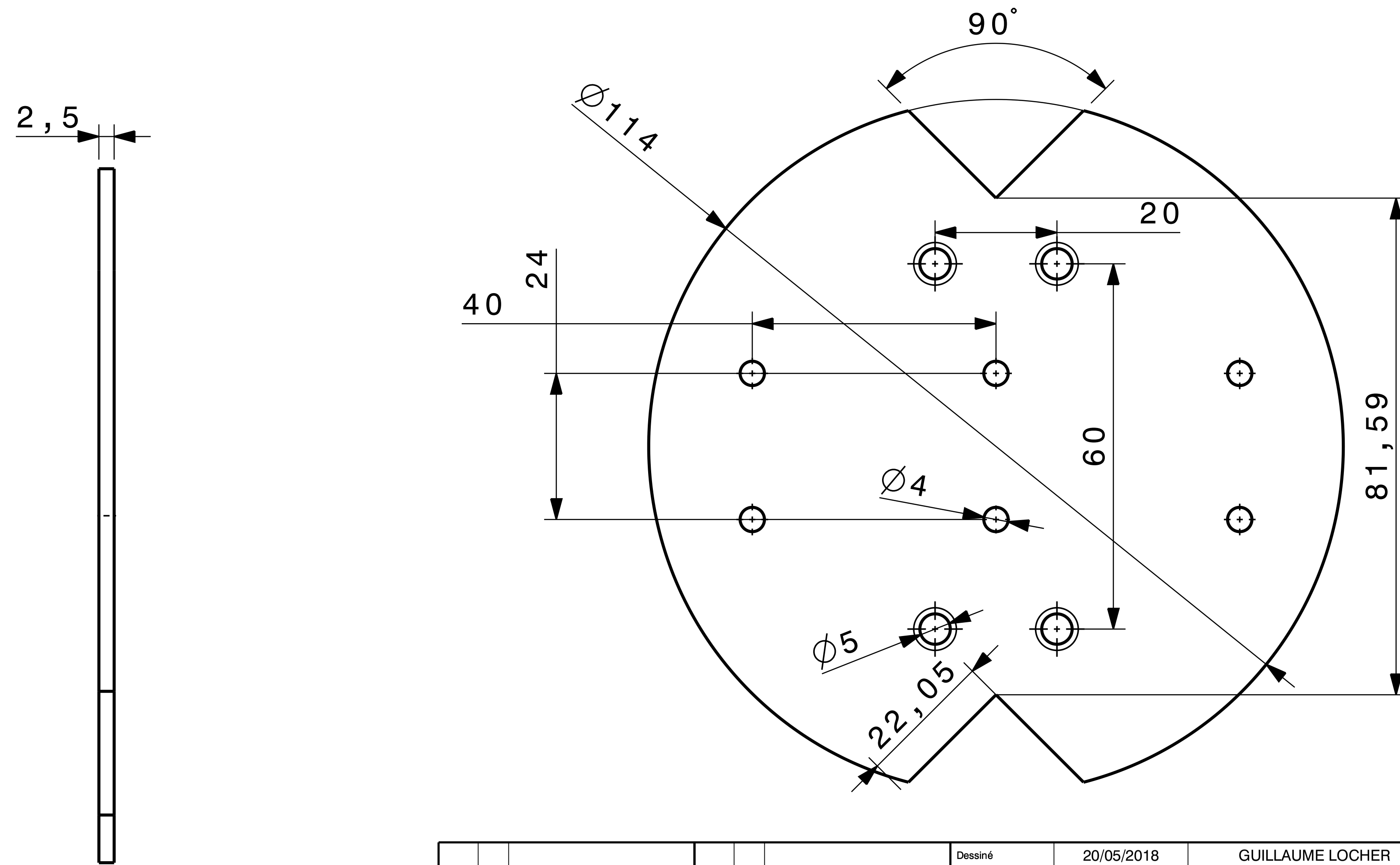
Format	Nb feuilles	Feuille N°
A4	1	1

EPFL

Dénomination
17100_Payload assembly

N° de dessin

1 2 3 4 5 6 7 8
A B C D E F



Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine		Format A4	Nb feuilles 1 / Feuille N° 1
Remplace			

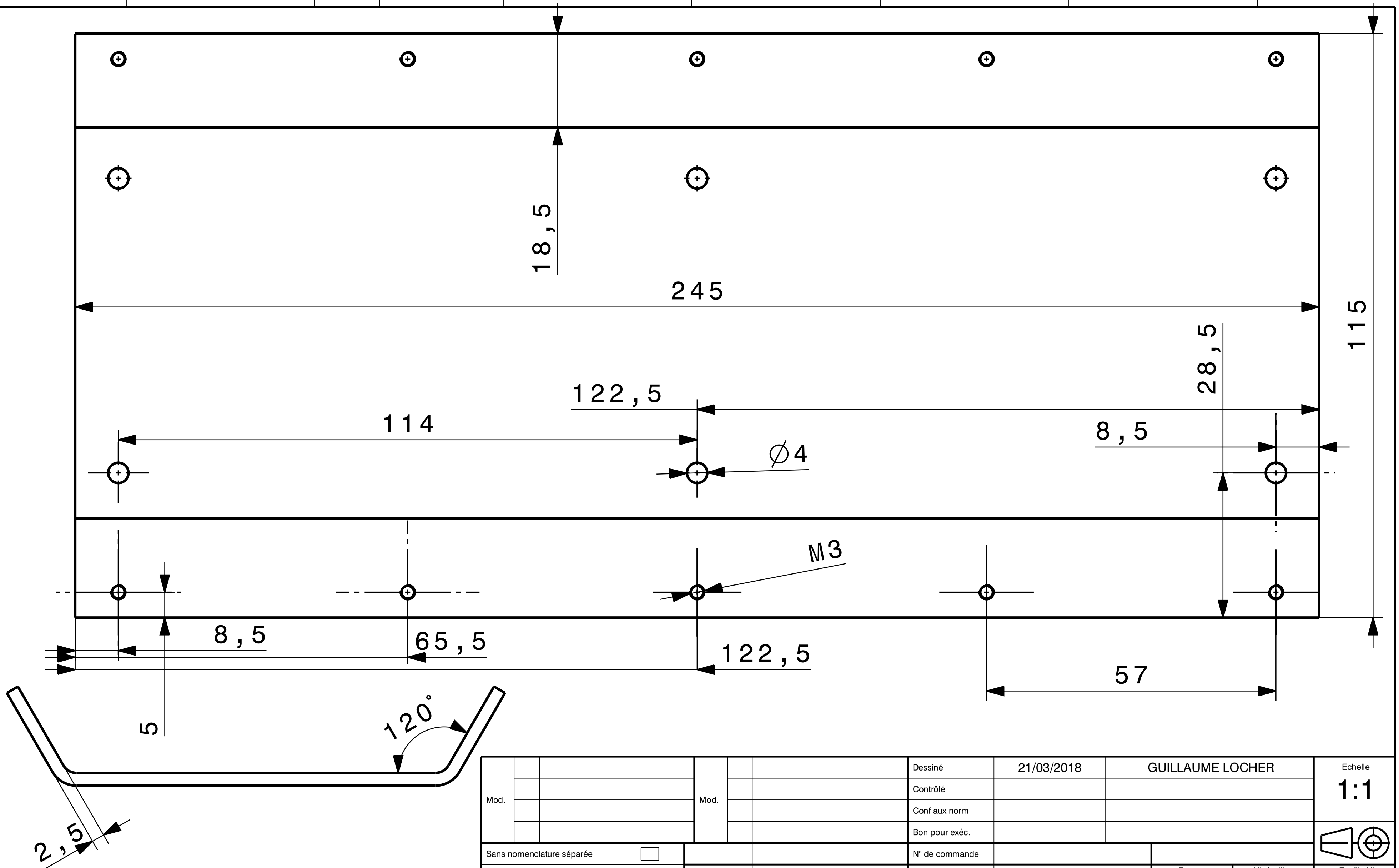
Sans nomenclature séparée		
Nomenclature sép de même N°	Matiere	Steel
Nomenclature sép de N° diff	Masse	0,198 kg

Mod. | Mod.

EPFL

Dénomination: 17101_DISC

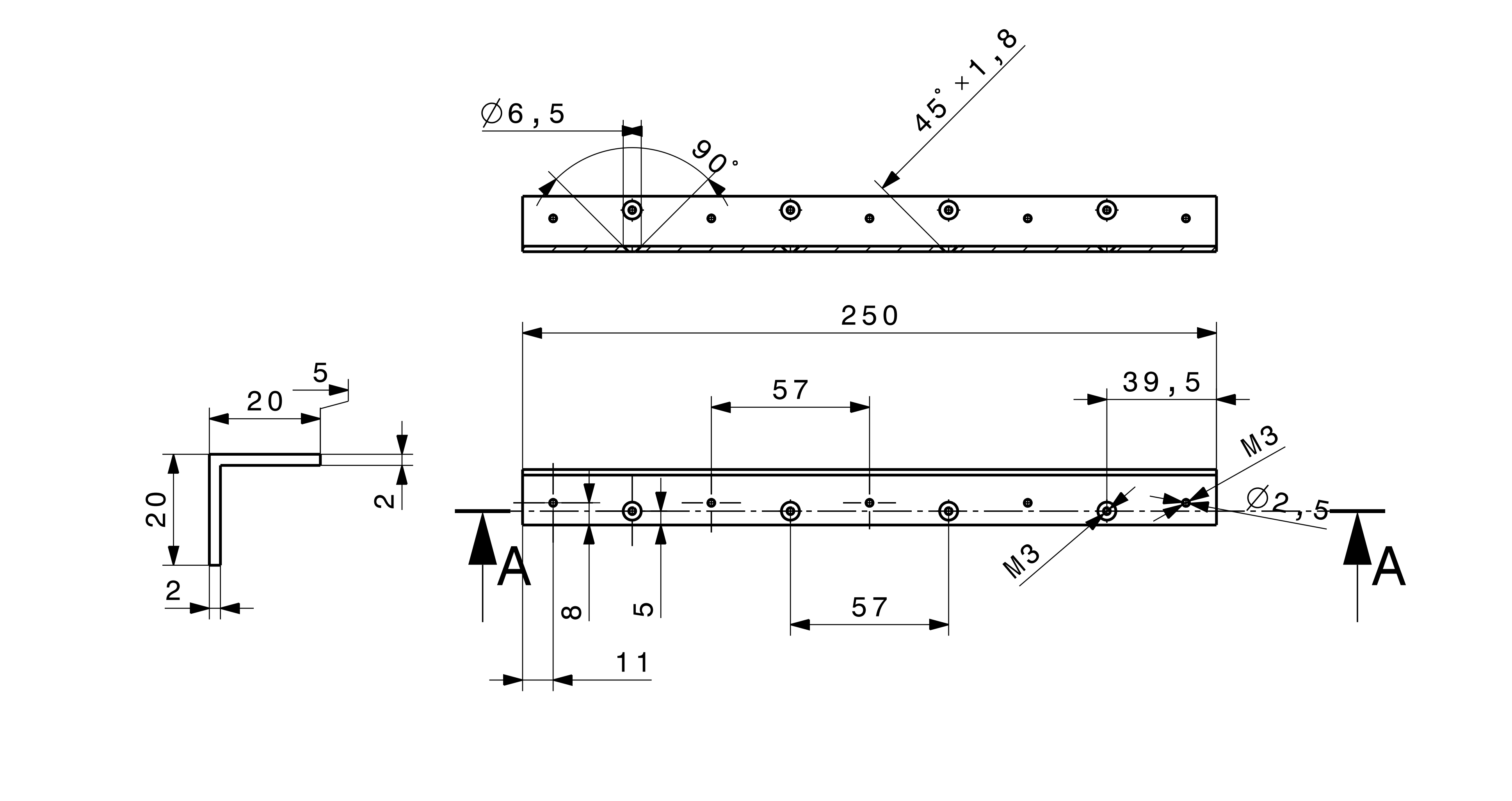
N° de dessin



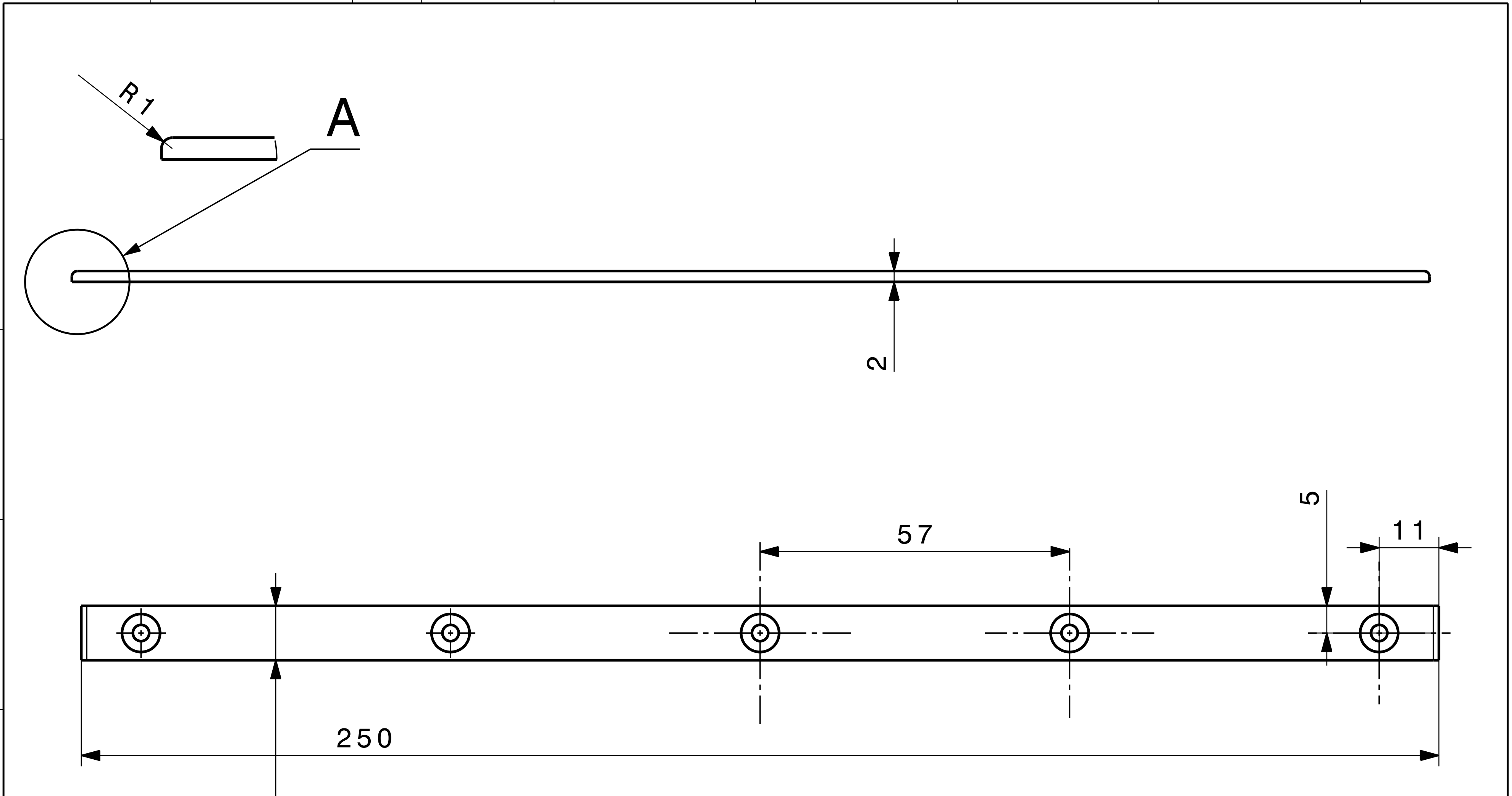
Dessiné	21/03/2018	GUILLAUME LOCHER	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Sans nomenclature séparée			
Nomenclature sép de même N°	Matiere	Steel	Origine
Nomenclature sép de N° diff	Masse	0,07 kg	Remplace
Format A4	Nb feuilles 1	Feuille N° 1	
Dénomination	17102_Sheet	N° de dessin	

Mod.

Mod.

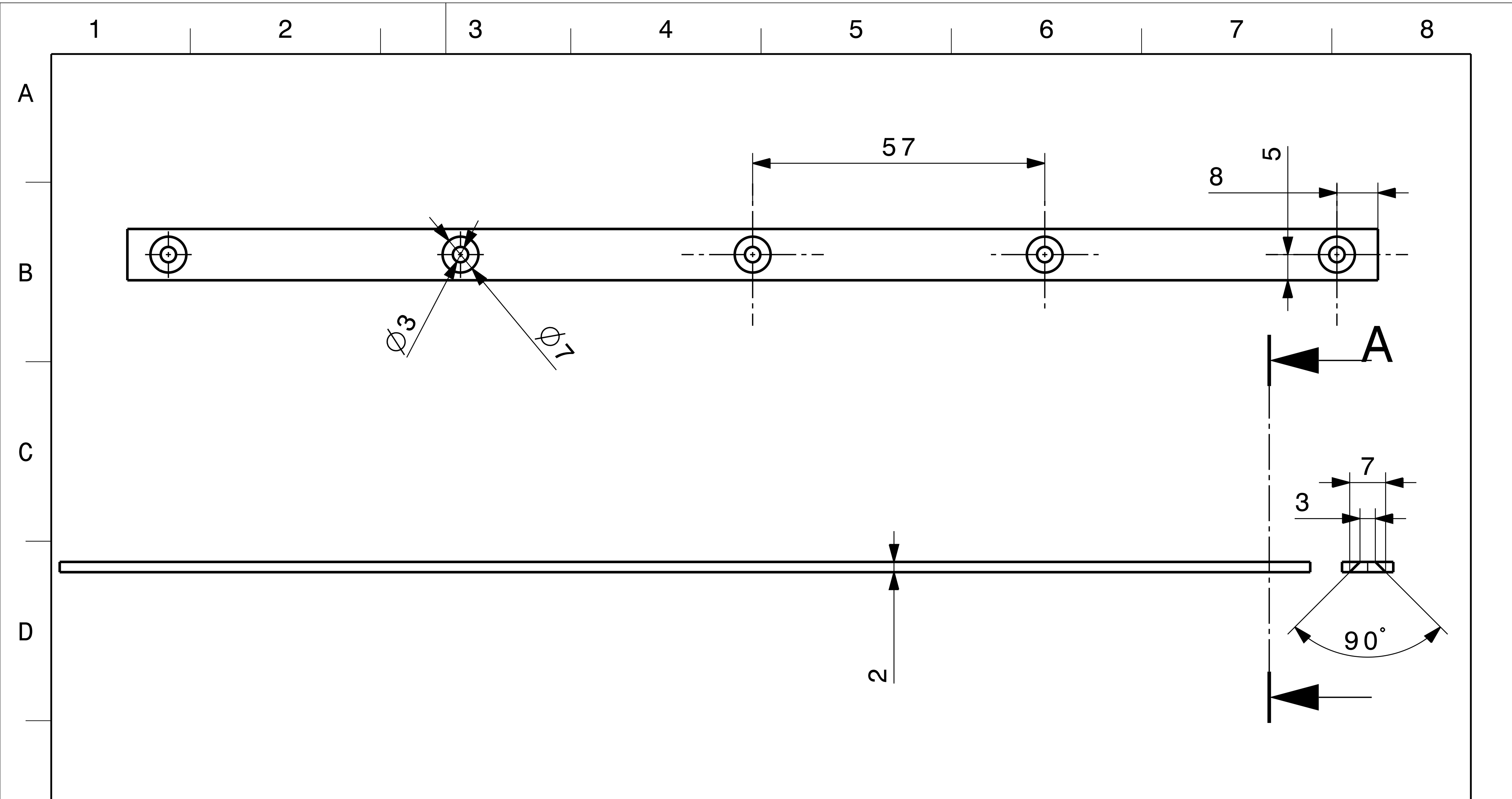


Mod.	Mod.	Dessiné	20/05/2018	GUILLAUME LOCHER		Echelle 1:1
		Contrôlé				
		Conf aux norm				
		Bon pour exéc.				
Sans nomenclature séparée		N° de commande				
Nomenclature sép de même N°	Matiere: Steel	Origine		Format: A4	Nb feuilles: 1	Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0,05 kg	Remplace				
EPFL	Dénomination: 17104_RAIL			N° de dessin		



Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
Sans nomenclature séparée		N° de commande	
Nomenclature sép de même N°	Matiere: PTFE	Origine	Format: A4 / Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0,01 kg	Remplace	
	Dénomination: 17106_TEFLON_SKATE_LONG		N° de dessin

Mod. | Mod.



Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Matiere	PTFE	Origine	Format A4
Masse	0,01 kg	Remplace	Nb feuilles 1
			Feuille N° 1

Mod.

Mod.

Sans nomenclature séparée

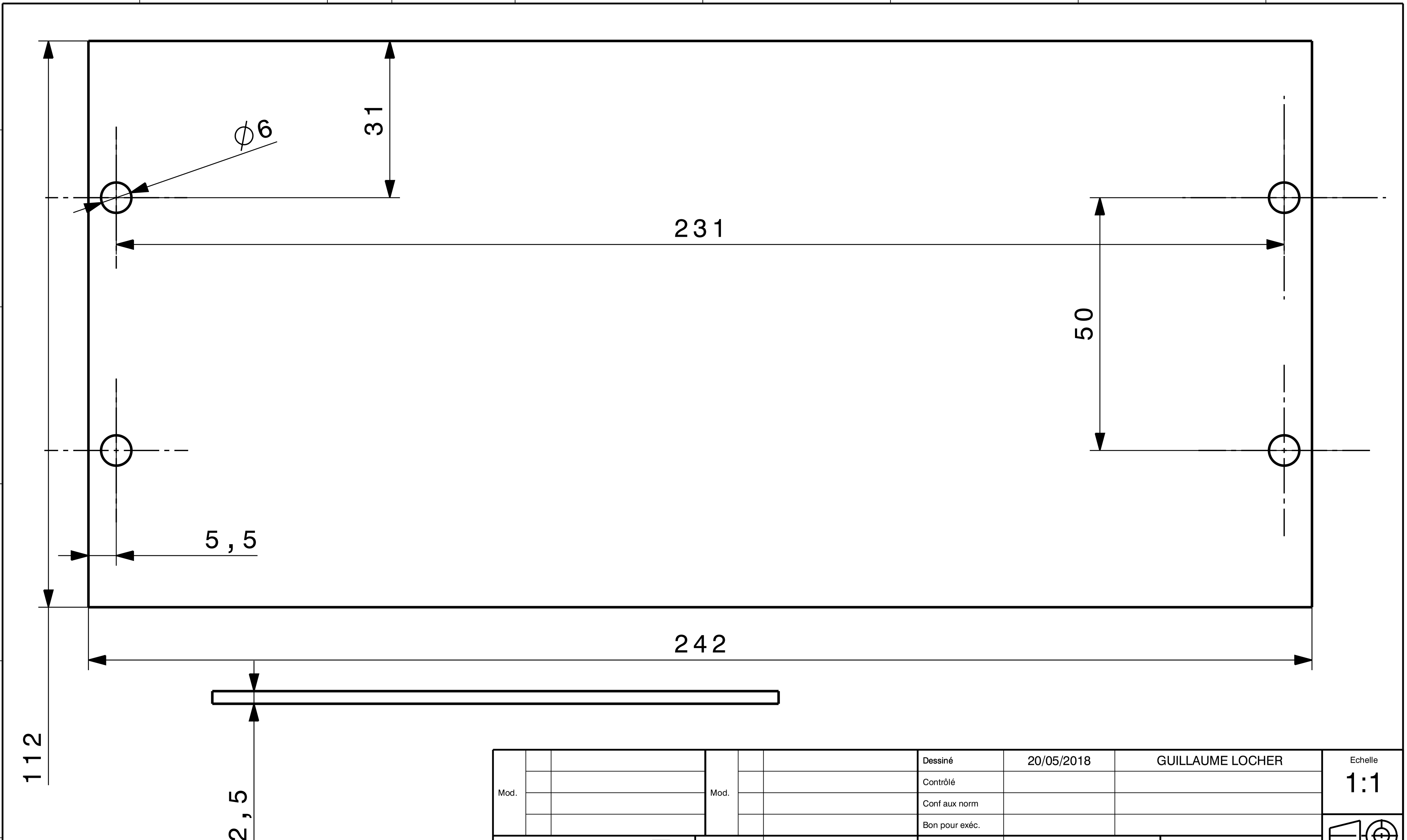
Nomenclature sép de même N°

Nomenclature sép de N° diff

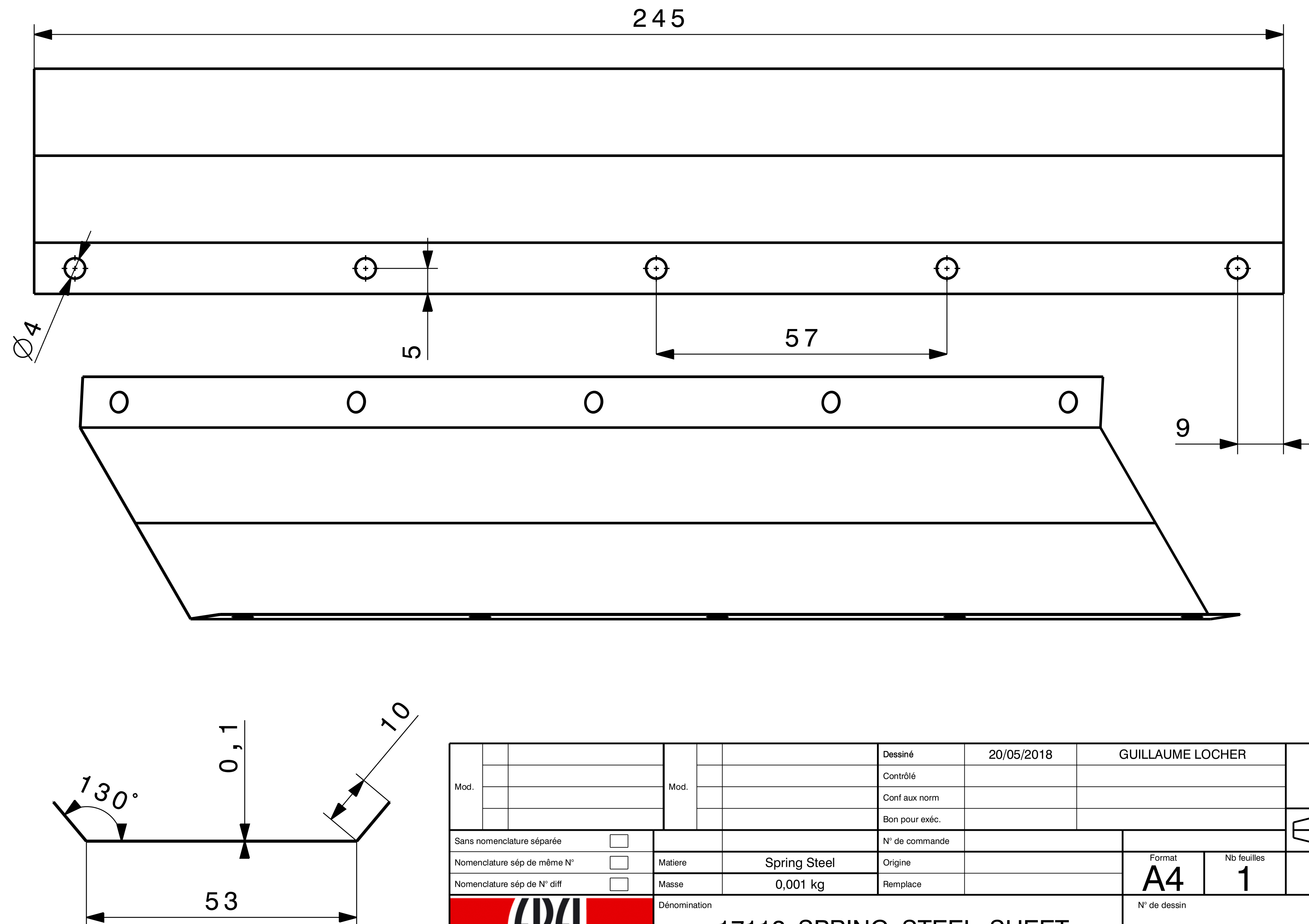
Dénomination

17107_TEFLON_SKATE_SHORT

N° de dessin



Mod.	Mod.	Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée ☐		N° de commande			
Nomenclature sép de même N° ☐	Matiere: Steel	Origine		Format: A4	Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff ☐	Masse: 0,53 kg	Remplace			
EPFL	Dénomination: 17110_ELECTRONIQUE_SUPPORT			N° de dessin	



Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine			
Remplace			

Sans nomenclature séparée	☐
Nomenclature sép de même N°	☐
Nomenclature sép de N° diff	☐

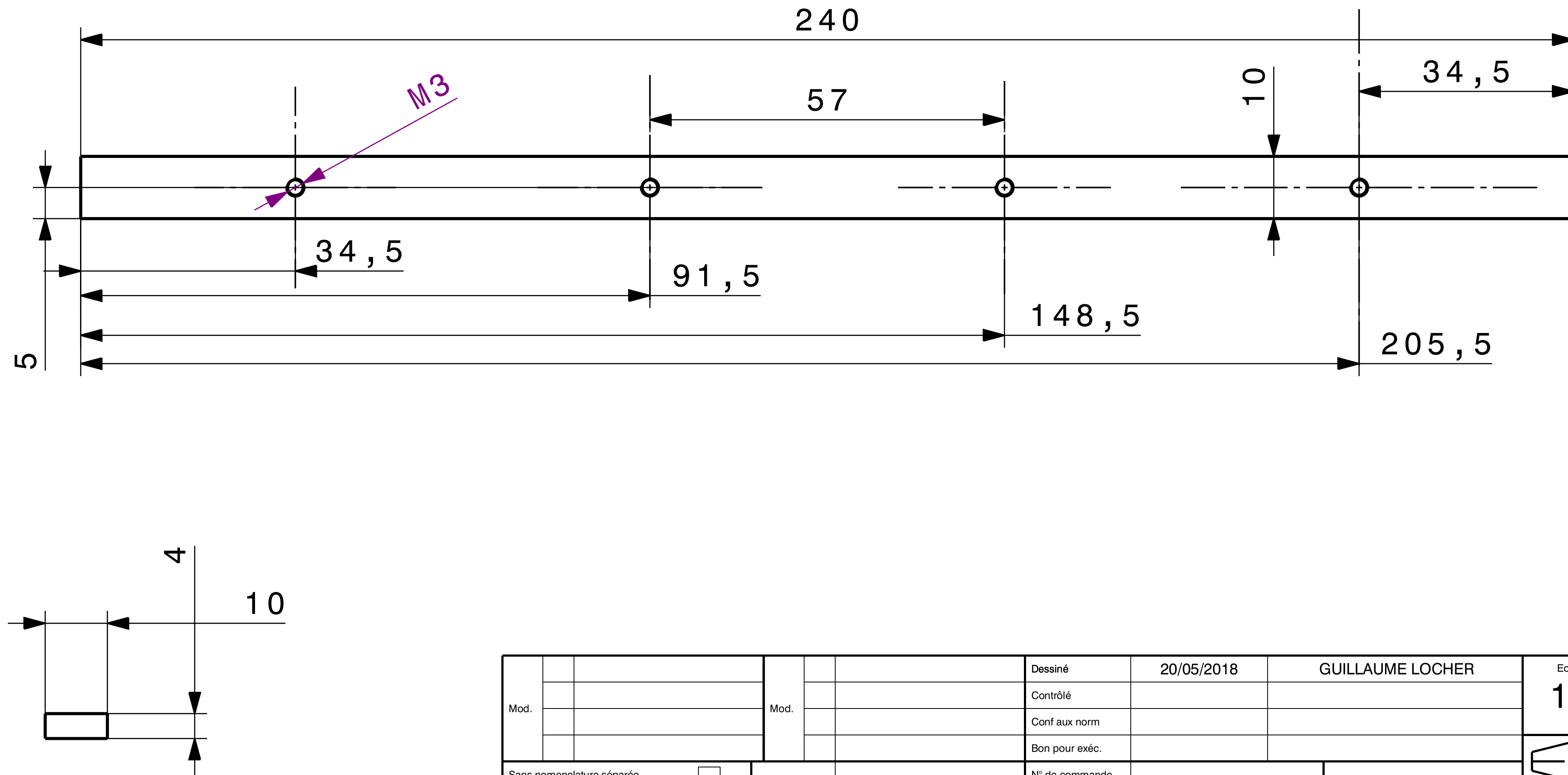
Matiere	Spring Steel
Masse	0,001 kg
Dénomination	17112_SPRING_STEEL_SHEET

Format	Nb feuilles	Feuille N°
A4	1	1

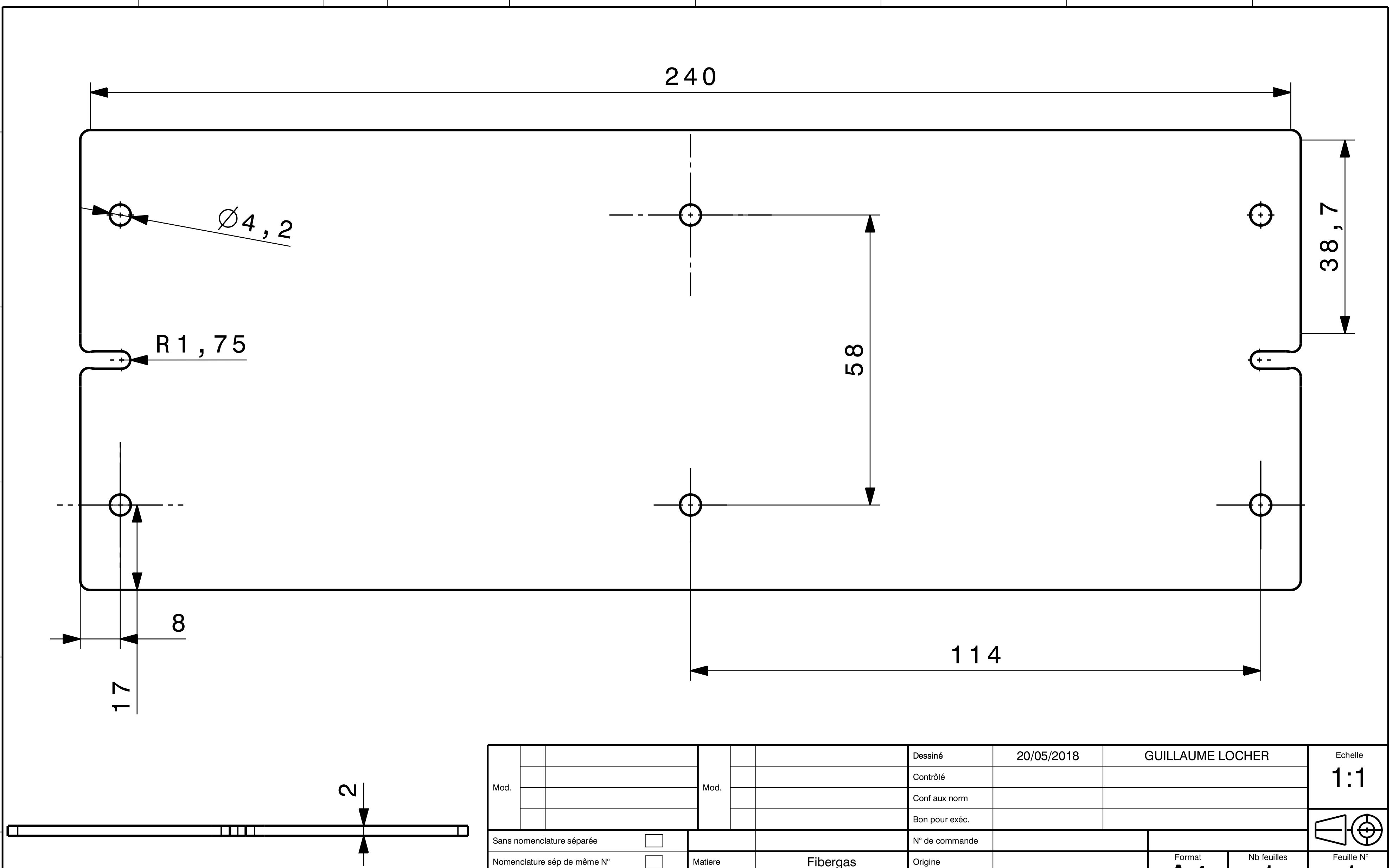
N° de dessin

Mod.

Mod.



Mod.	Mod.	Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Steel	Origine		Format: A4 / Nb feuilles: 1	Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0,075 kg	Remplace			
EPFL	Dénomination: 17113_BALLAST			N° de dessin	



Dessiné	20/05/2018	GUILLAUME LOCHER	Echelle 1:1		
Contrôlé					
Conf aux norm					
Bon pour exéc.					
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Fibergas	Origine	Format A4	Nb feuilles 1	Feuille N° 1
Nomenclature sép de N° diff	Masse: 0,045 kg	Remplace			

Mod.

Mod.

Dénomination: 17111_FIBERGLAS_SHEET

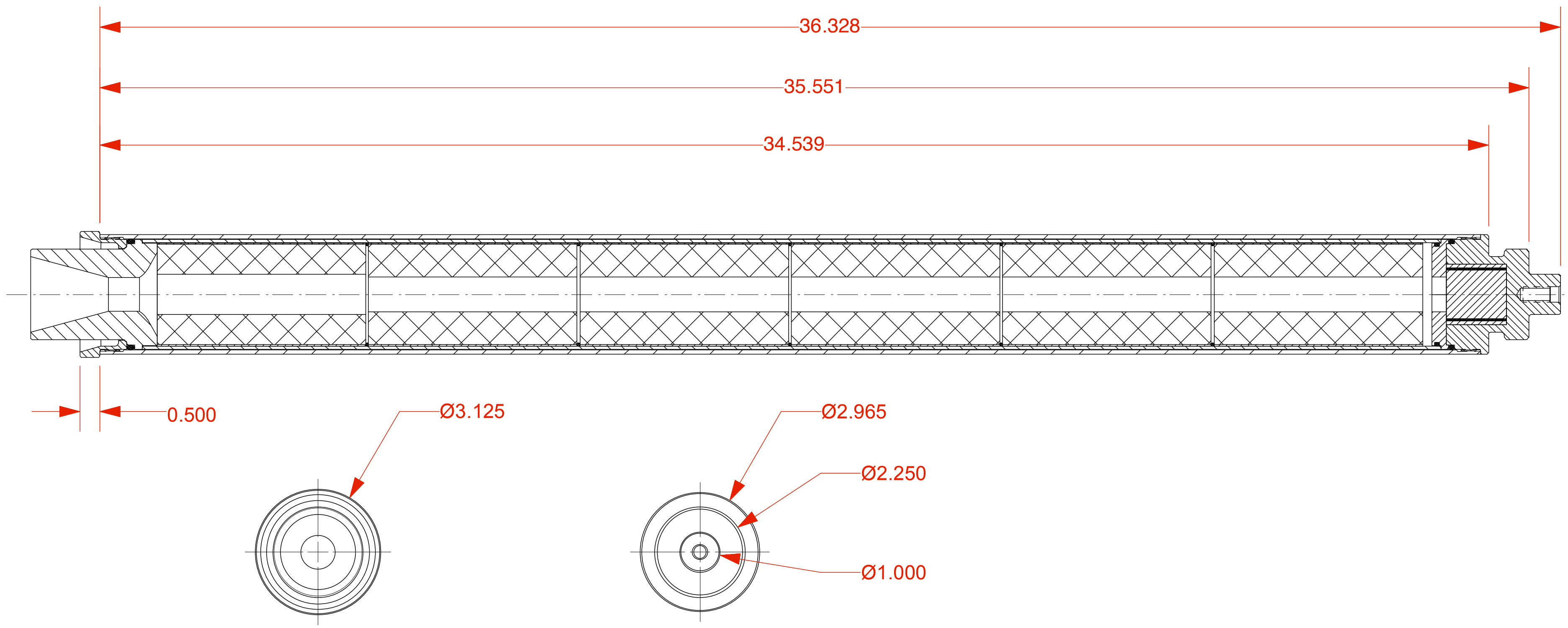
N° de dessin

REVISIONS

EFFECTIVITY	REV	DESCRIPTION	DATE	APPROVED
FUTURE	A	FIRST RELEASE ISSUE	2 / 21 / 18	

NOTES:

1. MOTOR ASSEMBLY SHOWN WITH OVERALL EXTERIOR DIMENSIONS.



VIEW AFT CLOSURE

VIEW FORWARD CLOSURE

SUPPLIER DATA	RELOAD KIT IDENTIFICATION	
	PART NUMBER	DESCRIPTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

.XX	.XXX	ANGLES
+/- .010	+/- .005	+/- 2 deg.

MATERIAL

FINISH

QTY	PART NUMBER	DESCRIPTION	ITEM

LIST OF MATERIAL

CONTRACT NUMBER

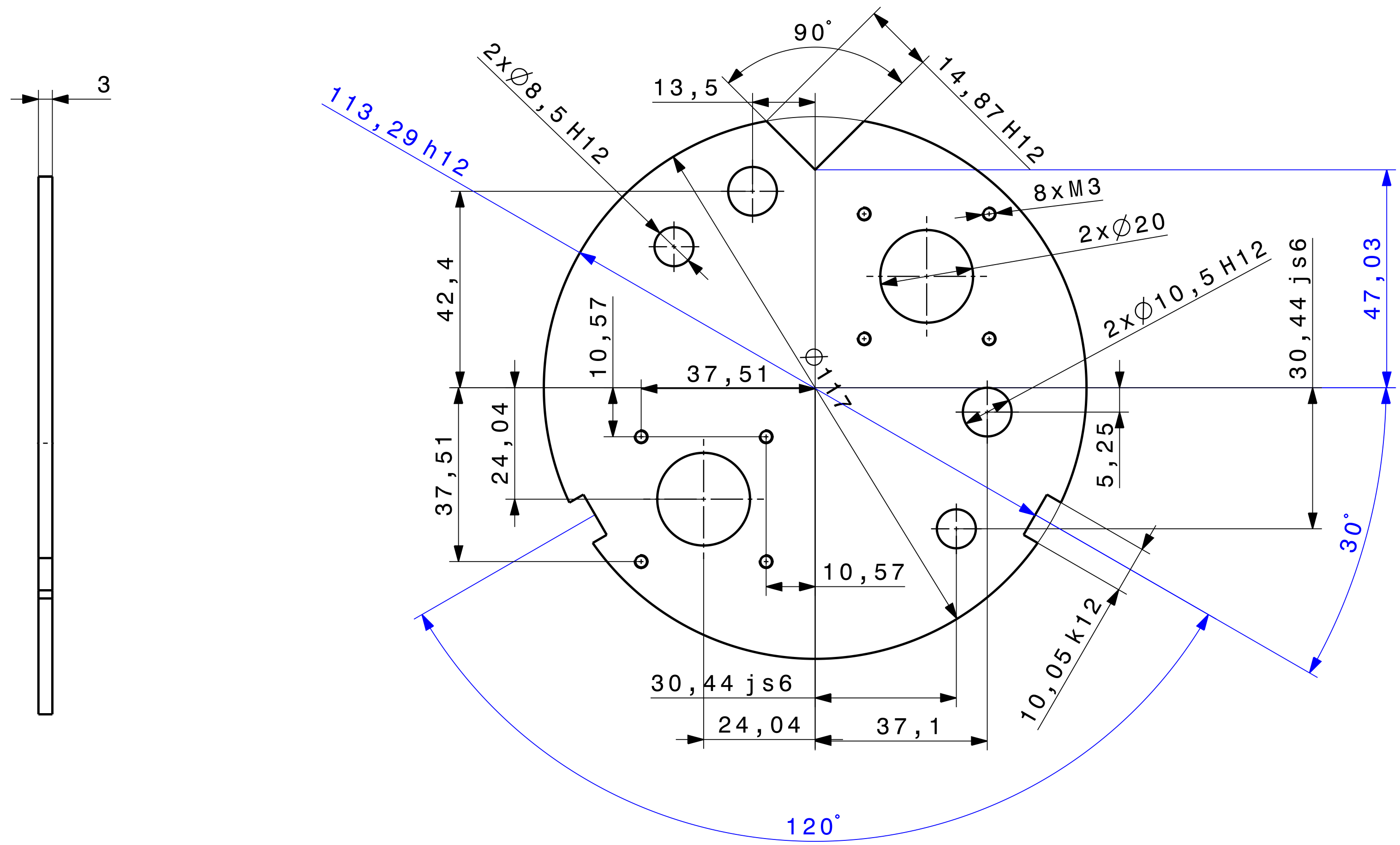
PREP	G. ROSENFIELD	2 / 18
CHKR		
APVD		
APVD		

ROCKET MOTOR COMPONENTS INC.
2113 W 850 N
Cedar City, Utah 84721
(435) 865-7100 (Ph)
(435) 865-7120 (Fax)

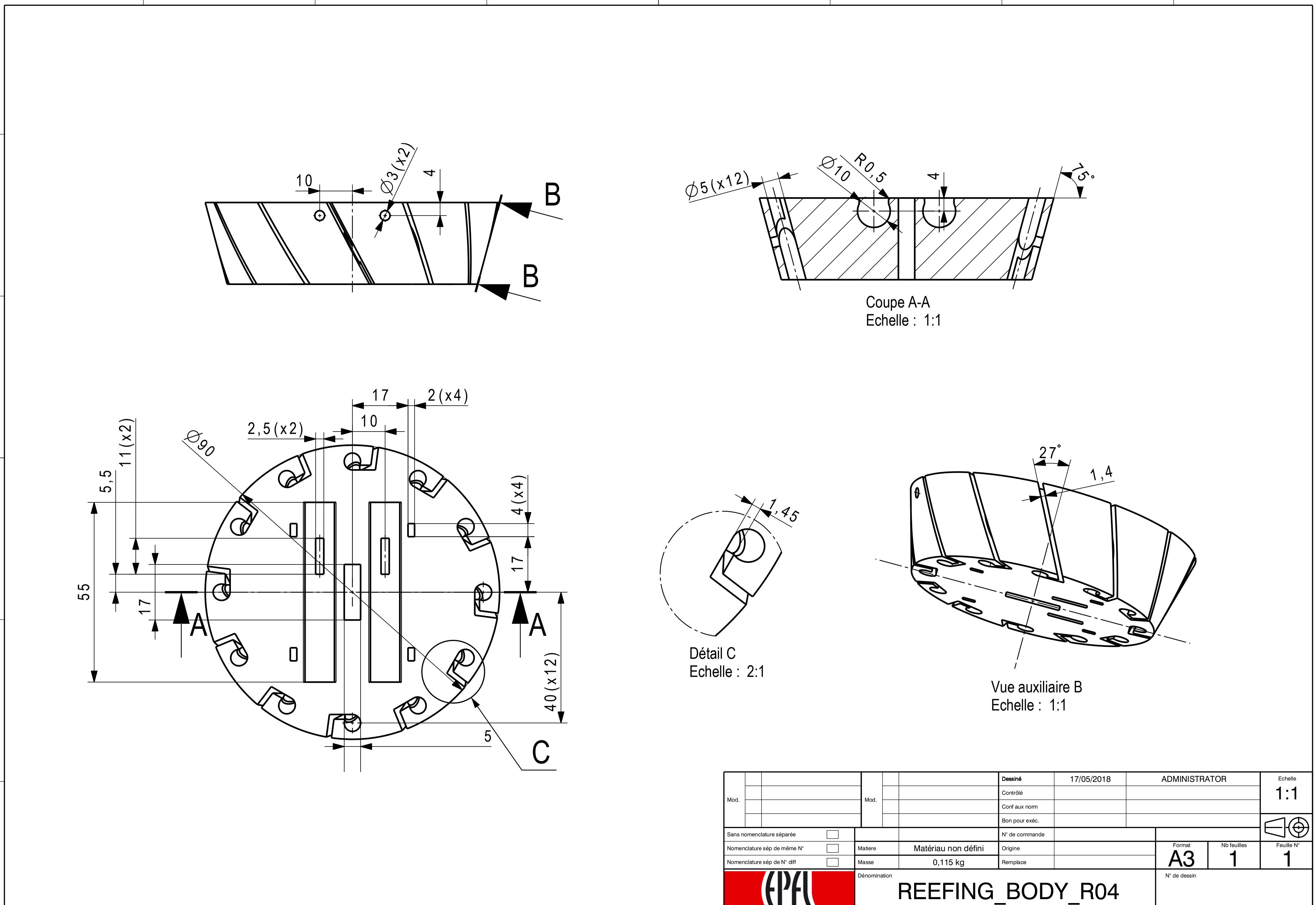
HP 75/7680 MOTOR DIMENSIONAL DRAWING

SIZE A NUMBER **ASSY DWG**

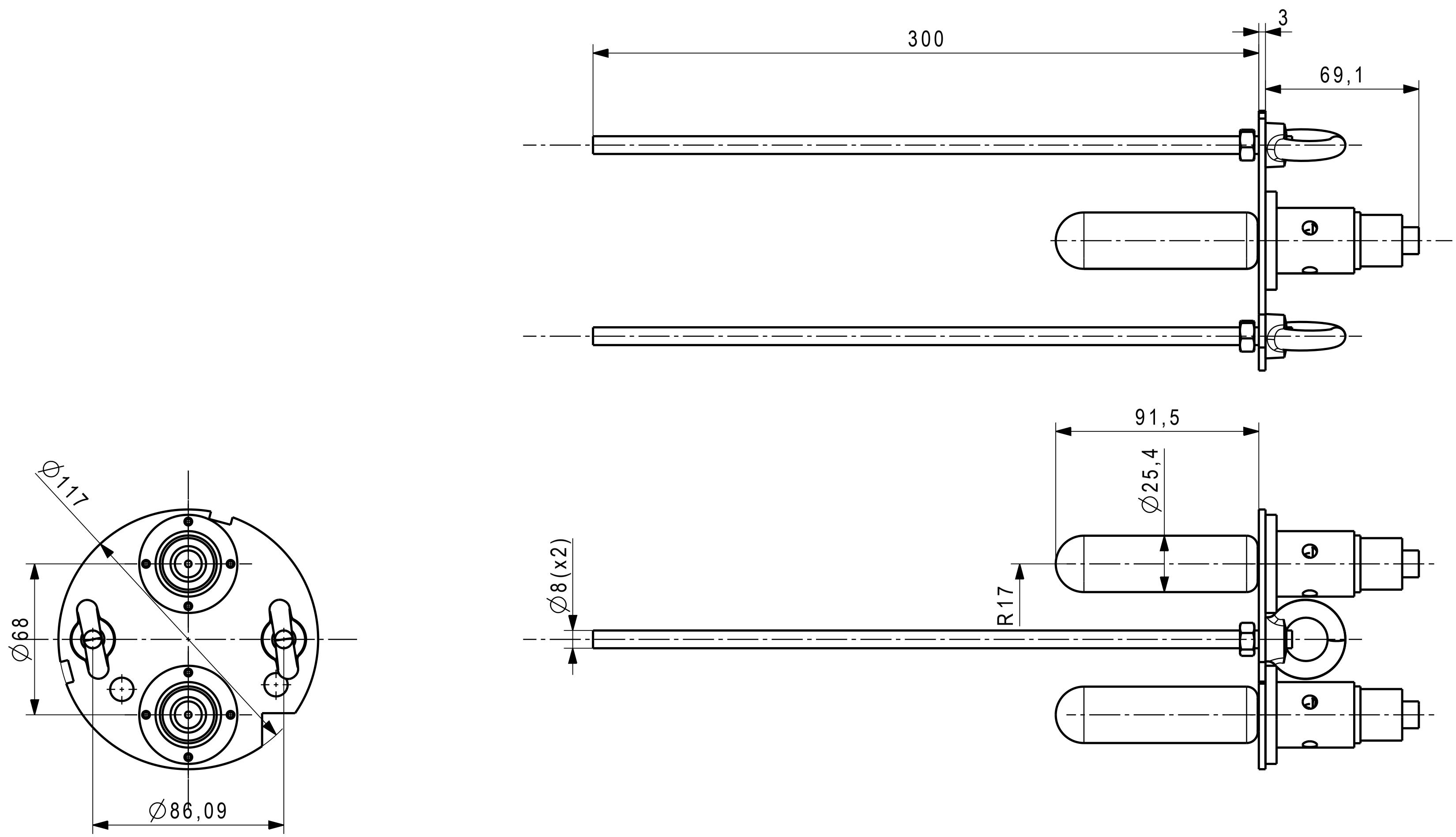
SCALE 1 / 4 SHEET 1 OF 1



Mod.		Mod.		Dessiné	16.03.2018		Echelle 1:1
				Contrôlé			
				Conf aux norm			
				Bon pour exéc.			
Sans nomenclature séparée	☐			N° de commande			
Nomenclature sép de même N°	☐	Matiere	CarbonFiber	Origine		Format A3	Nb feuilles 1 / Feuille N° 1
Nomenclature sép de N° diff	☐	Masse	0.078 kg	Remplace			
EPFL		Dénomination	12101_RECOVERY_PLATE			N° de dessin	



B
B
10
⌀3 (x2)
4
⌀5 (x12)
⌀10
R0,5
4
75°
Coupe A-A
Echelle : 1:1
⌀90
2,5 (x2)
17
10
2 (x4)
4 (x4)
17
55
5,5
11 (x2)
17
A
A
40 (x12)
5
C
1,45
Détail C
Echelle : 2:1
27°
1,4
Vue auxiliaire B
Echelle : 1:1
Dessiné 17/05/2018 ADMINISTRATOR
Echelle 1:1
Contrôlé
Conf aux norm
Bon pour exéc.
N° de commande
Mod.
Mod.
Sans nomenclature séparée
Nomenclature sép de même N°
Nomenclature sép de N° diff
Matiere Matériau non défini
Masse 0,115 kg
Origine
Remplace
Format A3
Nb feuilles 1
Feuille N° 1
Dénomination
REEFING_BODY_R04
N° de dessin



Dessiné	24/05/2018	ADMINISTRATOR	Echelle 1:2
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine		Format A3	Nb feuilles 1 / Feuille N° 1
Remplace			

Sans nomenclature séparée

Nomenclature sép de même N°

Nomenclature sép de N° diff

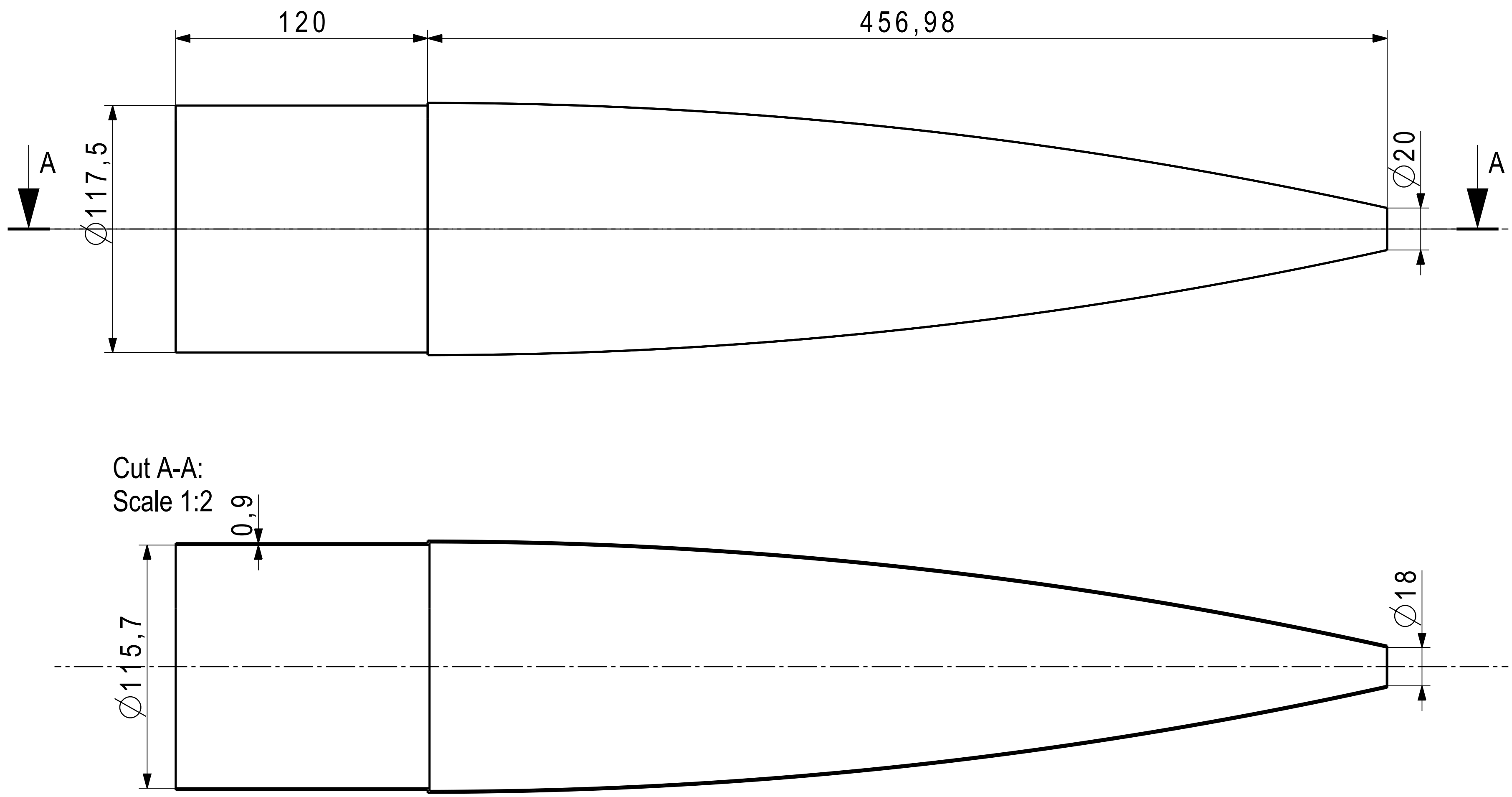
Matiere

Masse

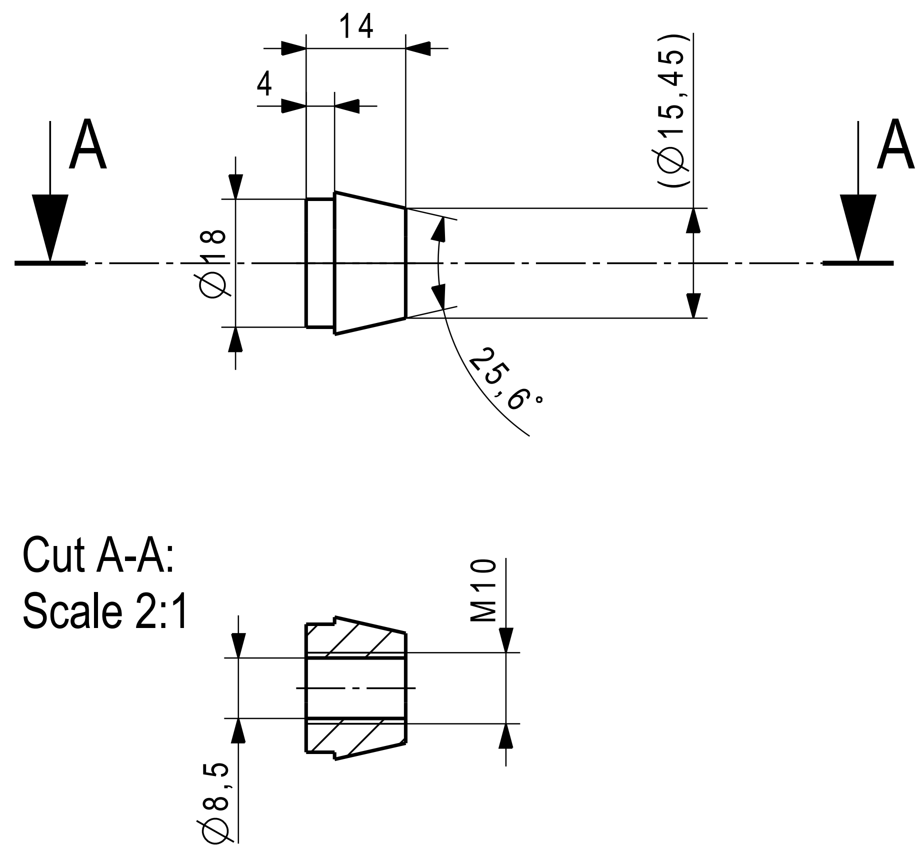
Dénomination: Recovery Module

N° de dessin

EPFL



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:2		
Contrôlé					
Conf aux norm					
Bon pour exéc.					
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: GFRP	Origine	Format A3	Nb feuilles 1	Feuille N° 1
Nomenclature sép de N° diff	Masse: 0.255	Remplace			
	Dénomination: 11101_NOSECONE_SHELL_117.5_500_R01		N° de dessin		



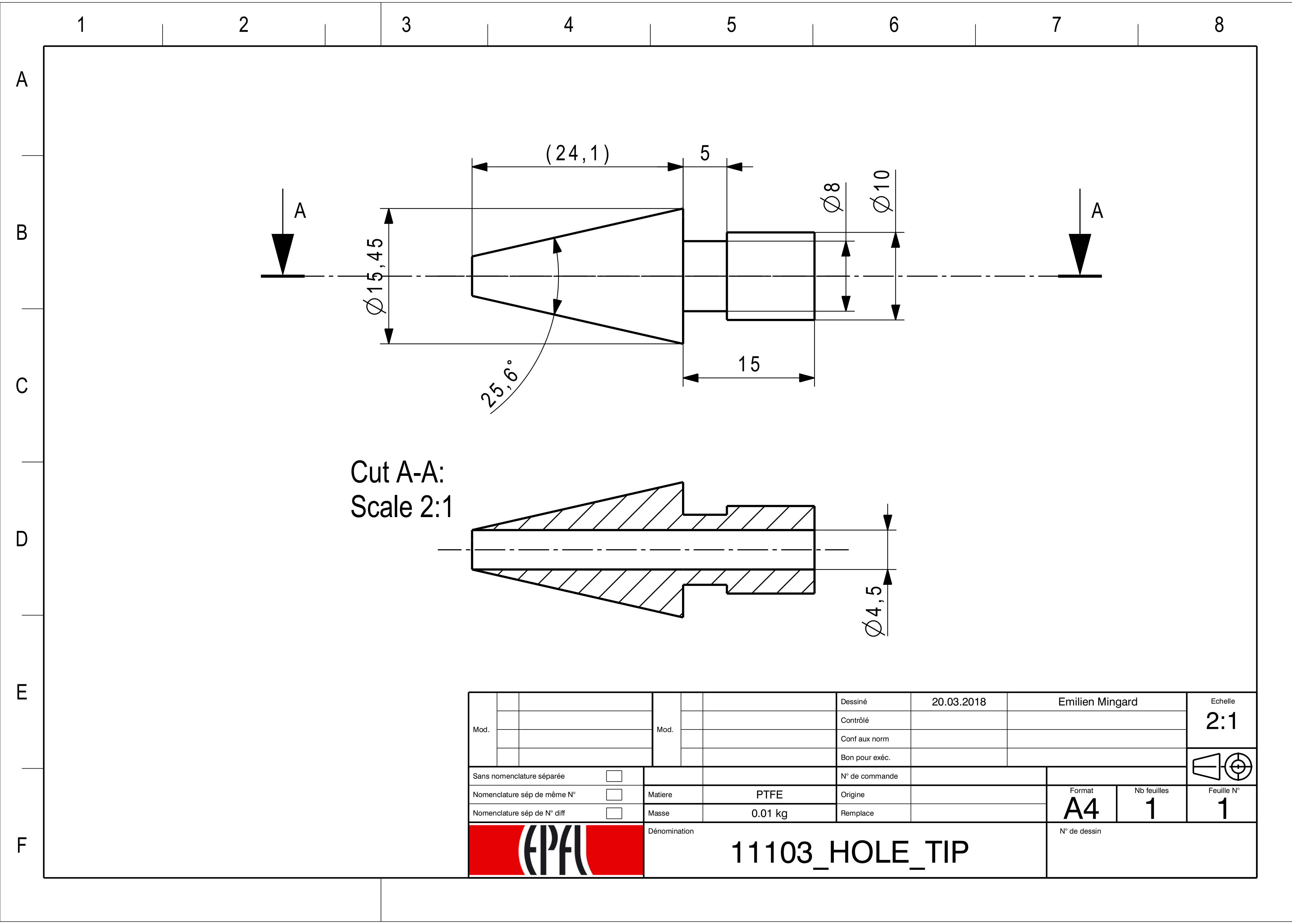
Cut A-A:
Scale 2:1

Dessiné	20.03.2018	Emilien Mingard	Echelle	2:1
Contrôlé				
Conf aux norm				
Bon pour exéc.				
Sans nomenclature séparée	N° de commande			
Nomenclature sép de même N°	Matiere	Al 6082	Origine	
Nomenclature sép de N° diff	Masse	0.005 kg	Remplace	
Format	A4	Nb feuilles	1	Feuille N° 1

Dénomination

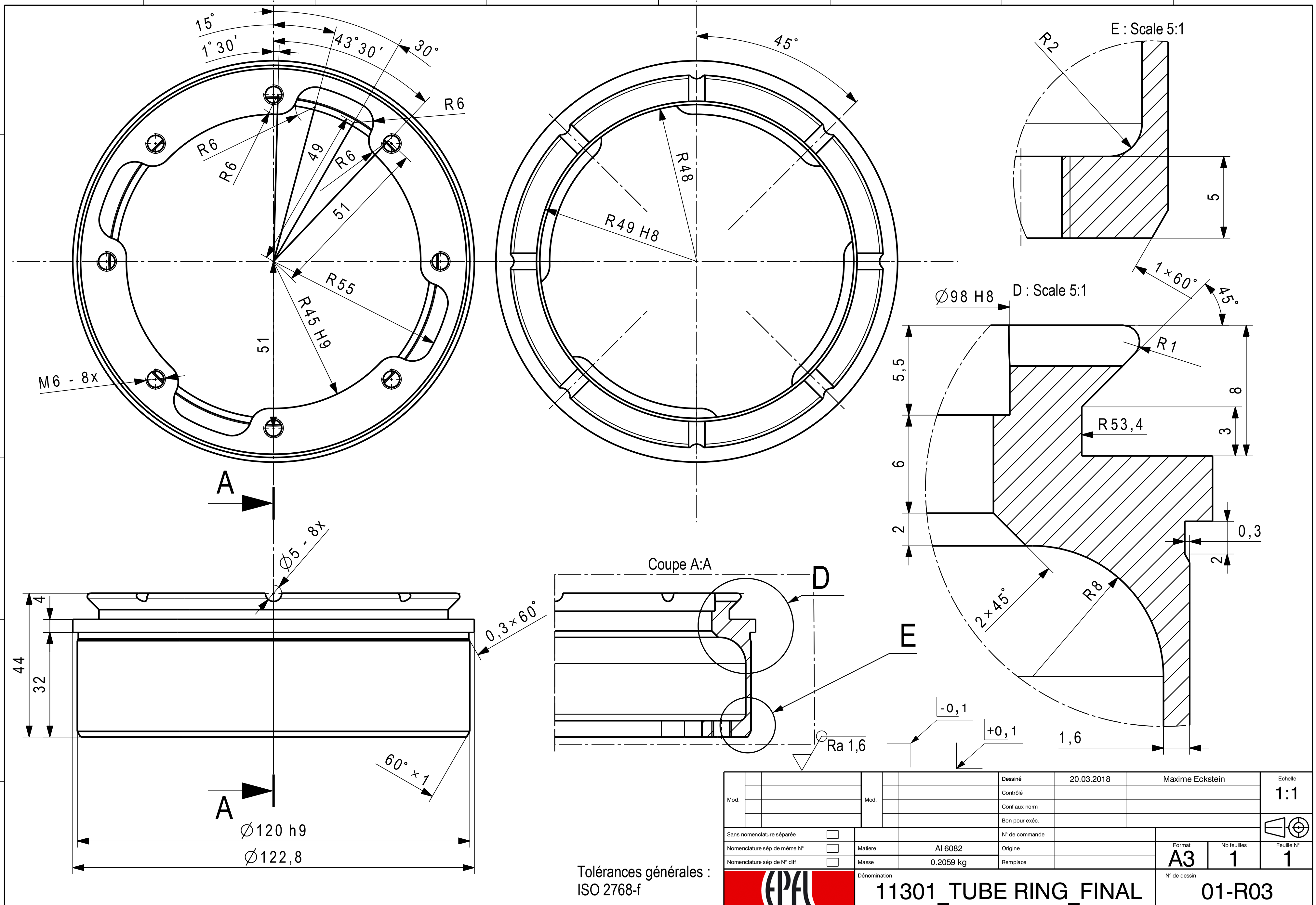
11102_INSERT_TIP

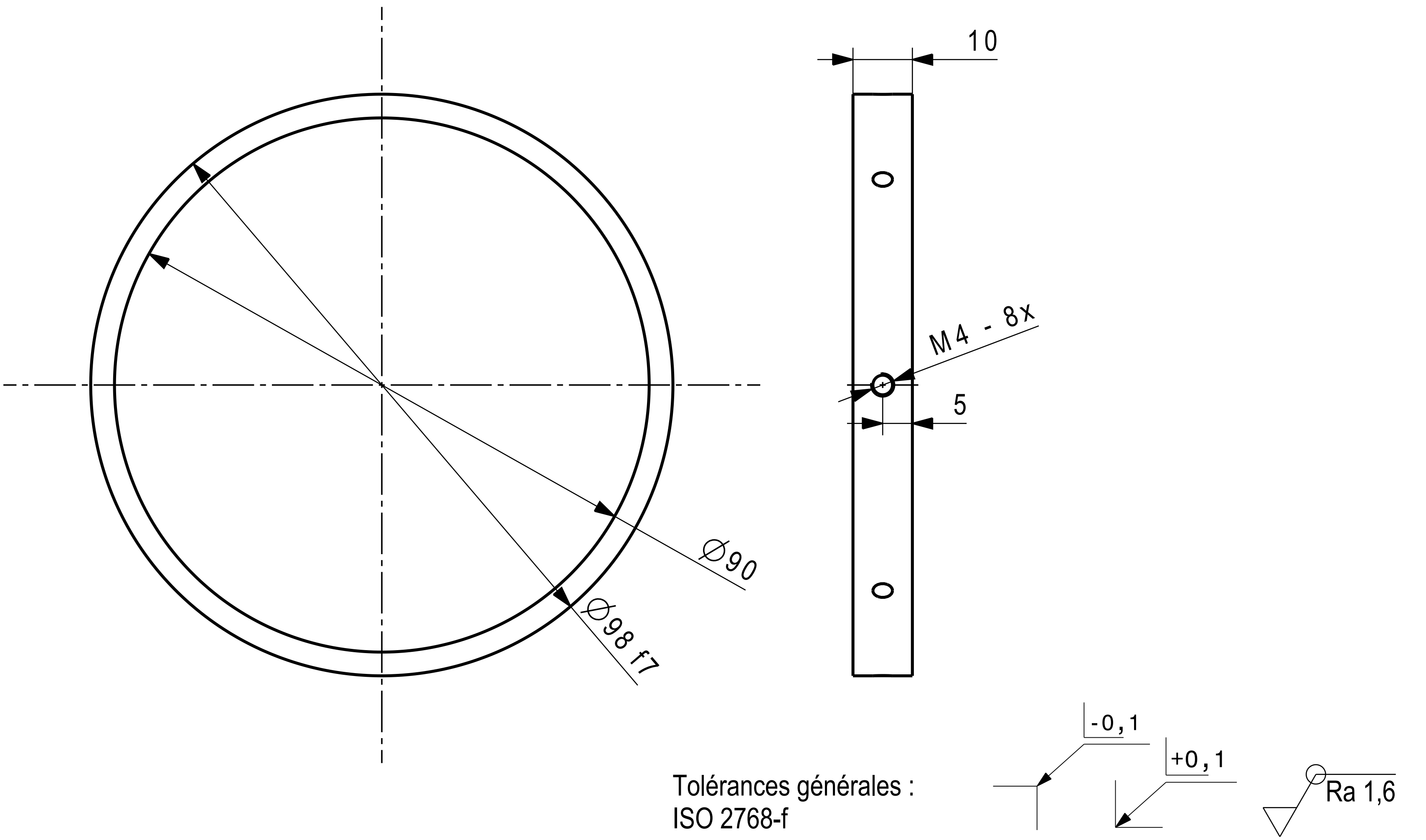
N° de dessin



Cut A-A:
Scale 2:1

Mod.		Mod.		Dessiné	20.03.2018	Emilien Mingard	Echelle 2:1
				Contrôlé			
				Conf aux norm			
				Bon pour exéc.			
Sans nomenclature séparée ☐				N° de commande			
Nomenclature sép de même N° ☐		Matiere	PTFE	Origine		Format A4 / Nb feuilles 1	Feuille N° 1
Nomenclature sép de N° diff ☐		Masse	0.01 kg	Remplace			
EPFL		Dénomination	11103_HOLE_TIP			N° de dessin	


15°
1°30'
43°30'
30°
R6
R6
R6
R6
49
51
51
R55
R45 H9
M6 - 8x
45°
R48
R49 H8
E : Scale 5:1
R2
5
1×60°
45°
Ø98 H8
D : Scale 5:1
R1
5,5
8
R53,4
3
6
2
0,3
2
2×45°
R8
1,6
-0,1
+0,1
Ra 1,6
A
A
Ø5 - 8x
4
44
32
0,3×60°
60°×1
Ø120 h9
Ø122,8
Coupe A:A
D
E
Tolérances générales :
ISO 2768-f
Mod.
Mod.
Dessiné
20.03.2018
Maxime Eckstein
Contrôlé
Conf aux norm
Bon pour exéc.
N° de commande
Origine
Remplace
Echelle
1:1
Sans nomenclature séparée
Nomenclature sép de même N°
Nomenclature sép de N° diff
Matiere
Al 6082
Masse
0.2059 kg
Format
A3
Nb feuilles
1
Feuille N°
1
Dénomination
11301_TUBE RING_FINAL
N° de dessin
01-R03



Tolérances générales :
ISO 2768-f

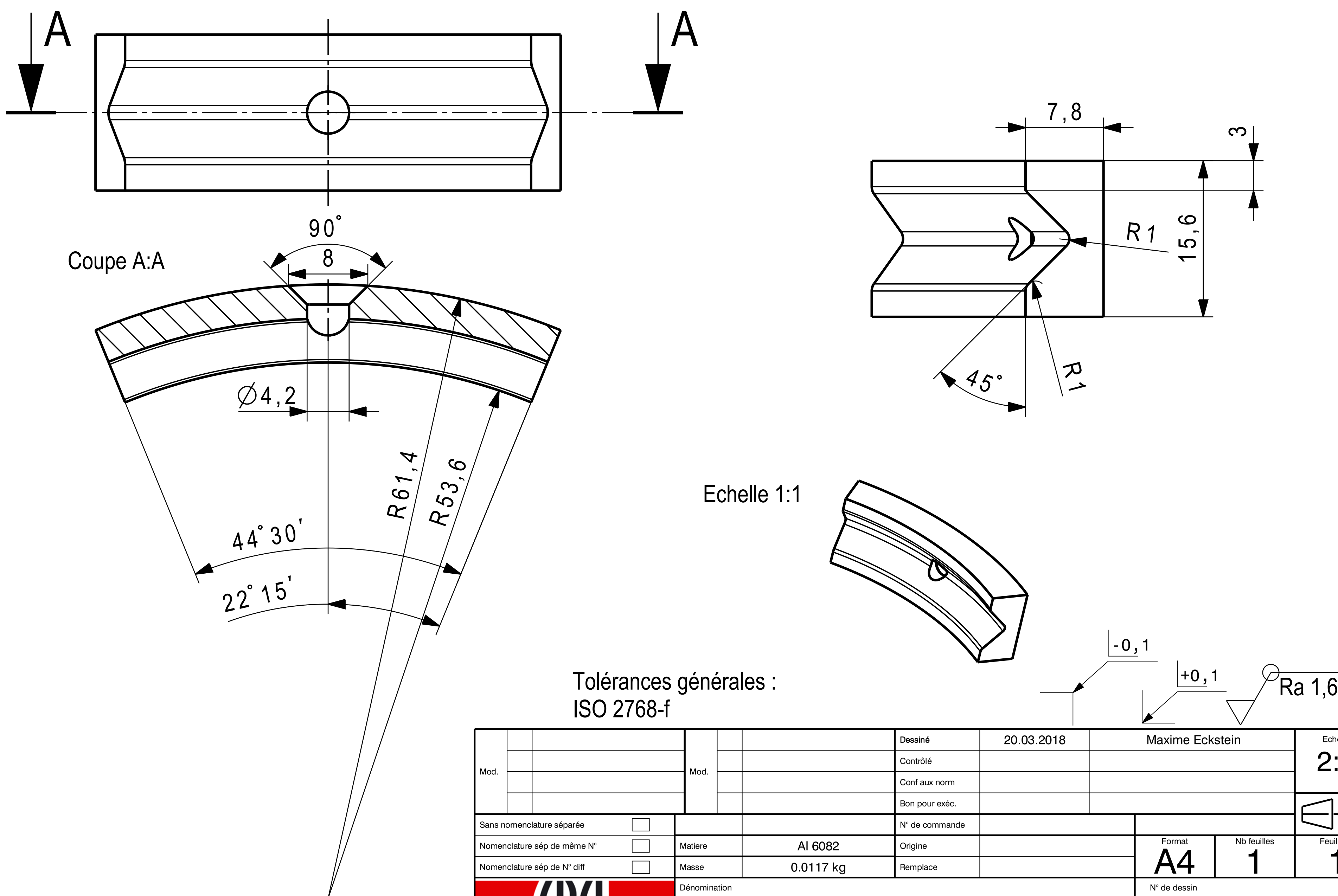
Dessiné	20.03.2018	Maxime Eckstein	Echelle	1:1
Contrôlé				
Conf aux norm				
Bon pour exéc.				
Sans nomenclature séparée	N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine	Format: A4	Nb feuilles: 1
Nomenclature sép de N° diff	Masse: 0.0297 kg	Remplace		Feuille N°: 1

Mod. | Mod.

EPFL

Dénomination: 11302_BAGUE_INTERNE

N° de dessin: 03-R03



Tolérances générales :
ISO 2768-f

Dessiné	20.03.2018	Maxime Eckstein	Echelle 2:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine			
Remplace			

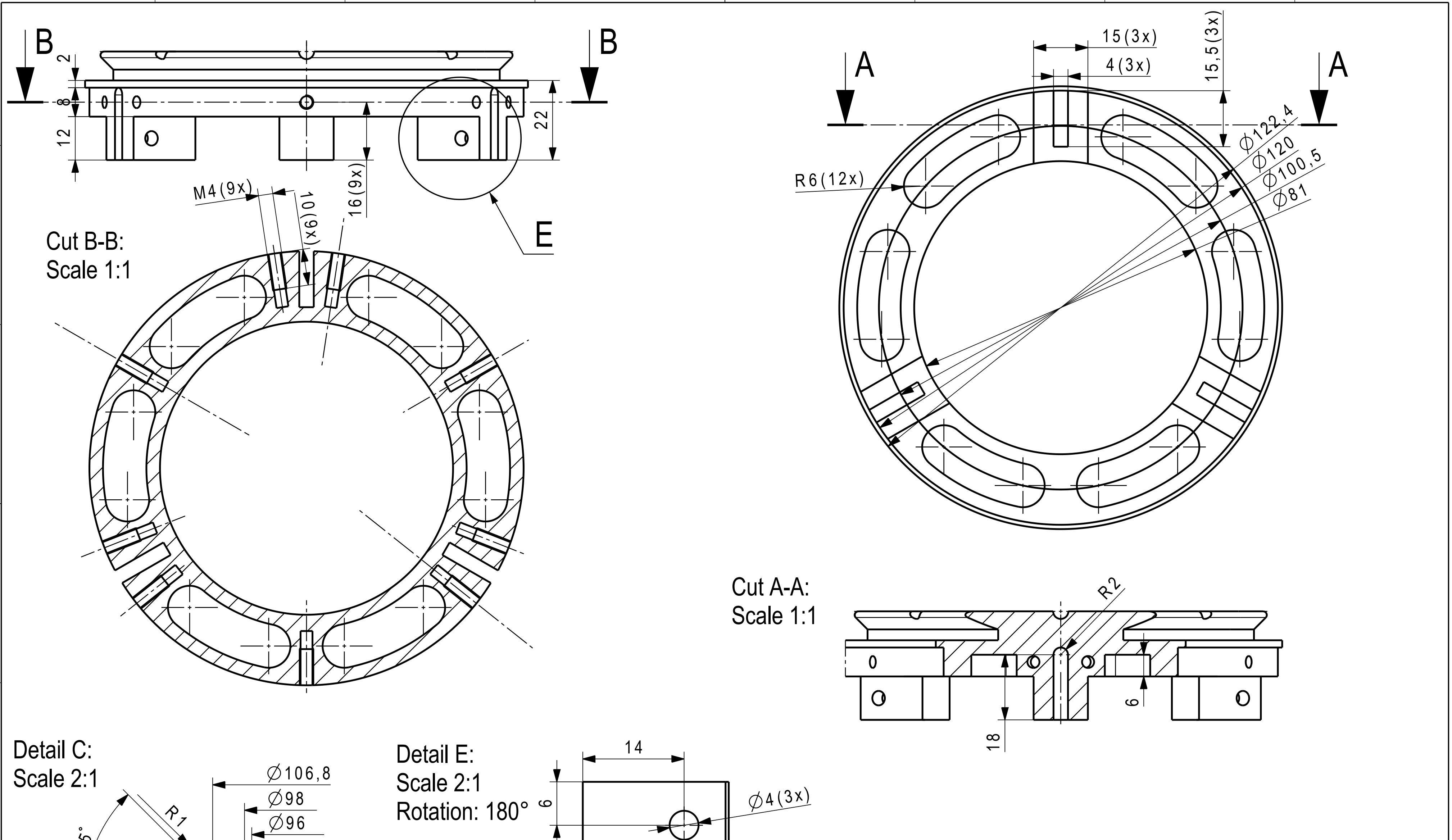
Sans nomenclature séparée	☐
Nomenclature sép de même N°	☐
Nomenclature sép de N° diff	☐

Matiere	Al 6082
Masse	0.0117 kg

Format	Nb feuilles	Feuille N°
A4	1	1

Dénomination
11303_BAGUE

N° de dessin
02-R03



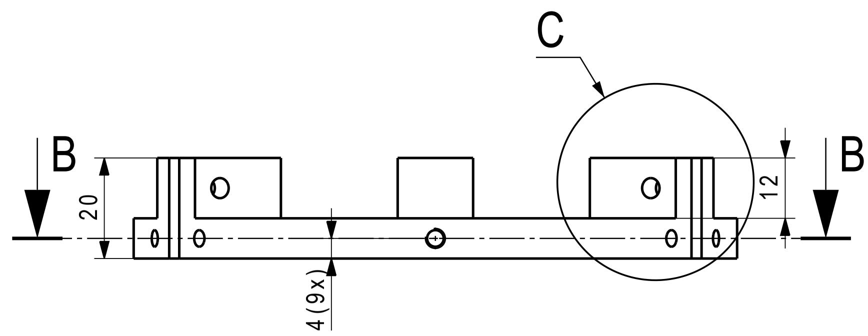
Cut B-B:
Scale 1:1

Cut A-A:
Scale 1:1

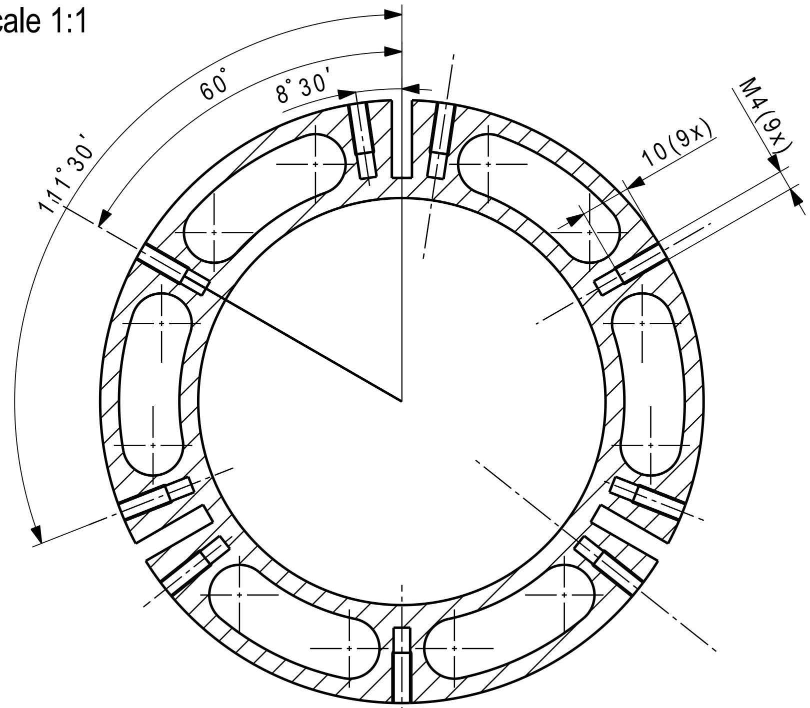
Detail C:
Scale 2:1

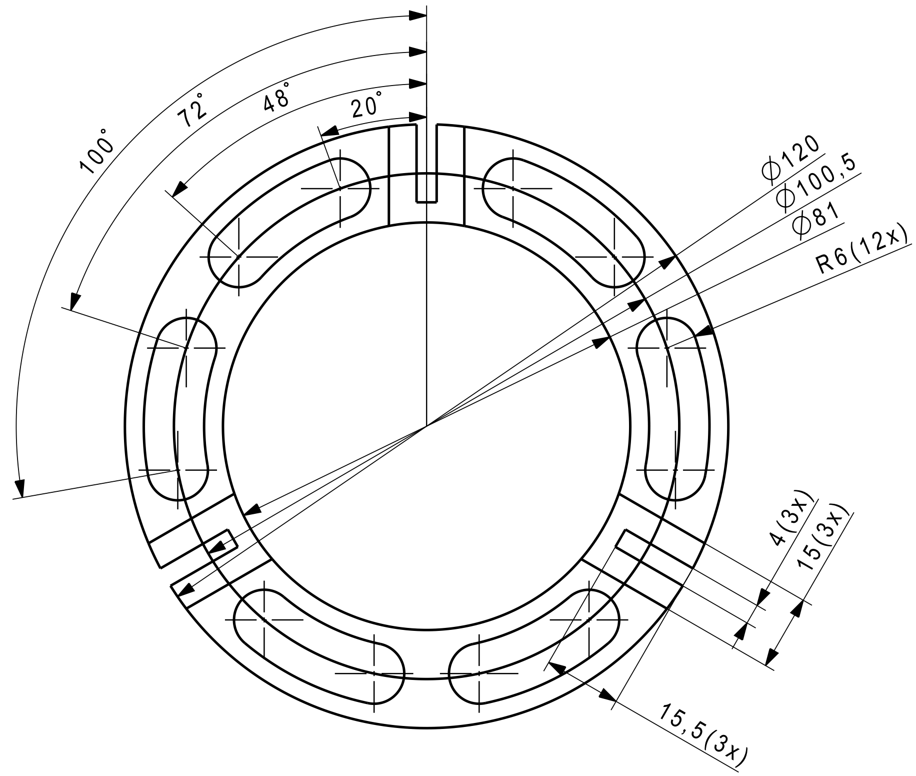
Detail E:
Scale 2:1
Rotation: 180°

Mod.	Mod.	Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine		Format: A3	Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.1841 kg	Remplace			
EPFL	Dénomination: 11401_UPPER_RING			N° de dessin: 3	

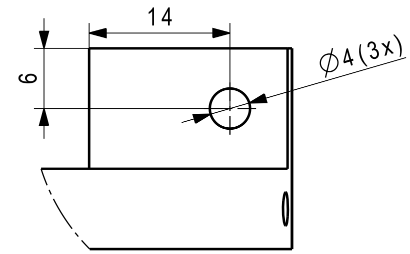


Cut B-B:
Scale 1:1

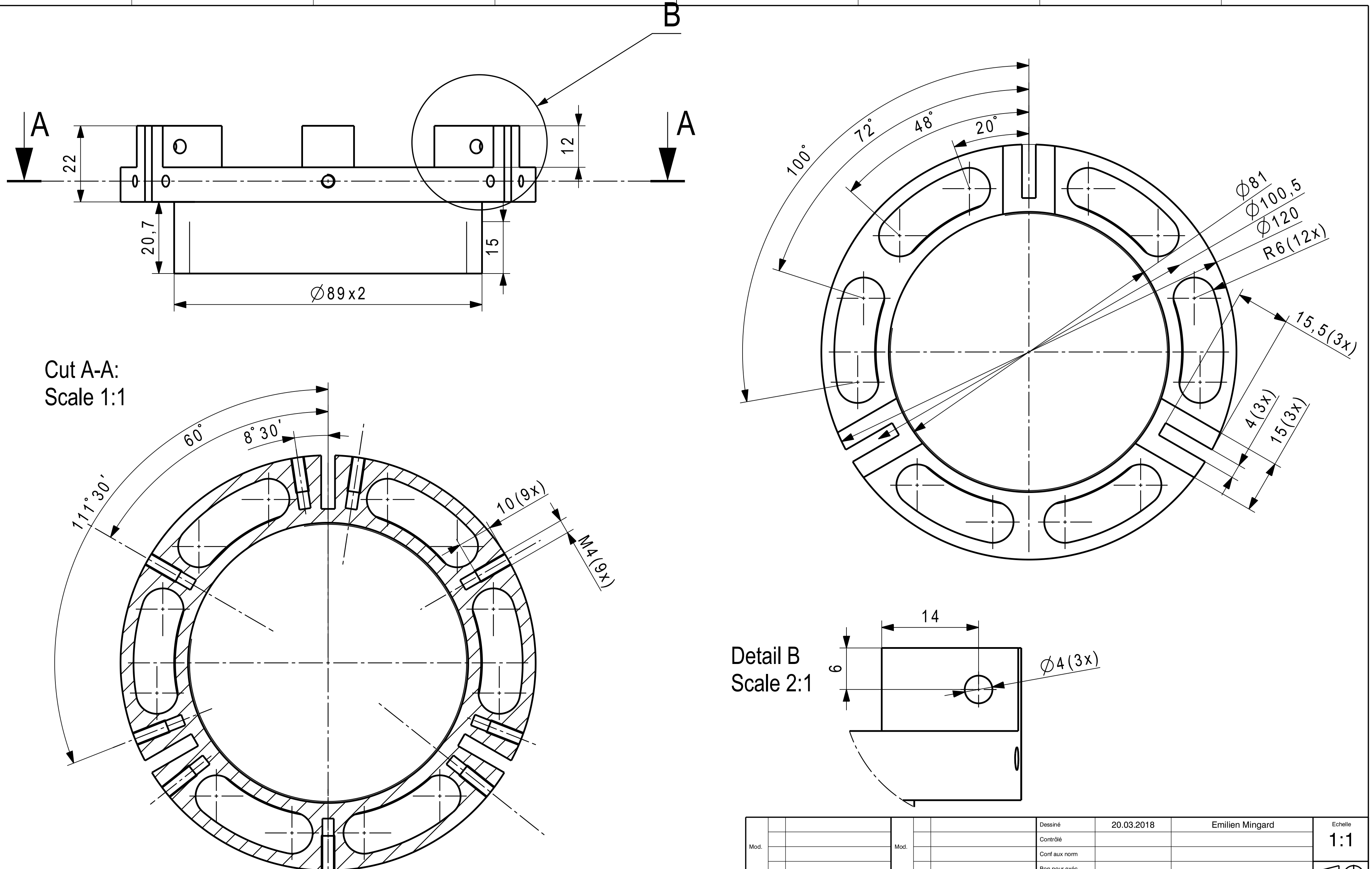




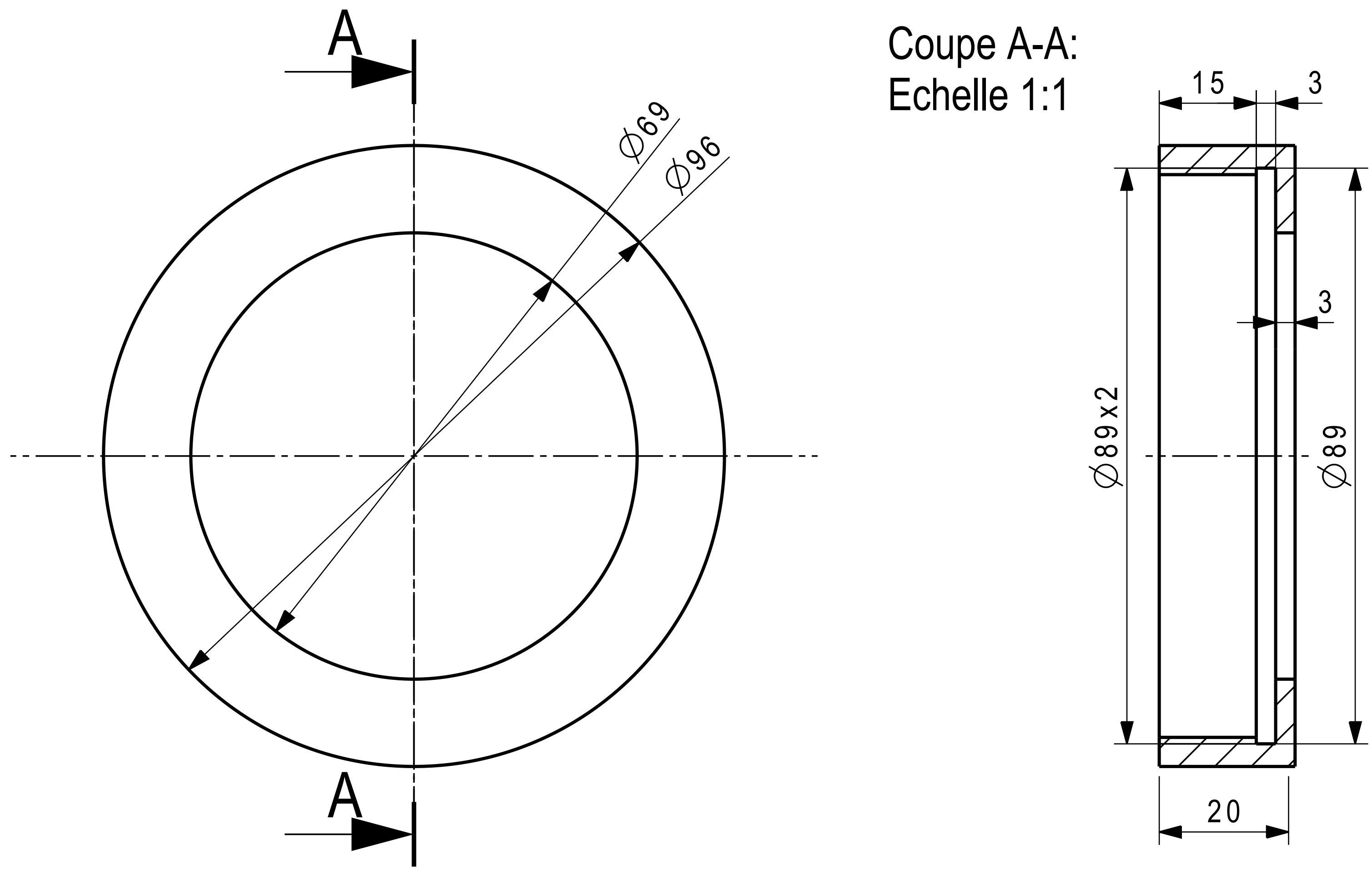
Detail C:
Scale 2:1



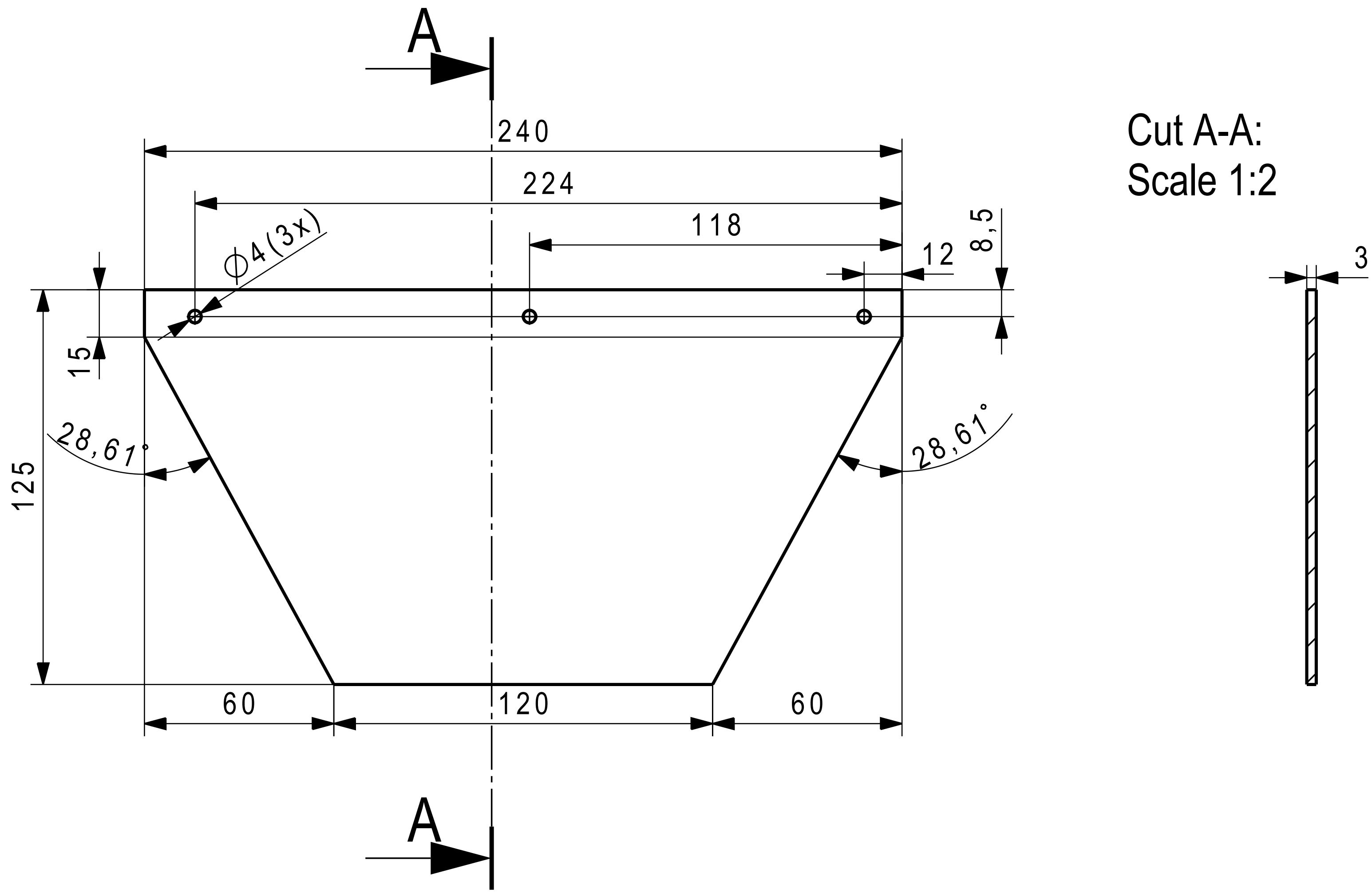
Mod.	Mod.	Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere Al 6082	Origine		Format A3	Nb feuilles 1 / Feuille N° 1
Nomenclature sép de N° diff	Masse 0.0942	Remplace			
EPFL	Dénomination 11402_MIDDLE_RING			N° de dessin 1	



Mod.	Mod.	Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine		Format: A3	Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.1613 kg	Remplace			
EPFL	Dénomination: 11403_LOWER_RING			N° de dessin: 2	



Mod.	Mod.	Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine		Format: A4	Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.0727 kg	Remplace			
EPFL	Dénomination: 11404_AFT_ENCLOSURE_75			N° de dessin	



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:2
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Matiere	CFRP	Origine	
Masse	0.1047 kg	Remplace	
Format A4	Nb feuilles 1	Feuille N° 1	

Sans nomenclature séparée
Nomenclature sép de même N°
Nomenclature sép de N° diff

Mod.
Mod.

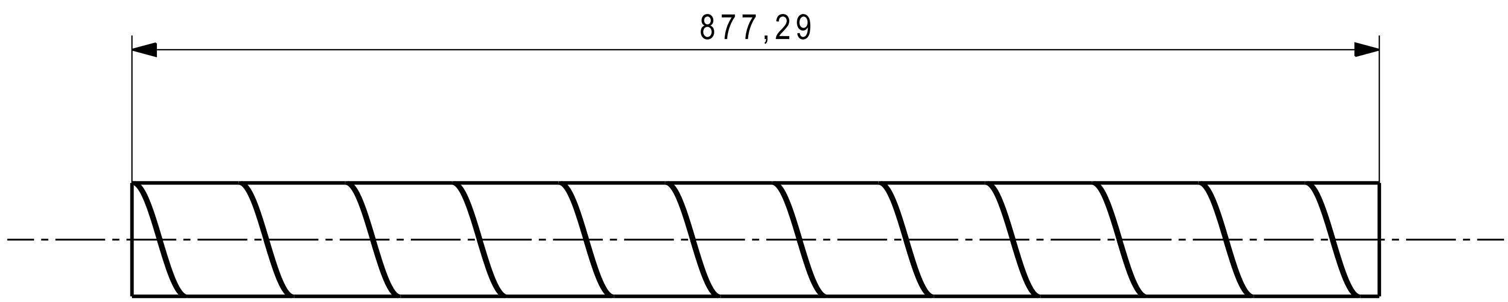
EPFL

Dénomination

11405_FINS_V1

N° de dessin

Commercial Part:
Public Missile 75mm motor mount
Ref n°: ADPTR-75/54
publicmissiles.com

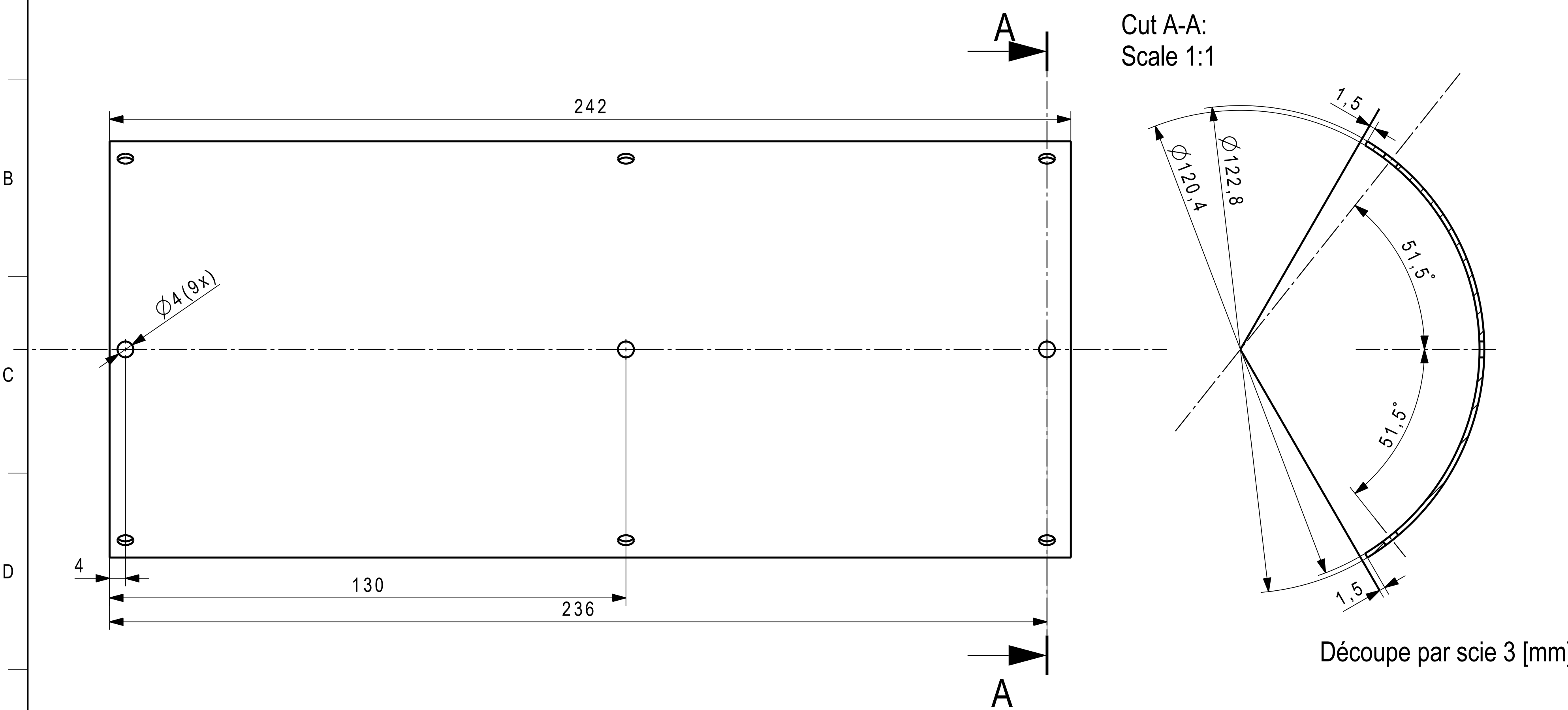


Sketch for length cut

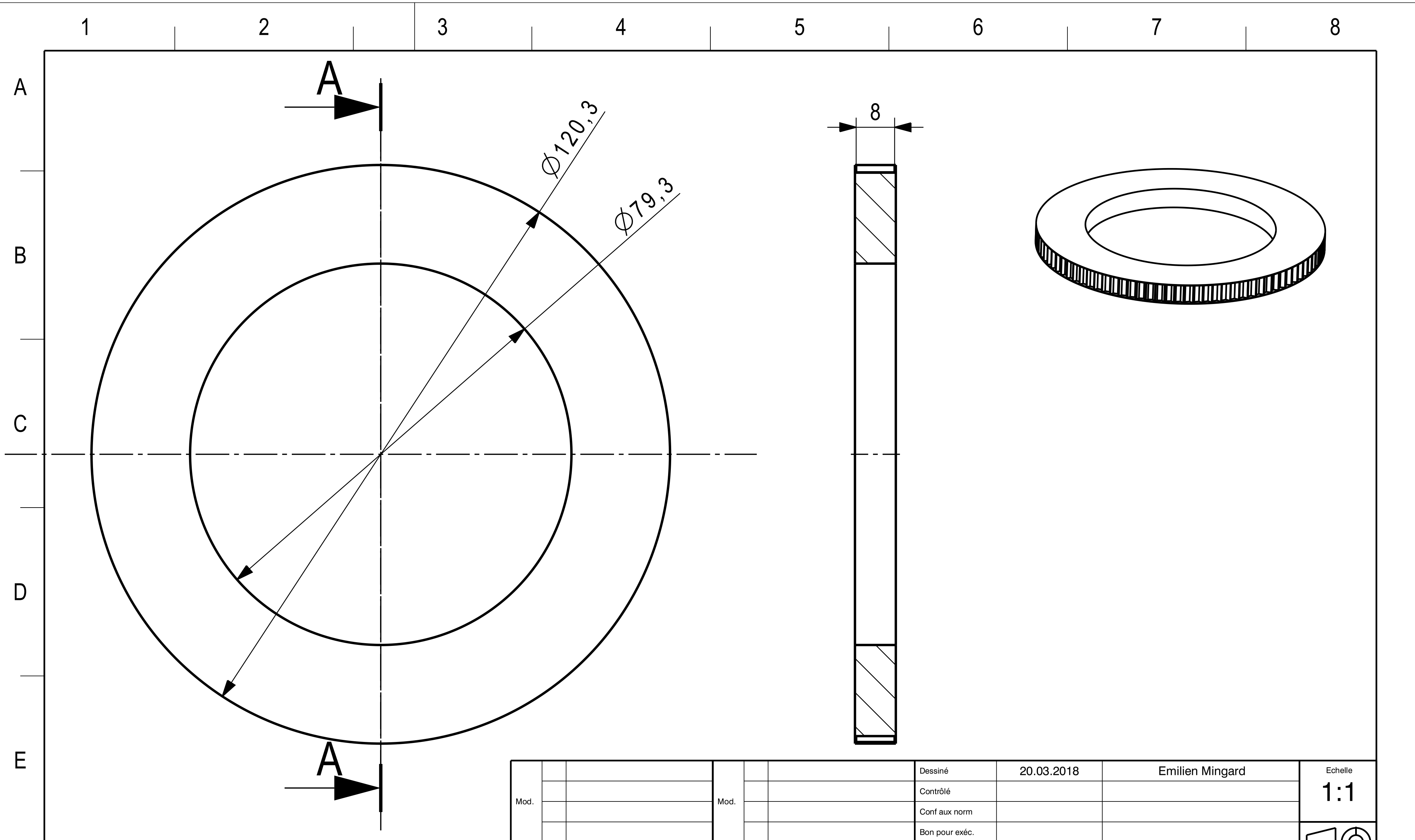
Dessiné	20.03.2018	Emilien Mingard	Echelle 1:5		
Contrôlé					
Conf aux norm					
Bon pour exéc.					
N° de commande					
Sans nomenclature séparée					
Nomenclature sép de même N°	Matiere	Phenolic Tube	Origine		
Nomenclature sép de N° diff	Masse	0.3225 kg	Remplace		
Format A4	Nb feuilles 1	Feuille N° 1			
Dénomination	11406_MOTOR_TUBE	N° de dessin			

Mod.

Mod.



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
Sans nomenclature séparée		N° de commande	
Nomenclature sép de même N°	Matiere: CFRP	Origine	Format: A3 / Nb feuilles: 1 / Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.0552 kg	Remplace	
EPFL	Dénomination: 11408_THIRD_OF_PANEL		N° de dessin

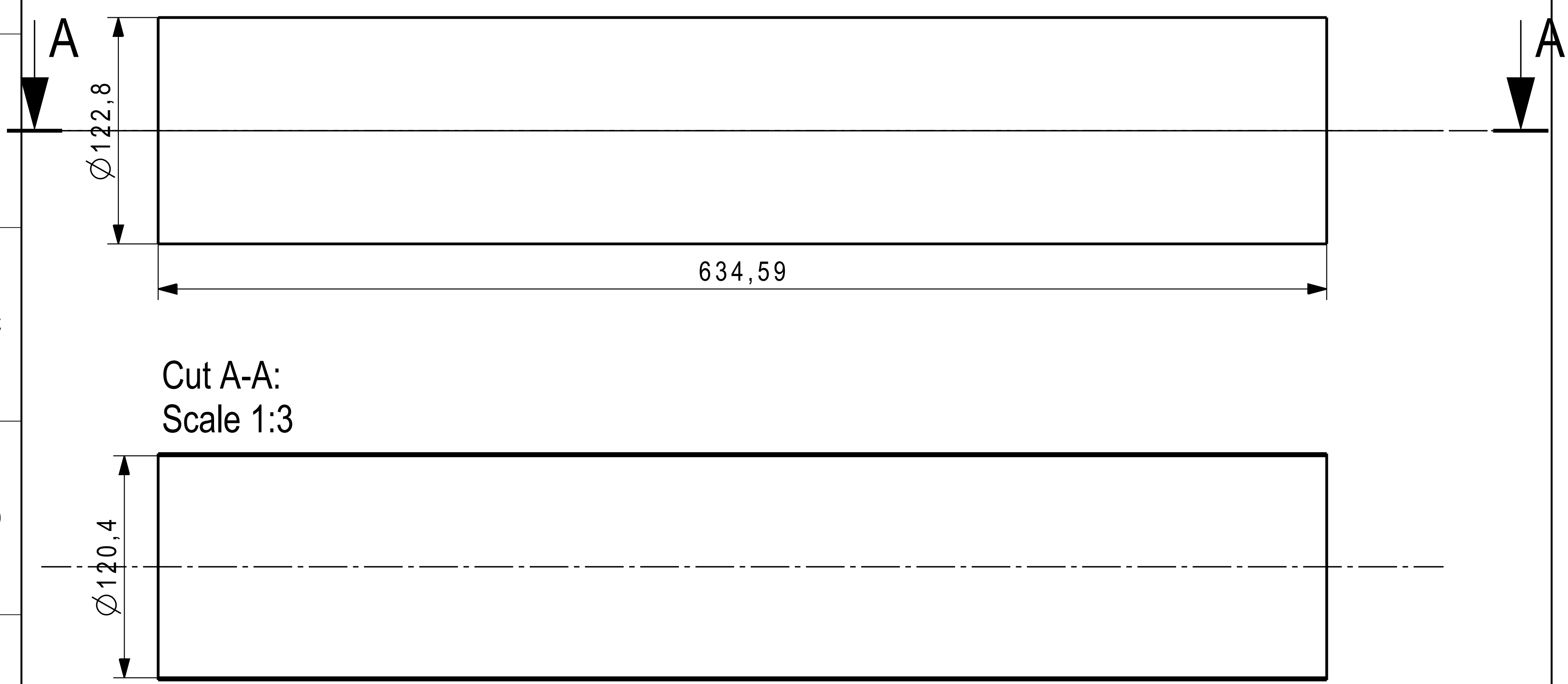


Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Matiere	CFRP-Aramid	Origine	
Masse	0.0083 kg	Remplace	
Format A4	Nb feuilles 1	Feuille N° 1	

Sans nomenclature séparée
Nomenclature sép de même N°
Nomenclature sép de N° diff

Dénomination
11504_SANDWICH_CENTERING_RING

N° de dessin



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:3
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine		Format A4	Nb feuilles 1
Remplace			Feuille N° 1

Sans nomenclature séparée	☐
Nomenclature sép de même N°	☐
Nomenclature sép de N° diff	☐

Mod.

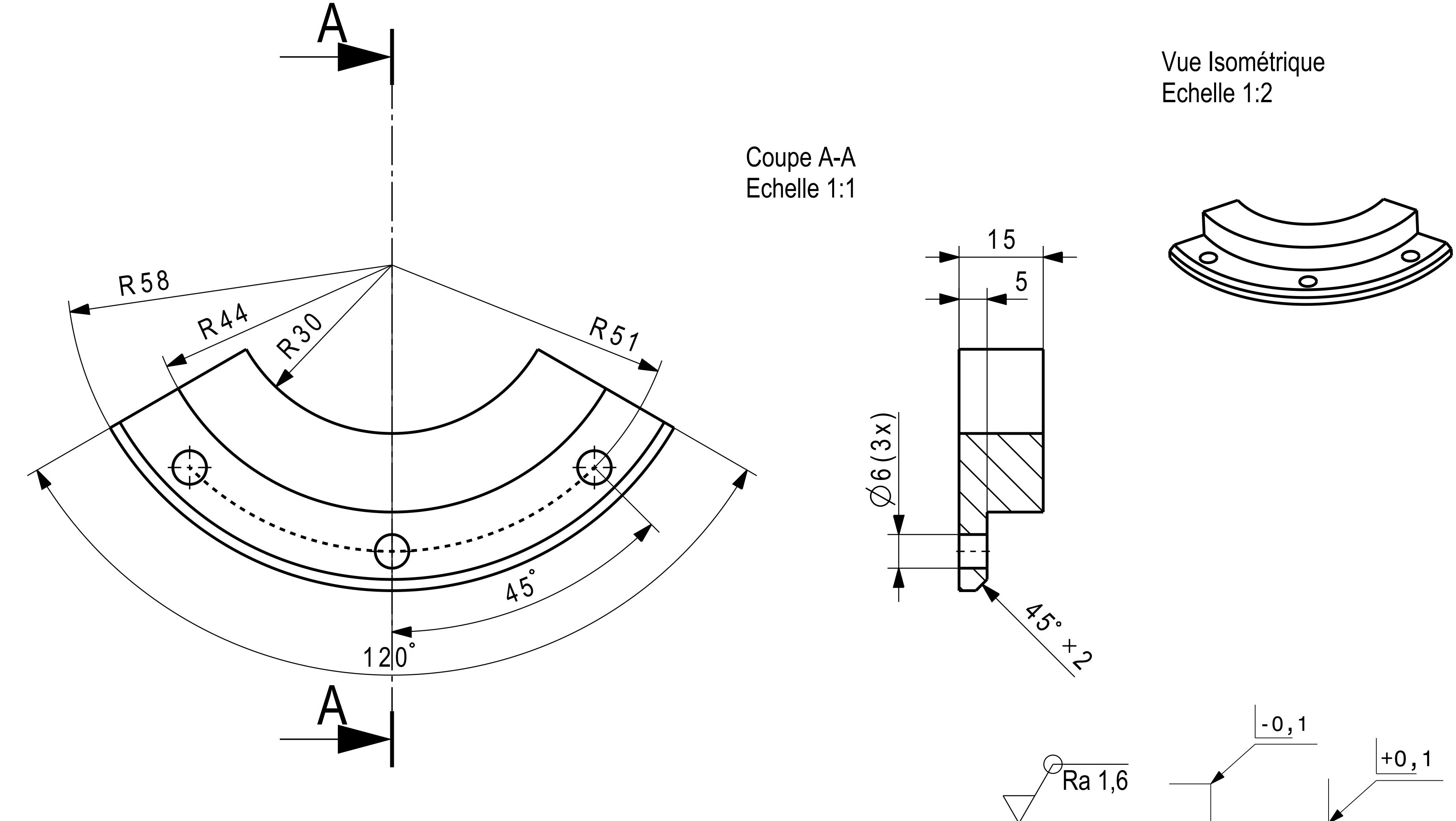
Mod.

Matiere	CFRP
Masse	0.4634 kg

Dénomination

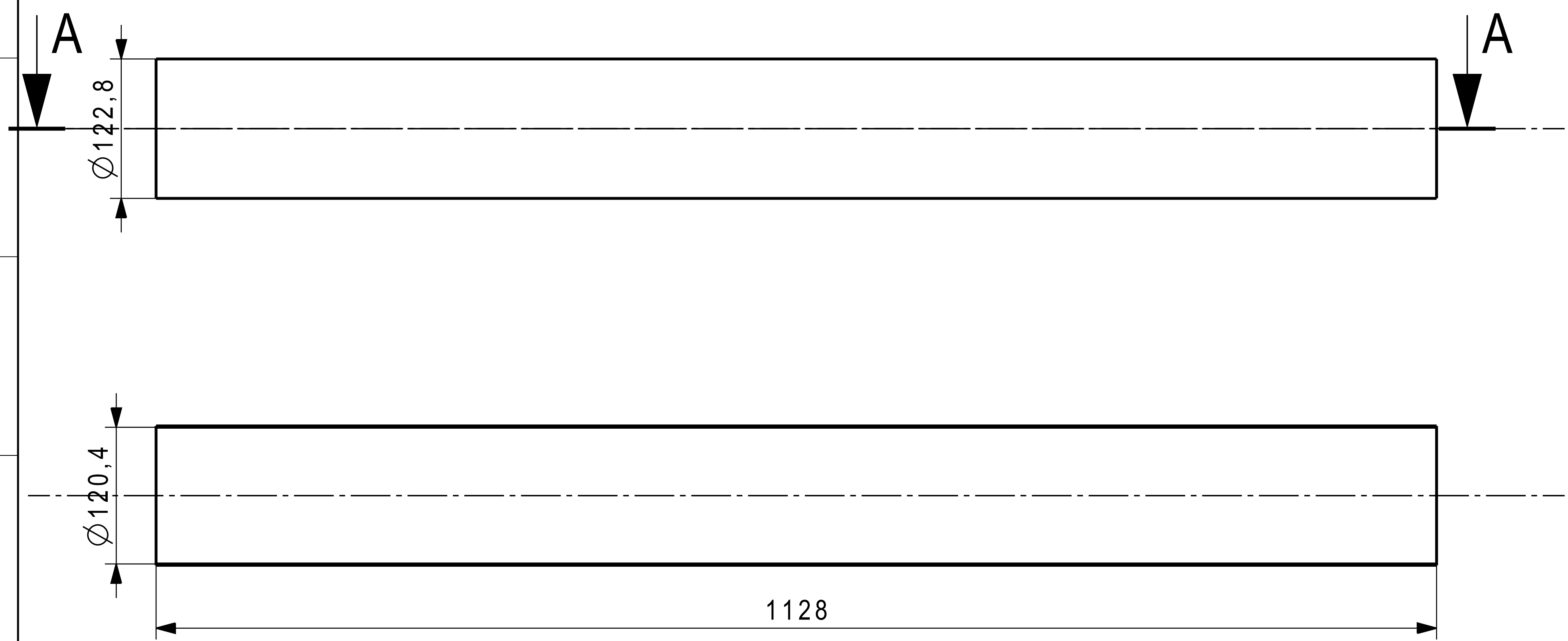
11501_LOWER_AIFRAME

N° de dessin

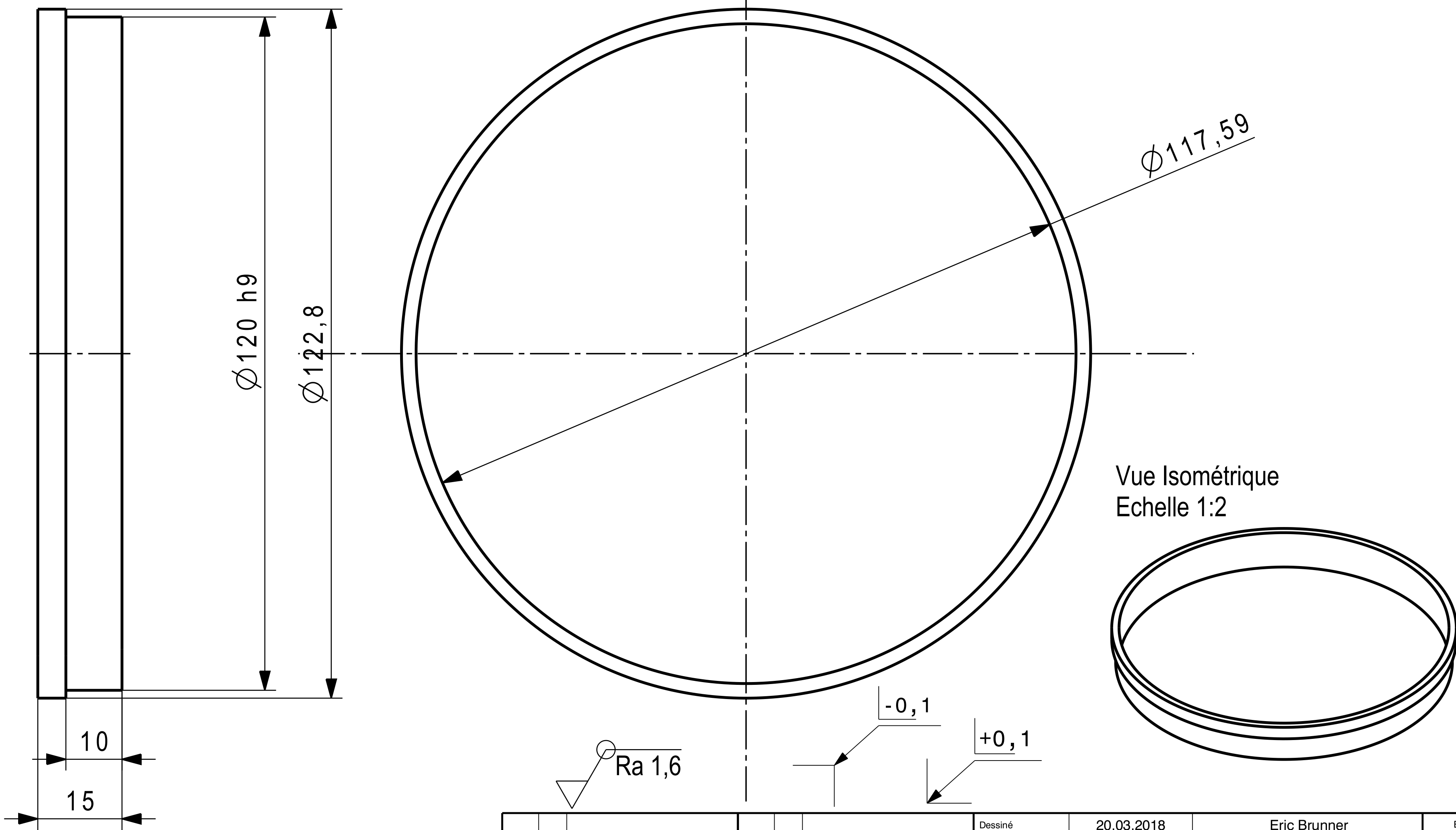


Tolérances Générale
ISO 2768 - f

Mod.	Mod.	Dessiné	20.03.2018	Emilien Mingard
		Contrôlé		
		Conf aux norm		
		Bon pour exéc.		
Sans nomenclature séparée ☐		N° de commande		
Nomenclature sép de même N° ☐	Matiere: Al 6082	Origine	Format: A4	Nb feuilles: 1
Nomenclature sép de N° diff ☐	Masse: 0.0623 kg	Remplace		Feuille N°: 1
EPFL	Dénomination: 11502_THRUST_PLATE		N° de dessin: 1	Echelle: 1:1

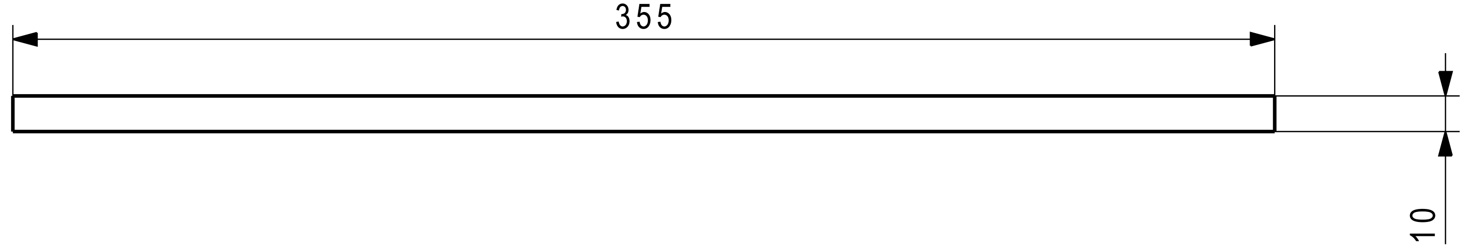


Dessiné	20.03.2018	Emilien Mingard	Echelle 1:5		
Contrôlé					
Conf aux norm					
Bon pour exéc.					
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere CFRP	Origine	Format A4	Nb feuilles 1	Feuille N° 1
Nomenclature sép de N° diff	Masse 0.8168 kg	Remplace			
EPFL	Dénomination 11601_UPPER_FRAME		N° de dessin		



Tolérances générales :
ISO 2768-f

Mod.	Mod.	Dessiné	20.03.2018	Eric Brunner	Echelle 1:1
		Contrôlé			
		Conf aux norm			
		Bon pour exéc.			
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine		Format: A4 / Nb feuilles: 1	Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.0245 kg	Remplace			
	Dénomination: 11602_BAGUE_RENFORT			N° de dessin	

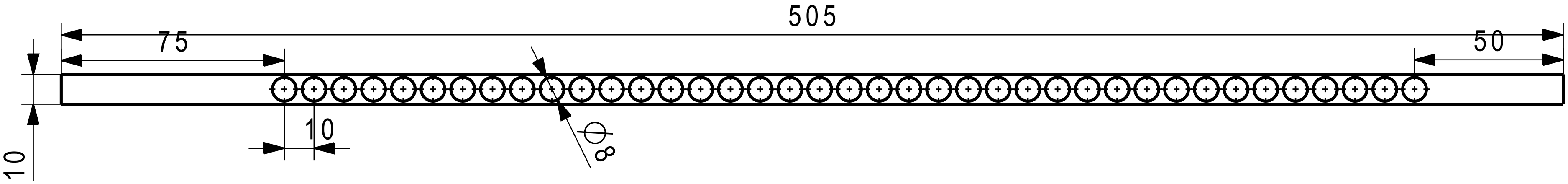


Dessiné	20.03.2018	Emilien Mingard	Echelle 1:2		
Contrôlé					
Conf aux norm					
Bon pour exéc.					
Sans nomenclature séparée		N° de commande			
Nomenclature sép de même N°	Matiere: Al 6082	Origine	Format: A4	Nb feuilles: 1	Feuille N°: 1
Nomenclature sép de N° diff	Masse: 0.0078 kg	Remplace			

Mod. | Mod.

Dénomination: 11604_LISTE_THIN

N° de dessin



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:2
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine		Format A4	Nb feuilles 1
Remplace			Feuille N° 1

Sans nomenclature séparée	
Nomenclature sép de même N°	
Nomenclature sép de N° diff	
Matiere	Al 6082
Masse	0.0447 kg

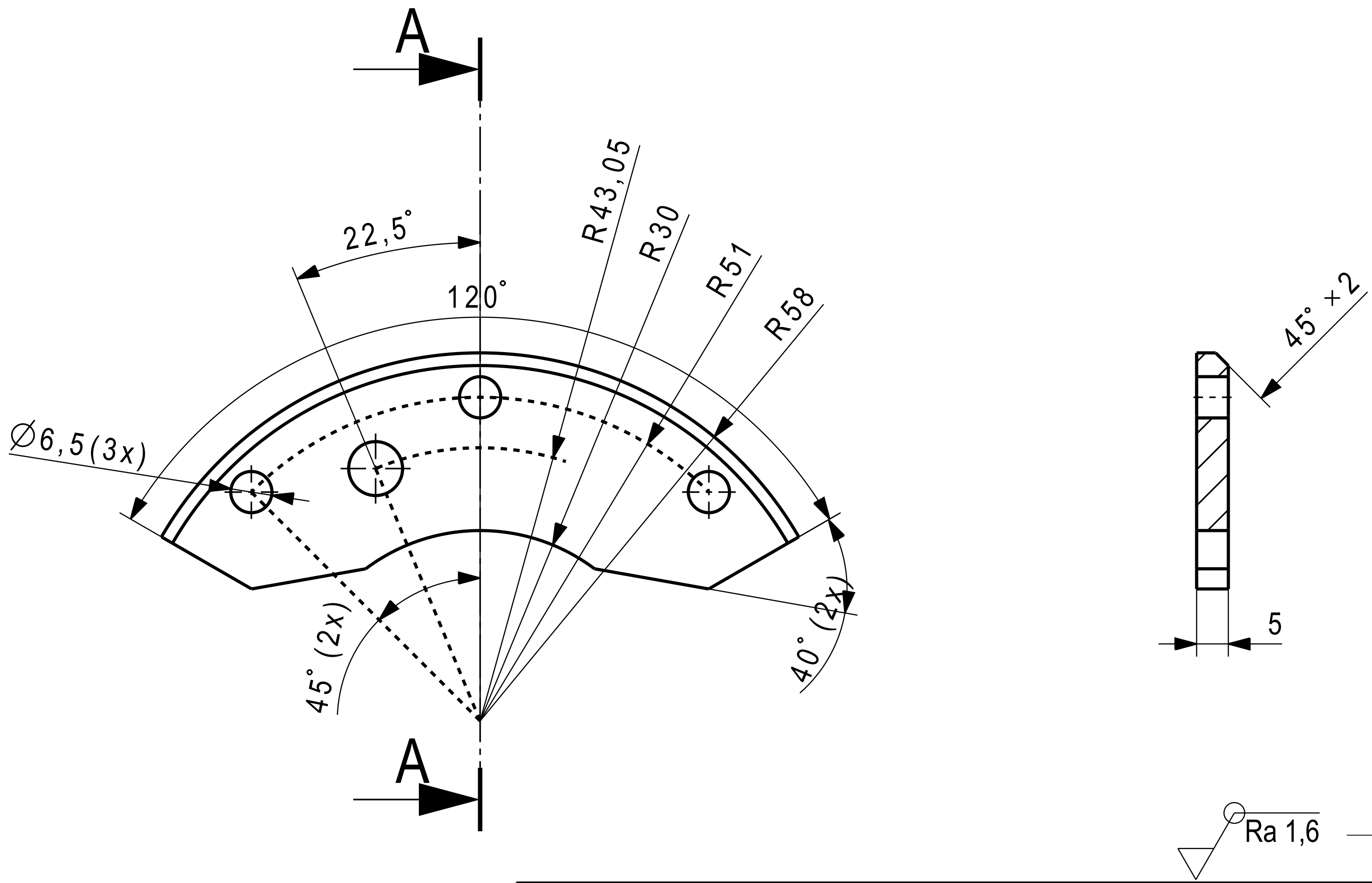
Mod.

Mod.

Dénomination

11605_LISTE_THICK

N° de dessin



Dessiné	20.03.2018	Emilien Mingard	Echelle 1:1
Contrôlé			
Conf aux norm			
Bon pour exéc.			
N° de commande			
Origine			
Remplace			

Sans nomenclature séparée			
Nomenclature sép de même N°	Matiere	Al 6082	
Nomenclature sép de N° diff	Masse	0.0301 kg	

Mod. | Mod.

Format A4 | Nb feuilles 1 | Feuille N° 1

Dénomination

11608_RECOVERY_COUPLING_RINGS

N° de dessin

G. Other

1. Propulsion Subsystem

Documents regarding hazard analysis and safety procedures:

- `2018_PP_SP_0001_RELOAD_INGNITER_MANIPULATION _R01`

HAZARDOUS MATERIAL SAFETY PROCEDURE

Title:	**Hazardous material handling, transportation and storage**	Date :27.03.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_PP_SP_0001_Reload-Igniter_Manipulation _R01	
Prepared by:	Alexandre Looten PP	
Checked by:	C3PO	
Approved by:	Darth Vader	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This document exposes manipulation, transportation and storage of propellant grain (reload) of RSPS (reloadable solid propulsion system) and motor igniter. These two types of hazardous elements
should be taken carefully, they are composed of explosive or highly flammable materials capable of harming the manipulator or the surrounding people. It can cause external burning and/or perforing impact by high velocity dispersed particles and respiratory problems due to the combustion gases.
So these elements should always be stored and transported in a hermetic and specific package and placed away from any source of fire or heat.
The manipulations of the igniters and the propellant should only be done by the formed propulsion team members.

2 SCOPE

This document addresses practices for grain reload and igniters handling, transportation and operations within the framework of the ERT.

This document points out the role of the responsible for the designated hazardous material.

This document points out many safety and health issues and recommended practices. However, safety standards and recommendations provided by EPFL, swiss federation, facility or any entity in charge remains applicable.

Communal, cantonal, federal and international legislations about the concerned hazardous material are still applicable.

3 STANDARDS AND REFERENCES

The references presented here are the hazardous materials safety datasheet of the producer.

Table 3-1 Normative Documents

Ref	Description	Doc. Number	Issue
[ND01]	AeroTech Motor & Reload MSDS.pdf		
[ND02]	AeroTech-Motor-Reload-SDS-10-28-15.pdf		
[ND03]	http://www.aerotech-rocketry.com/uploads/1cf8af3e-6c53-4eba-9538-167caefe9518_AeroTech%20Igniter%20SDS%2012-3-15.pdf		

Table 3-2 Reference Documents

4 HAZARDOUS MATERIAL OFFICER

An active member must be designated by system engineering and by the subsystem team in charge as the responsible of the relevant grain reload and igniter. This responsible must be cautious and informed about the legislation about the concerned hazardous material.

More than one officer may be assigned if more than one subsystem is using the same hazardous material. In this case, each subsystem must have his own officer. In any case a subsystem should have more than one person in charge of the hazardous material in question.

An officer can turn the responsibility of the handling, transportation or storage over another active member under the following conditions:

- The member is informed about the legislation about the concerned hazardous material.
- The member has read the present document.
- The member has all the information about the hazardous material, the setup and procedures in his possession, to ensure the safety of every person and piece of equipment involved.
- The member has no precedent concerning the designed hazardous material.
- The officer is not present during the test or unable to do the specified task.
- The head of the ERT, including SE is warned of this decision.

An officer may be dismissed by the system engineering team, by a majority of a sub team, or by recommendation of an external stakeholder if the head of the ERT, including SE agree with the decision.
An officer may resign at any moment by addressing a written and signed letter to the head of the ERT, including SE. All the subsystems must be informed of this decision.

At the moment an officer resigns or is dismissed, all the hazardous material must be returned to the head of the ERT or SE. SE must assign a new officer within 5 days. During this period, an active member must be chosen as temporary officer in order to manage the transport and storage of the hazardous material. Until a permanent officer is assigned, any handling of the hazardous material is prohibited. If more than one officer oversees the hazardous material in question, one of the remaining officers take immediately the role of temporary officer for the other subsystem and the previous restriction is no longer valid.

5 STORAGE

The grain reloads elements and the igniters should be stored in a dry location, far from any fire or source of heat and acids.[ND02] and [ND03].

Hence all these two type of elemets (grain reloads and igniters) should be deposited in a dedicated specific locker with the precaution of handling datasheet and the flammable pictogram placed on it.

These reloads grains and the igniters cannot be stored in the ERT room unless a special agreement is signed between the EPFL and the ERT.

In the locker, these elemets must be stored in separate closed box reserved for this purpose.

The locker must be locked and only the member responsible should have the key.

The room, box or the environment temperature in which the reloads and igniters are stored must not exceeded the limit of 325F (50°C).

Ensure the environment is sparks and fire free and is not closed to high electromagnetic fields.

No current source, battery, electronical component or conductive material should be directly in contact neither with the black powder and the packaging.

6 TRANSPORTATION

6.1 General recommendations

Hazard class 1 or 4 depending on whether special permit DOT-SP 7887 is used. (USA transport class)

The transportation of the grain reloads and the igniters should always be done in in their dedicted locked boxes.

The surrounding temperature shoulf not exceeded the limit of 325F (50°C).

No current source, battery, electronical component or conductive material should be directly in contact neither with the materials and the packaging.

6.2 Individual transport

General recommendations about transportation remain applicable.

If possible keep these elements well attached in the trunk.

Do not leave the black powder inside an enclosed vehicle.

Prevent overturning of the box during travel.

Prevent shocks received from any direction and therefore even if the case is overturned.

Ensure the environment is sparks and fire free.

In case of fire of your vehicle containing these hazardous materials, warn immediately the fire rescue brigade their presence, location and type.

6.3 Shipping

General recommendations about transportation remain applicable.

The shipping rules and classes depend on the countries regulations present on the shipping path. These regulations should be known and considerate by the responsible.

The shipping company must be informed of the presence of explosive material in the parcel.

The shipping package must be sealed.

The shipping package should be prepared within the supervision of professionals certified to transport hazardous materials according to its trip.

7 HANDLING AND OPERATIONS

7.1 General recommendations

Important, in case of fire with grain reloads use water and **not** foam or CO_2 that are ineffective. And it is recommanded to wear a full-face mask to prevent inhaling toxic combustion gases.

Disposable rubber gloves are recommended for handling of grain reloads and igniters.

Do not smoke near grain reloads and igniters.

Prevent any shock or scratch that can induce damage, contamination or pollution.

No current source, battery, electronical component or conductive material should be directly in contact with the reloads and igniters.

Ensure the environment is sparks and fire free. Motors, actuators and igniters are exempted of the previous restriction.

7.2 Preparation and handling recommendations

Some disposable rubber gloves should be provided with the dedicated boxes, so the materials can always be manipulated without risks.

7.3 Test and launch recommendations

General recommendations about handling and operation remain applicable.

Keep away from the system during fire or explosion. The safety distance from the system should be determined before starting the experiment, test or launch according to the risks of projection, failure, or nominal functioning of the system. The minimal safety distance must be 10m regardless of the set-up.

In case of problems of non-ignition, a delay should be respect before breaking the safety distance. The duration of this delay should be determined before the test or launch but it should last at least 300s.

The local security organisation or office must be informed of the use and type of grain reloads and igniters during the experimentation, the launch or any handling involving the charged motor.

8 WASTE MANAGEMENT

For the grain reloads:

"Recommendations of appropriate disposal methods to employ: Bury loaded rocket motor in hole in ground with only the nozzle exposed, away from people, buildings, animals and flammable materials. Ignite motor electrically from a safe distance. Propellant and other pyrotechnic materials will burn until consumed. After the motor has cooled down, dispose of spent components in an inert trash receptacle." [ND02]

There is no dedicated container for this type of waste, so when all the pyrotechnics element have been burned, they must be deposited in the classic garbage bin.

For the igniters:

"Recommendations of appropriate disposal methods to employ: Discharge igniter at a safe distance using a 12 volt car battery or similar power source. The pyrotechnic coating on the igniter will burn until consumed. Dispose of spent igniter in an inert trash receptacle." [ND03]

There is no dedicated container for this type of waste, so when all the pyrotechnics element have been burned, they must be deposited in the classic garbage.

Under no condition the used products should be dispose in landfills or in sewer system.

2. Recovery Subsystem

Documents regarding hazard analysis and safety procedures:

- 2018_RE_SP_0001_CO2_SAFETY_PROCEDURE_R02
- 2018_RE_SP_0002_BLACK_POWDER_SAFETY_PROCEDURE_R01

The method used to estimate opening forces on the parachute are presented:

- 2018_RE_TN_0001_OPENING_FORCES_R03

More details on manufacturing are included:

- 2018_RE_TN_0002_ELECTRICAL_SHOCK_CORD_R02
- 2018_RE_TN_0003_PARACHUTE_R01

Documents regarding test procedures:

- 2018_RE_TP_0002 _WIND_TUNNEL_REEFING_POC_R01
- 2018_RE_TP_0003_SMALL_SCALE_MODULE_INTEGRATED_R01
- 2018_RE_TP_0004_SMALL_SCALE_MODULE_GT_R03
- 2018_RE_TP_0005_SMALL_SCALE_MODULE_DT_R02
- 2018_RE_TP_0006_DT_R01
- 2018_RE_TP_0007_GT_R01
- 2018_RE_TP_0008_INTEGRATED_R01
- 2018_RE_TP_0009_DEPLOYMENT_BAG_R01

HAZARDOUS MATERIAL SAFETY PROCEDURE

Title:	**CO2 cartridge handling, transportation and storage**	Date :01/11/2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_TP_01 _CO2_SAFETY_PROCEDURE_R01	
Prepared by:	Guilain Lang	
Checked by:	Malo Goury	
Approved by:	Eric Brunner	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

Rocketry involves often the use of CO2 cartridges to perform specific tasks as the separation of the nosecone at the apogee.

The pressure of the CO2 inside a cartridge is 60bar at 300K (25°C). A particularly cautious attitude must be adopted when using a high-pressure gaz.

This document addresses practices for CO2 handling, transportation and operations within the framework of the ERT.

This document points out the position of the officer for the designated hazardous material.

This document points out many safety and health issues and recommended practices. However, safety standards and recommendations provided by EPFL, swiss federation, facility or any entity in charge remains applicable.

Communal, cantonal, federal and international legislations about the concerned hazardous material are still applicable.

2 STANDARDS AND REFERENCES

3 HAZARDOUS MATERIAL OFFICER

An active member must be designated by system engineering and by the subsystem team in charge as the responsible of the relevant CO2. This responsible must be cautious and informed about the legislation about the concerned hazardous material.

More than one officer may be designed if more than one subsystem is using the same hazardous material. In this case, each subsystem must have this own officer. In any case a subsystem should have more than one person in charge of the hazardous material in question.

An officer can turn the responsibility of the handling, transportation or storage over another active member under the following conditions:

- The member is informed about the legislation about the concerned hazardous material.
- The member has read of the present document.
- The member has all the information about the hazardous material, the setup and procedures in his possession, to ensure the safety of every people and equipment involved
- The member has no precedent concerning the designed hazardous material.
- The officer is not present during the test or unable to do the specified task.
- The head of the ERT, including SE is warned of this decision.

An officer may be dismissed by the system engineering team, by a majority of a sub team, or by anyone if the head of the ERT, including SE agree with the decision.
An officer may resign at any moment by addressing a written and signed letter to the head of the ERT, including SE. All the subsystems must be informed of this decision.

At the moment of an officer resign or is dismissed, all the hazardous material must be return to the head of the ERT or SE. The ERT must design a new officer within 5 days. During this period, an active member must be design as temporary officer in order to manage the transport and storage of the hazardous material. Since a definitive officer is design, any handling of the hazardous material is prohibited. If more than one officer oversees the hazardous material in question, one of the remaining officers take immediately the role of temporary officer for the other subsystem and the previous restriction is no longer valid.

4 STORAGE

CO2 cartridge must be stored in closed box reserved for this purpose. A compartmented box could be used providing a reserved compartment for CO2 cartridges.

The room, box or the environment temperature in which the cartridges are stored must not exceeded the manufacturer limit or 325F (50°C).

Protect at any time from a direct and prolonged exposition to sunlight.

No current source, battery, electronical component or conductive material should be directly in contact with the cartridges. Other cartridges are exempted of the previous restriction.

Mechanical stress and strain on the cartridges is forbidden.

The storage room must be ventilated to prevent CO2 contamination in case of porous sealing.

5 TRANSPORTATION

5.1 General recommendations

CO2 cartridge must be stored in closed box reserved for this purpose. A compartmented box could be used providing a reserved compartment for CO2 cartridges.

The box, car or the environment temperature in which the cartridges are stored must not exceeded the manufacturer limit or 325F (50°C).

Protect at any time from a direct and prolonged exposition to sunlight.

No current source, battery, electronical component or conductive material should be directly in contact with the cartridges. Other cartridges are exempted of the previous restriction.

Mechanical stress and strain on the cartridges is forbidden.

5.2 Individual transport

General recommendations about transportation remain applicable.

Do not leave the cartridge inside an enclosed vehicle.

Prevent overturning of the box during travel.

Prevent shocks received from any direction and therefore even if the case is overturned.

5.3 Shipping

General recommendations about transportation remain applicable.

The shipping company must be informed of the presence of high-pressured gas in the parcel.

The shipping package must be sealed but not hermetic.

The shipping package should be prepared (foam, compartments, etc.) to prevent cartridges from shocks and damage.

6 HANDLING AND OPERATIONS

The environment temperature must not exceed the manufacturer limit or 325F (50°C).

Protect at any time from a direct and prolonged exposition to sunlight.

No current source, battery, electronical component or conductive material should be directly in contact with the cartridges. Other cartridges are exempted of the previous restriction.

Mechanical stress and strain on the cartridges is forbidden.

Keep away from the system while the gas is expending. The safety distance from the system should be determined before starting the experiment, test or launch according to the risks of projection, brake or of the system itself. Although the minimal safety distance must be 5m regardless of the set-up.

Never put finger or any other direct skin contact on a cartridge right after the gas expansion.

In case of problems during the opening of a cartridge, a delay should be respect before breaking the safety distance. The duration of this delay should be determined before the test or launch but it should last at least 200s.

7 WASTE MANAGEMENT

Empty CO2 cartridge must be discarded in a secure location.

Dispose an empty cartridge in an environmentally friendly manner.

Never put a cartridge into fire, even empty.

HAZARDOUS MATERIAL SAFETY PROCEDURE

Title:	**Black powder handling, transportation and storage**	Date :12/01/2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_SP_02 _BLACK_POWDER_SAFETY_PROCEDURE_R01	
Prepared by:	Guilain Lang	
Checked by:	Malo Goury	
Approved by:	Eric Brunner	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

Rocketry involves often the use of black powder to perform specific tasks as the separation of the nosecone at the apogee.
An explosive must be manipulated with caution both for the people and for the hardware.

2 SCOPE

This document addresses practices for Black powder handling, transportation and operations within the framework of the ERT.

This document points out the role of the responsible for the designated hazardous material.

This document points out many safety and health issues and recommended practices. However, safety standards and recommendations provided by EPFL, swiss federation, facility or any entity in charge remains applicable.

Communal, cantonal, federal and international legislations about the concerned hazardous material are still applicable.

3 STANDARDS AND REFERENCES

Table 3-1 Normative Documents

Ref	Description	Doc. Number	Issue

[]

Table 3-2 Reference Documents

4 HAZARDOUS MATERIAL OFFICER

An active member must be designated by system engineering and by the subsystem team in charge as the responsible of the relevant black powder. This responsible must be cautious and informed about the legislation about the concerned hazardous material.

More than one officer may be assigned if more than one subsystem is using the same hazardous material. In this case, each subsystem must have his own officer. In any case a subsystem should have more than one person in charge of the hazardous material in question.

An officer can turn the responsibility of the handling, transportation or storage over another active member under the following conditions:

- The member is informed about the legislation about the concerned hazardous material.
- The member has read the present document.
- The member has all the information about the hazardous material, the setup and procedures in his possession, to ensure the safety of every person and piece of equipment involved.
- The member has no precedent concerning the designed hazardous material.
- The officer is not present during the test or unable to do the specified task.
- The head of the ERT, including SE is warned of this decision.

An officer may be dismissed by the system engineering team, by a majority of a sub team, or by recommendation of an external stakeholder if the head of the ERT, including SE agree with the decision.
An officer may resign at any moment by addressing a written and signed letter to the head of the ERT, including SE. All the subsystems must be informed of this decision.

At the moment an officer resigns or is dismissed, all the hazardous material must be returned to the head of the ERT or SE. SE must assign a new officer within 5 days. During this period, an active member must be chosen as temporary officer in order to manage the transport and storage of the hazardous material. Until a permanent officer is assigned, any handling of the hazardous material is prohibited. If more than one officer oversees the hazardous material in question, one of the remaining officers take immediately the role of temporary officer for the other subsystem and the previous restriction is no longer valid.

5 STORAGE

The black powder cannot be stored in the ERT room unless a special agreement is signed between the EPFL and the ERT.

Black powder must be stored in closed box reserved for this purpose. A compartmented box could be used providing a reserved compartment for black powder if all the other clauses mentioned in this document are met.

The box must be locked and only the member responsible should have the key.

The room, box or the environment temperature in which the black powder is stored must not exceeded the limit of 325F (50°C).

Ensure the environment is sparks and fire free

No current source, battery, electronical component or conductive material should be directly in contact neither with the black powder and the packaging.

The storage room must be ventilated and relatively dry.

6 TRANSPORTATION

6.1 General recommendations

Black powder must be stored in closed box reserved for this purpose. A compartmented box could be used providing a reserved compartment for black powder if all the other clauses mentioned in this document are met.

The room, box or the environment temperature in which the black powder is stored must not exceeded the limit of 325F (50°C).

No current source, battery, electronical component or conductive material should be directly in contact neither with the black powder and the packaging.

6.2 Individual transport

General recommendations about transportation remain applicable.

Do not leave the black powder inside an enclosed vehicle.

Prevent overturning of the box during travel.

Prevent shocks received from any direction and therefore even if the case is overturned.

Ensure the environment is sparks and fire free.

6.3 Shipping

General recommendations about transportation remain applicable.

The shipping company must be informed of the presence of explosive material in the parcel.

The shipping package must be sealed.

The shipping package should be prepared within the supervision of professionals certified to transport hazardous materials.

7 HANDLING AND OPERATIONS

7.1 General recommendations

The environment temperature must not exceed the limit of 325F (50°C).

No current source, battery, electronical component or conductive material should be directly in contact with the cartridges. Other cartridges are exempted of the previous restriction.

Ensure the environment is sparks and fire free. Motors, actuators and igniters are exempted of the previous restriction.

7.2 Preparation and handling recommendations

General recommendations about handling and operation remain applicable.

Wear protection gloves and glasses for handle black powder.

Black powder is electrostatic sensitive, ensure you are discharged.

7.3 Test and launch recommendations

General recommendations about handling and operation remain applicable.

Keep away from the system during the explosion. The safety distance from the system should be determined before starting the experiment, test or launch according to the risks of projection, failure, or nominal functioning of the system. The minimal safety distance must be 5m regardless of the set-up.

In case of problems of non-ignition, a delay should be respect before breaking the safety distance. The duration of this delay should be determined before the test or launch but it should last at least 300s.

The local security organisation or office must be informed of the use of explosive during the experimentation, the launch or any handling involving the ignition of black powder.

8 WASTE MANAGEMENT

The black powder waste or any object in direct contact with black powder during the process must be discarded in a secure location.

Dispose wastes in adapted environmental friendly manner.

Never expose waste or any object in direct contact with black powder during the process to fire or spark.

Due to the possibility of waste of black powder in the environment, a special concern and cautiousness is required even after the handling done.

TECHNICAL NOTES

Title:	**Comutation of maximum opening forces during parachute inflation using Pflanz and $\left[\frac{W}{(C_D S)_p}\right]$ methods**
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename:	2018_RE_TN_0001_OPENING_FORCES_R02
Prepared by:	Guilain Lang
Checked by:	Malo Goury du Roslan
Approved by:	Guilain Lang

Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

By first approximation, the opening acceleration of the parachute was estimated to 25g, which correspond to a maximal force of almost 3.5kN. This is much more that every measurements done during smaller launches as LV1 Tripoli certifications. So we investigated methods to have a better idea about te forces occurring during parachute inflation.

2 NORMATIVE AND REFERENCE DOCUMENTS

Table 2-1 Reference Documents

Ref	Description	Doc. Number	Issue
[RD01]	W. KNACKE, Theo, “*Parachute Recovery Systems Design Manual*”, China Lake, CA : Naval Weapons Center, March 1991		

3 DEFINITIONS AND ABBREVIATIONS

RD	Reference Document
LV	Launch Vehicle
C_D	Drag Coefficient
S	Projected area of the canopy
ρ	Air density
g	Gravitational acceleration equals to $9.81\,\frac{m}{s}$

4 CONCEPT EXPLANATION

We investigate two methods proposed in a document published by the US Navy in 1992: "Parachute Recovery System Design Manual" to quantify the maximum opening forces occurring during parachute inflation:

- The $\left[\frac{W}{(C_D S)_p}\right]$ method is accurate for high canopy loading parachute. Therefore, it is adapted for drogue chutes and reefed chutes. But computing the opening force of main stage with this method can introduce an error of ±20%
- The Pflanz method has a good accuracy for all type of condition, including disreefing of main parachute. However, this method does not take in consideration the effect of gravity: for our calculation we must consider another force: the weight of the LV.

4.1 Parachute characterization

The coefficient of opening force at infinite mass depends of the shape of the chute.
The chute is a mix of an annular parachute ($C_x \sim 1.4$) and a disk gap band parachute ($C_x \sim 1.3$). Therfore we assume the coefficient of opening force at infinite mass for our chute should be in between ie. $C_x \sim 1.35$.
We have done a small-scale parachute to characterize our design in wind tunnel. We assumed that the same parachute within a diameter of 4.5m will slow down the LV to $speed_m = 5m \cdot s^{-1}$ at an altitude of 1200m from sea level[1].
When the fully capability of the parachute is defined by its design, the reefing drag can be tuned depending on the level of retractation of the central line. We assumed that the LV is descending at $speed_{\mathrm{r}} = 10m \cdot s^{-1}$ at an altitude of 2750 from sea level[2].
We introduce a variable σ, to consider the variation of air density within the altitude.

$$\sigma_h = \frac{\rho_0}{\rho_h} \Rightarrow \begin{cases} \sigma_1 = 0.6503, & \text{@4300m from sea level} \\ \sigma_{\mathrm{r}} = 0.7621, & \text{@2750m from sea level} \\ \sigma_{\mathrm{m}} = 0.9710, & \text{@1200m from sea level} \end{cases}$$

4.2 Reefed parachute inflation

Weight of the LV: $W_d = m_{LV} \cdot g = 147.15[N]$
Assuming the lateral speed due to the trajectory and the relative wind is 10 m/s, and the parachute inflate 2.5 s after the apogee:

$$\mathrm{speed}_1 = \sqrt{\mathrm{speed}_{\mathrm{lat}}^2 + (\mathrm{g} \cdot \mathrm{t}_{\mathrm{opening}})^2} \approx 26.5\left[\frac{\mathrm{m}}{\mathrm{s}}\right]$$

We first compute the dynamic pressure on the parachute for a reefed parachute at the altitude of 4300m from sea level.

$$\mathrm{q_r} = \frac{\rho}{2} \cdot \frac{\sigma_{\mathrm{r}}}{\sigma_1} \cdot \mathrm{speed}_{\mathrm{r}}^2 = 287.1[\mathrm{Pa}]$$

From this value, we compute an equivalent active drag surface of the reefed parachute:

$$(\mathrm{C_D S})_{\mathrm{r}} = \frac{\mathrm{W_d}}{\mathrm{q_r}} = 0.5125[\mathrm{m}^2]$$

[1] Approximately ground level of the launch area.

[2] Approximately 1550m from ground level of the launch area.

4.2.1 $\left[\frac{W}{(C_D S)_p}\right]$ method

We define the canopy loading:

$$\left[\frac{W}{(C_D S)_p}\right]_{\mathrm{r}} = \frac{\mathrm{W_d}}{(\mathrm{C_D S})_{\mathrm{r}}} = 287[\mathrm{Pa}] \approx 58.8\left[\frac{lb}{ft^2}\right]$$

Using the table 5.41 [RD01], we define the opening reduction factor, $X_{1,r,\frac{W}{C_D S}} = 0.9$

Finally, we find the maximum opening force of first event:

$$\mathrm{F}_{\mathrm{r},\frac{\mathrm{W}}{\mathrm{C_D S}}} = (\mathrm{C_D S})_{\mathrm{r}} \cdot \mathrm{q_1} \cdot \mathrm{C_x} \cdot \mathrm{X}_{1,\mathrm{r},\frac{\mathrm{W}}{\mathrm{C_D S}}} = 411.4[N]$$

With, $\mathrm{q_1} = \frac{\rho \cdot \sigma_1}{2} \cdot \mathrm{speed}_1^2 = 660.7[\mathrm{Pa}]$ the initial dynamic pressure.

4.2.2 Pflanz method

To use Pflanz method, we need to compute the equivalent dynamic pressure and active drag area at 4300m from sea level for the fully deployed parachute as it was done for reefed stage:

$$\mathrm{q_m} = \frac{\rho}{2} \cdot \frac{\sigma_{\mathrm{m}}}{\sigma_1} \cdot \mathrm{speed}_{\mathrm{m}}^2 = 20.3[\mathrm{Pa}]$$

$$(\mathrm{C_D S})_{\mathrm{m}} = \frac{\mathrm{W_d}}{\mathrm{q_m}} = 7.25[\mathrm{m}^2]$$

Then we define the ballistic parameter as follow.

$$\mathrm{A_r} = \frac{2\mathrm{W_d}}{(\mathrm{C_D S})_{\mathrm{r}} \cdot \rho \cdot \mathrm{g} \cdot \mathrm{t_{f,r}} \cdot \mathrm{speed}_1} = 79.9[-]$$

With $\mathrm{t_{f,r}} = \frac{\mathrm{D_0}}{\mathrm{speed_1} \cdot \mathrm{n_r} \cdot \sqrt{\frac{(\mathrm{C_D S})_{\mathrm{r}}}{(\mathrm{C_D S})_{\mathrm{p}}}}} = 0.023[\mathrm{s}]$, the time the reefed parachute takes to inflate and D_0 the diameter of the fully inflated canopy.

We choose $\mathrm{n_r} = \frac{1}{2}$ which is a default value for reefed stage.

Using the table 5.51 [RD01], we define the opening factor reduction factor, $X_{1,r,\mathrm{Pflanz}} = 0.95$.
Finally, we find the maximum opening force of first event:

$$F_{r,Pflanz} = (C_D S)_r \cdot q_1 \cdot C_x \cdot X_{1,r,\mathrm{Pflanz}} = 434.3[N]$$

With, $\mathrm{q_1} = \frac{\rho \cdot \sigma_1}{2} \cdot \mathrm{speed}_1^2 = 660.7[\mathrm{Pa}]$ the initial dynamic pressure.

Because this method does not include the effect of the gravity, we must add the weight of the LV.

$$\tilde{F}_{r,Pflanz} = F_{r,Pflanz} + W_d = 581.4[N]$$

4.3 Parachute disreefing

We first compute the dynamic pressure on the reefed parachute and unreefed at the altitude of 1500m from sea level.

$$q_r = \frac{\rho}{2} \cdot \frac{\sigma_r}{\sigma_0} \cdot \mathrm{speed}_r^2 \ = 216.7$$
$$q_0 = \frac{\rho}{2} \cdot \frac{\sigma_0}{\sigma_0} \cdot \mathrm{speed}_m^2 \ = 15.31$$

From this value, we compute an equivalent active drag surface:

$$(C_D S)_r = \frac{W_d}{q_r} = 0.679[\mathrm{m}^2]$$
$$(C_D S)_p = \frac{W_d}{q_0} = 9.61[\mathrm{m}^2]$$

We define the relative active drag surface as follow:

$$(C_D S)_{p-r} = (C_D S)_p \ - \ (C_D S)_r = 8.93[\mathrm{m}^2]$$

4.3.1 $\left[\frac{W}{(C_D S)_p}\right]$ method

We define the canopy loading:

$$\left[\frac{W}{(C_D S)_p}\right]_m = \frac{W_d}{(C_D S)_{p-r}} = 16.48\left[\frac{\mathrm{N}}{\mathrm{m}^2}\right] = \ 3.38\left[\frac{lb}{ft^2}\right]$$

Using the table 5.41 [RD01], we define the opening reduction factor, $X_{1,m,\frac{W}{C_D S}} = 0.3$

The dynamic pressure during disreefing is 10 to 20% higher than the terminal reefed dynamic pressure, we define $q_2 = 1.2 \cdot q_r \ = \ 260.0[\mathrm{Pa}]$.

Finally, we find the maximum opening force of first event:

$$F_{r,\frac{W}{C_D S}} = (C_D S)_{p-r} \cdot q_2 \cdot C_x \cdot X_{1,m,\frac{W}{C_D S}} \ = \ 940.5[N]$$

4.3.2 Pflanz method

Then we define the ballistic parameter as follow.

$$A_r = \frac{2W_d}{(C_D S)_{p-r} \cdot \rho \cdot g \cdot t_{f,r} \cdot \mathrm{speed}_1} = 0.32[-]$$

With $t_{f,m} = \frac{D_0}{\mathrm{speed}_r \cdot n_m \cdot \sqrt{\frac{(C_D S)_{p-r}}{(C_D S)_p}}} \ = \ 0.44\ [\mathrm{s}]$, the time the parachute takes to inflate and D_0 the diameter of the fully inflated canopy.

We choose $n_m = 2$ because the inflation time is close to the experimental results.

Using the table 5.51 [RD01], we define the opening factor reduction factor, $X_{1,m,\mathrm{Pflanz}} = 0.3$.

The dynamic pressure during disreefing is 10 to 20% higher than the terminal reefed dynamic pressure, we define $\mathrm{q}_2 = 1.2 \cdot q_r = 260.0[\mathrm{Pa}]$.

Finally, we find the maximum opening force of first event:

$$F_{m,Pflanz} = (C_D S)_{p-r} \cdot q_2 \cdot C_x \cdot X_{1,m,\mathrm{Pflanz}} = 940.5\ [N]$$

Because this method does not include the effect of the gravity, we must add the weight of the LV.

$$\tilde{F}_{m,Pflanz} = F_{r,Pflanz} + W_d = 1088[N]$$

5 CONCLUSION

The calculation of maximum opening forces using Pflanz method seems consistent with the typical value of 6-8g involved during recovery of sounding rocket. Moreover the $\left[\frac{W}{(C_D S)_p}\right]$ method, validates these results which is assumed to be precise at +/- 20%. As expected, the force is greater during the reefing release, than during the deployment of the reefed parachute at apogee.
We assume the experimental conditions may differe from the one considered in [RD01], that why we recommend to use a safety factor of minimum SF=3 during the design of the recovery system as the shock cord or the eyebolts.

TECHNICAL NOTES

Title:	**Technical notes, Electrical shock cord**
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename:	2018_RE_TN_0001_ELECTRICAL_SHOCK_CORD_R01
Prepared by:	Malo Goury du Roslan
Checked by:	Guilain Lang
Approved by:	Guilain Lang — Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This technical note describes the process used to adapt an existing shock cord to obtain an electrical shock cord used to send an electrical signal from the rocket body to the base of the parachute's lines. This electric line transmits the signal for the reefing release mechanism for the second event of the recovery. This release mechanism is composed of two line cutters, using one igniter each. Therefore, a total of four wires need to be carried through the shock cord.

2 NORMATIVE AND REFERENCE DOCUMENTS

Table 2-1 Reference Documents

Ref	Description	Doc. Number	Issue
[RD01]	W. KNACKE, Theo, "*Parachute Recovery Systems Design Manual*", China Lake, CA : Naval Weapons Center, March 1991		
[RD02]	2018_RE_TN_0001_OPENING_FORCES	2018_RE_TN_0001	2.0

3 DEFINITIONS AND ABBREVIATIONS

SC	Shock Cord
RD	Reference Document

4 CONCEPT EXPLANATION

4.1 Parachute assumption

The biggest shock will happen at the second recovery event, when the parachute will pass form a reefed to a fully deployed configuration. This transistion happens faster than a normal parachute deployment, resulting in higher accelerations to withstand for the SC. Based on RD01 and calculations detailed in RD02 the stronger force at this moment is 1088 [N].

4.2 Shock cord's choice

In order to facilitate integration of the rocket, the compact kevlar SC of 1/4 inches from Fruity Chutes was used. The latter is sold to withstand forces up to 9'786 N, leaving a sufficient safety factor of 9 on the previous calculations. A length of 6m was used, chosen with a more empiric approach since it is based on previous rocketery experiences. Indeed, the SC shouldn't be too short in order to benefit from its mechanical elasticity to damp the parachute's opening shock.

4.3 Insertion of the electrical wire

The idea is to benefit from the emptiness of the SC's core to pass the electrical wires all the way through it. Since at each end the central hole is blocked by the sewed attach loops, the electrical wires were introduced and come out right after those attach loops, according to Fig. 1. In order to keep the mechanical propreties of the shock cord, no holes were made to introduce the wires. Instead, the fibers were moved apart until the room left was sufficient to let the wires pass. Once the tip of the wires are introduced inside the SC's core, it is guided and pulled with patience until the other end of the shock cord where the same approach is used to extract the wires from the SC's core.

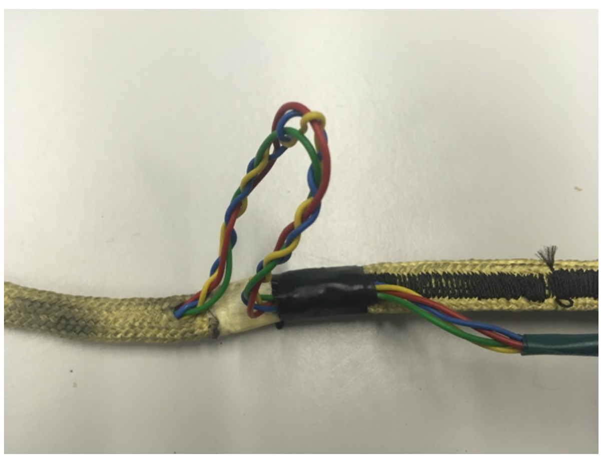


Figure 1. Wire's insertion in shock cord

4.4 Manage SC's elasticity

An important point to anticipate is the elasticity of the SC when a high force is applied since an electrical wire dosen't have this same mechanical proprety. Two solutions where applied. Firstly, the four wires are plaited, introducing a certain mechanical elasticity. Secondly, the cables are pulled out od the SC to form a small loop every meters, as in Fig. 2.

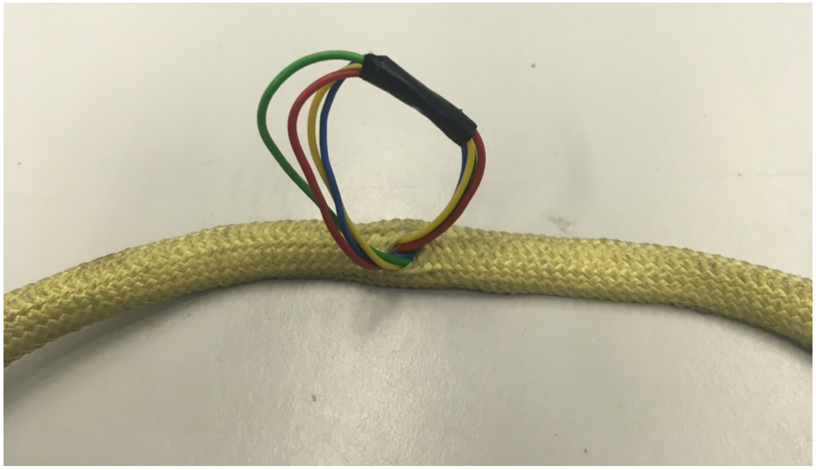


Figure 2. Wire's loop every meters

5 CONCLUSION

The two critical points were to keep the integrity of the SC's mechanical propreties and to anticipate its elasticity.

TECHNICAL NOTES

Title:	**Technical notes, Parachute**
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename:	2018_RE_TN_0002_Parachute _R01
Prepared by:	Malo Goury du Roslan
Checked by:	Guilain Lang
Approved by:	Guilain Lang

Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This technical note describes the process followed to design and manufacture the main parachute. Since both recovery events will be fullfiled with this single parachute, using a reefing technique, the design was adapted to optimize its performance.

2 NORMATIVE AND REFERENCE DOCUMENTS

Table 2-1 Reference Documents

Ref	Description	Doc. Number	Issue
[RD01]	POYNTER, Dan, "*the parachute manual a technical treatise on the parachute*" Santa Barbara, Calif. : Parachuting Publications , 1977	-	-
[RD02]	W. KNACKE, Theo, "*Parachute Recovery Systems Design Manual*", China Lake, CA : Naval Weapons Center, March 1991	-	-

3 DEFINITIONS AND ABBREVIATIONS

RD	Reference Document
CAD	Computer Aided Design

4 CONCEPT EXPLANATION

4.1 Canopy 3D design

To optimize reefing in order to apply it to a dual event recovery a SRAD parachute was developed. The design of the parachute was mainly done qualitatively, based on the RD01 and existing rocketry parachute. Using those designs assured a certain reliability. The quality would then be approved through a series of tests.

For the design of the general shape, the toroid shape of the canopy is considered in most of parachute treatise as the shape with the highest drag coefficient. Then, different features were applied to the canopy. Firstly, a circular vent is introduced in the upper part. With a short central line, so in reefed position, these vents are parallel to the projected area of the canopy. Thus, it reduces the drag coefficient. While the reefing is released, so the central lines are longer, the projected area of those vents diminishes. Furthermore, during every recovery we experienced an oscillation of the parachute during the descent. Smaller vents at the basis of the canopy help to stabilize it. The Fig. 1 shows the 3D CAD of the canopy, the location of the upper and lower vents when the parachute is in reefed and unreefed position can be observed.

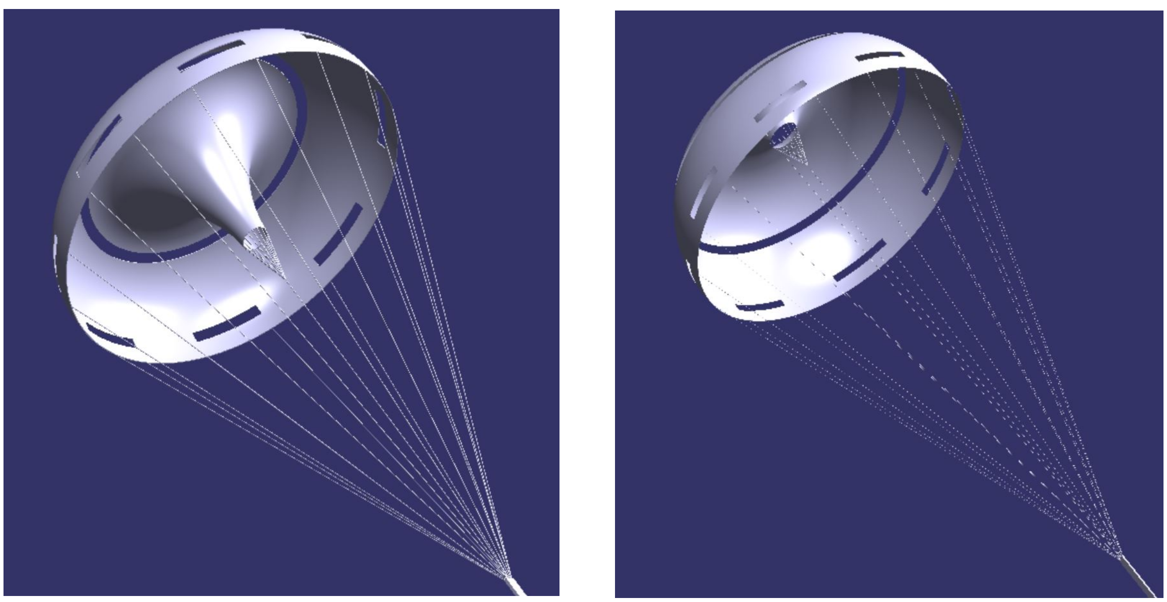


Figure 1. SRAD parachute in reefed (left) and unreefed (right) position

4.2 2D Textile Pattern

The CAD software[1] offers a very usefull feature permitting to project the 3D design on a 2D plane, but the projection is done while following the curvature of the canopy. Therefore, the output is directly the required textile to manufacture the canopy. This projection is divided in 12 slices, in order to obtain the different textile's patterns which, when assembled together, will form the canopy. The different patterns are then drawn on the textile. By using textile cisors, the cutting is

[1] The software used is CATIA V5 from Dassault Systems

done by following a perimeter which is 1cm away from the pattern in order to leave some textile for the sewing. An important point was to think about the direction of the textile's fibers when drawing and cutting the textile. Indeed, one direction must go from the upper part to the lower part of the canopy and the other one should go around the canopy. Therefore, the textile's mechanical propreties are used in the right way.

Figure 2. Canopy manufacturing. From left to right: cutting, assembly with pins, sewing

4.3 Sewing of the canopy

The two parts of textile are assembled as described in the Fig. 3 using pins and then two passes of sewing are done according to the two exterior red lines on the figure. Therefore, at each joint there are two sewing passing through four layers of textile. Once the canopy is fully assempled, the edges at the lower and upper circle are folded one time on themselves and sewed.

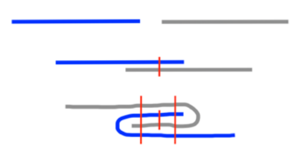


Figure 3. Sewing technique

4.4 Sewing of the lines

The length of the line is dependant on the diameter of the canopy, it was chosen according to the RD01 recommendation to be one and a half time the diameter, so a length of 6.75m. Each extremity of a 13.5m line is sewed to two opposite textile joints of the canopy. The sewing can be seen on the Fig. 4. For the central line, it splits in twelve different short lines when reaching the top of the canopy. Each short line is also sewed to the textile joints.

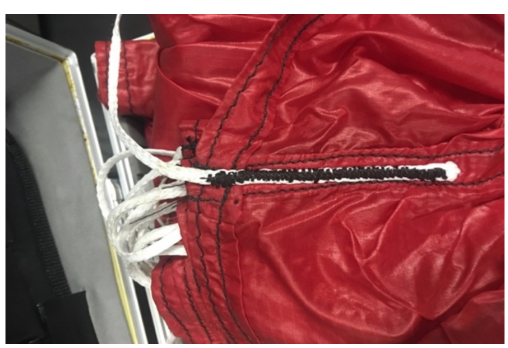


Figure 4. Parachute's line sewing

5 CONCLUSION

All the sewing requires some training to guaranty a certain quality and to gain some time during the manufacturing.

TEST PROCEDURES

Title:	**Wind tunel test, Proof of concept reefing**	Test Completed (Date) :02.14.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_TP_0002 _WIND_TUNNEL_REEFING_POC _R01	
Prepared by:	Malo Goury du Roslan	
Checked by:	Guilain Lang	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

In a very basic model of recovery, a spring-mass-force system, the peak of acceleration is very high. Therefore, a huge force is applied on the canopy, on the line and on the rocket. To minimize this effect most of the system tend to slow down the parachute's opening : This concept is called reefing. An analyse of NASA mission shows that the effective drag of their parachute can be less than 20% of the maximal drag [1].

Traditional dual event recovery techniques in high power rocketry is implemented with two parachutes, a drogue with a low effective drag and a main for a soft landing. ESRA requirements in terms of descent rate are 46 to 26 m/s during the first phase and less than 9 mps for the landing. In first approximation we consider the rocket follows the following equation.

$$m\ddot{z} = mg + \frac{\rho C_{drag,eff}\dot{x}^2}{2} = 0 \qquad [1,2]$$

From this we deduce the relation between efficient drag and the speeds of the different phases :

$$C_{drag,eff,reefing} = C_{drag,eff,main}\frac{\dot{x}^2_{landing}}{\dot{x}^2_{phaseI}} \leq C_{drag,eff,main}\frac{9m.s^{-1}}{26m.s^{-1}} \simeq 12\% C_{drag,eff,main}$$

These values are very close to the computation and measurements of the previously mentioned paper. Therefore reefing can be an alternative in the implementation of dual recovery.

The reefing is implemented by shortening the central line of the parachute, resulting in a diminishing of the effective area of the canopy.

[1] $C_{drag,eff} = C_{drag} * A$

[2] We are only interested in this study by the steady state speed.

2 NORMATIVE AND REFERENCE DOCUMENTS

[1] J. R. S. a. P. G. McFadden, «Reefing of Quarter Spherical Ribbon Parachutes used in the».*United Space Alliance*

3 DEFINITIONS AND ABBREVIATIONS

Cd	Drag Coefficient
A	Projected canopy area

4 VERIFICATION PROCESS

4.1 Verification objectives

The goal of this test is to prove that the required diffence of drag between the phases of dual event recovery can be achieved with a single parachute by using reefing. The objectives of this test is to gather enough data in order to get two different plots. Firstly, the drag force versus the length of the reefing line, which is the central line. This plot should be done for different wind speed. Secondly, for a constant force applied by the the parachute, one shall plot the wind speed in function of the length of the reefing line.

4.2 Verifcation method

The parachute will be fixed to a dynamometer in a wind tunnel. The length of the reefing line can be changed from the outside of the wind tunnel. By reading the force sensor values for different wind speed and reefing line's length, one can get the required plots.

4.3 Test procedures

For each of the two different wind speed: 4.5 m/s, 6.5 m/s , we should write down the value of the force sensor for different reefing line's length, starting in a fully reefed position in order to observe if the maximum range of the force sensor is reached. Then, we should try to maintain a constant force for different wind speed. This last part is more representative of the real use of the parachute.

4.4 Test conditions

The tests will be done in EPFL windtunnel. It is 2.38 m large and 1.98 m height. The wind speed can go up to 10 m/s.

4.5 Test set-up and equipment

In order to fix the parachute to the force sensor a set-up system has been designed. During the test, a smaller scale parachute is used. It has a 1m diameter but reefing system is similar to the one that will be used for the final parachute. The reefing line's length is changed from the outside of the wind tunnel, there is no need to switch the wind off to change it's length.

4.6 Step-by-step testing procedure

4.7 Pass-fail criteria

The first important point is to check that the drag force ratio is sufficient between maximum and minimum reefed position. This is checked with the recovered data from the force sensor. The second point is the shape of the canopy in reefed and unreefed position. Finally, this test permits to determine the right position of the upper vents.

5 TESTS RESULTS

CRITERIA	PASS / FAIL
Sufficient drag ratio between maximum and minimum drag	PASS
Correct position of upper vent	FAIL
Entanglements avoided thanks to reefing body	PASS

6 CONCLUSION

The general design of the canopy is correct. The upper vents resuted in a “flat” of the drag force according to the reefing line’s length in a certain region. This will give stability to the falling speed. The next canopy design shall have its upper vent in a lower postion in order to have the “flat” of the curve at a reefing line’s length corresponding to a lower drag.

TEST PROCEDURES

Title:	**Small Scale Module – Integrated Test**	Test Completed (Date) : 03.24.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0003_SMALL_SCALE_MODULE_INTEGRATED_R01	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

In order to test the recovery system, the whole model has been tested thanks to a smaller scale module. The aim was to sort out the main issues before going to the normal scale system. Thanks to this approach several critical points were pointed out as vital for the final launch.

The following test were performed on a 3 inches rocket during a launch. The first event triggering the rocket separation was done thanks to the motor ejection piston. The second event, which normally corresponds to the deployment of the main parachute, but in our case is the release of the reefing mechanism, was triggered by a RAVEN system.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the reefing principle is functional and can be considered as an alternative for a recovery using two parachutes. As such, non negligible volume and mass savings could be achieved as only one parachute and subsequently, one shock cord and fixation system would be needed.

2.2 Verification method

The recovery for the competitions consists in two main events. The first one is the release at the apogee of the parachute and the second one is the full deployment of the latter at an altitude of 100m to reach a descending speed lower than 10 m/s. This test should validate the proof of concept of the reefing principle. As such, the evaluation of the system was only a visual inspection of the descending speed.

2.3 Test procedures

The test is performed during a launch. The rocket used is the *BIC rocket*, 3 inches diameter rocket. The rocket motor shall be prepared as usual. The parachute is directly wrapped in the rocket. It is linked to the rocket body thanks to the electrical shock cord and equipped with a reefing mechanism.

2.4 Test conditions

In-flight-test performed with a small scale model.

2.5 Test set-up and equipment

As stated before, the recovery system is composed of only one parachute, a reefing mechanism, an electrical shock cord and a RAVEN to trigger the second event. The parachute is directly wrapped in the rocket body. It is linked to the rocket body thanks to the electrical shock cord. The reefing mechanism consists of two line cutters (one for redundancy) placed along a cord attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is reached at 100m altitude and the line cutters are triggered thanks to the current passing through the electrical shock cord.

Note that this trigger is sent by the RAVEN and detected thanks to a pressure sensor.

Then, the parachute will not be constrainted anymore, enabling it to fully deploy and to slow down the rocket.

2.6 Step-by-step testing procedure

1. Set up the RAVEN's trigger to be executed at 100m altitude
2. Follow the line cutter's filling procedure
3. Place the line cutters along the reefing line
4. Set up the reefing line on the parachute
5. Wrap the parachute
6. Connect the line cutters with the electrical shock cord
7. Insert the electrical shock cord and the parachute in the rocket
8. Close the rocket
9. Install the rocket's motor
10. Launch
11. Apogee detection
12. Ejection of the Parachute
13. 100m detection
14. Trigger of the first line cutter
15. Trigger of the second line cutter

2.7 Pass-fail criteria

Criteria	PASS conditions	Implications if failure
1st event – piston trigger	Ejection of the piston	
1st event – parachute out of rocket body	Rocket separation and parachute inflation	Need for a deployment bag and a pilot parachute
1st event – accelerations during less than one second after deployment	Inflation of the parachute	
1st phase – parachute lines fully stretched	Inflation of the parachute	Addition of a pilot parachute
1st phase – canopy not fully deployed	Inflation of the parachute	Addition of a pilot parachute
2nd event – 1st line cutter avionic trigger – RAVEN data review	Detection of the 100m altitude	Software implementation of a timer
2nd event – 1st igniter ignition	Line cut	Review of the line cutters
2nd event – 2nd line cutter avionic trigger – RAVEN data review	Detection of the 100m altitude	Software implementation of a timer
2nd event – 2nd igniter ignition	Line cut	Review of the line cutters
2nd event – reefing line cut	Full deployment of the parachute	Review of the line cutters and reefing line resistance
2nd phase – canopy fully deployed	Change of the descending rate to 10 m/s	

3 TESTS RESULTS

CRITERIA	PASS / FAIL
1st event – piston trigger	PASS
1st event – parachute out of rocket body	FAIL
1st event – accelerations during less than one second after deployment	FAIL
1st phase – parachute lines fully stretched	FAIL
1st phase – canopy not fully deployed	FAIL
2nd event – 1st line cutter avionic trigger – RAVEN data review	FAIL
2nd event – 1st igniter ignition	FAIL
2nd event – 2nd line cutter avionic trigger – RAVEN data review	PASS
2nd event – 2nd igniter ignition	FAIL
2nd event – reefing line cut	FAIL
2nd phase – canopy fully deployed	FAIL

4 CONCLUSION

Firstly, let's discuss the failure of the ejection of the parachute. The use of a deployment bag is necessary, it fixes the diameter used by the parachute in the rocket's tube and avoids the "earplug effect" which makes pulling the parachute out of the rocket body too hard. Furthermore, the use of a pilot parachute to extract the main parachute is necessary, it shall not be the ejection mechanism which fulfils this task.
Secondly, the 1st line cutter avionic trigger failed since it didn't trigger at the right timing. Indeed, a pressure increase was detected when leaving the launching rail which simulated the apogee. A timer shall be used to unable any trigger during this first part of the flight.
Thirdly, the igniters failed to burn even if the trigger was sent. This will be discussed in the "small scale module ground test" of the 31st of Mars.

TEST PROCEDURES

Title:	**Small Scale Module – Ground Tests**	Test Completed (Date) : 03.31.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0004_SMALL_SCALE_MODULE_GT_R01	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

In order to test the recovery system, the whole model has been tested thanks to a smaller scale module. The aim was to sort out the main issues before going to the normal scale system. Thanks to this approach several critical points were pointed out as vital for the final launch.

The following tests were performed in a 4 inches rocket upper body on the ground. Their purpose was to test the full recovery system including the RAPTOR CO_2 deployment system from Peregrine, the reefing mechanism and SRAD Recovery not used in the final rocket but developed for future drop tests.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the recovery system is functional in a small scale rocket. All hardware components are tested with this ground test except the parachute inflation. It will then be adapted for the final rocket.

2.2 Verification method

The recovery for the competitions consists in two main events. The first one is the release at the apogee of the parachute and the second one is the full deployment of the latter at an altitude located below 450m to reach a descending speed lower than 10 m/s. These two events are simulated in this test and will be manually triggered.

After the first event, the nose cone and the pilot parachute should be ejected from the rocket. By manually pulling on the pilot parachute, the main parachute should come out of the rocket body and be separated from the deployment bag.

The reefing line is then cutted using AEROCON line cutter 20 seconds after the first event thanks to a software activated trigger.

Both events should be visually inspected.

2.3 Test procedures

The test is performed on the ground. The rocket is assembled without the lower stage. The parachute is linked to the rocket body thanks to the electrical shock cord and reefed. It is wrapped in a deployment bag above which is located a pilot parachute. The different events are triggered by the SRAD recovery's avionics thanks to two different timers activated manually.
The first one will trigger the RAPTOR ejection mechanism by sending a current of 0.8A during 1 second and the second one will trigger the line cutters with the same event. The trigger duration was adjusted to 2 seconds after the fourth small scale ground test to ensure the ignition of the igniters.

2.4 Test conditions

Five ground tests were performed in similar conditions with a small scale model. Several adjustments were made from one test to another to solve the issues encountered.

The tests following the first one were performed with only one igniter for the reefing mechanism and the electrical trigger duration was increased to 2 seconds for the final ground test.

2.5 Test set-up and equipment

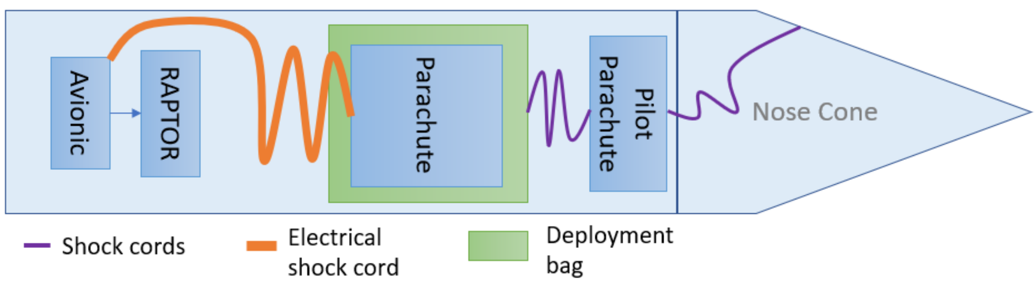


Figure 1 - Diagram of the Recovery Configuration in the Small Scale Module

As stated before, the recovery system is composed of a pilot parachute, a main parachute wrapped in a deployment bag, a reefing mechanism, an electrical shock cord and a SRAD Recovery's Avionics to trigger both event. The main parachute is linked to the rocket body thanks to the electrical shock cord. The reefing mechanism consists of two line cutters (one for redundancy) placed along a cord attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is set. Both events are triggered thanks to a current of 0.8 A. This current should set the igniters which will light up the black powder.

For the RAPTOR, the black powder's explosion will push a sharp metal piece on the CO_2 caltridge's operculum. The CO_2 expelled will push the parachute in the deployment bag which will bring the pilot parachute and the nose cone out.

During the second event, the signal should ignite the black powder in the line cutters. The latters will then cut the reefing line.

2.6 Step-by-step testing procedure

1. Set up the SRAD Recovery's Avionics's trigger to be executed after 11 sec after pressing the button
2. Set up the line cutters' timer to 31 sec
3. Follow the line cutter's filling procedure
4. Place the line cutters along the reefing line
5. Set up the reefing line on the parachute
6. Wrap the parachute
7. Put the parachute in the deployment bag
8. Attach the pilot parachute to the deployment bag and the nose cone
9. Connect the line cutters with the electrical shock cord
10. Insert the electrical shock cord, the parachute and the pilot in the rocket body
11. Close the rocket
12. Activate the timers

2.7 Pass-fail criteria

N°	Criteria	PASS conditions	Implications if failure
1	1st event – trigger sent by avionic to RAPTOR	Ignition of the RAPTOR	Review of the SRAD recovery
2	1st event – RAPTOR igniter ignition	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
3	1st event – RAPTOR CO2 cartridge pierced	Caltridge opened	Need for a better guiding system
4	1st event – nose cone ejection	Nose cone and rocket body separation	Need for bigger CO2 caltridge
5	1st event – pilot parachute out of rocket body	Pilot parachute going out of the rocket body	Review of the order of storage in the rocket body
6	1st event – no entanglement when pulling the drogue parachute	No knot in the lines	Change in the folding procedure
7	1st event – main parachute comes out of the deployment bag	Opening of the deployment bag	Openings in the deployment bag should be larger
8	1st event – no entanglement observed in the parachute lines	No knot in the lines	Change in the folding procedure
9	2nd event – trigger sent by avionic to line cutter	Ignition of the line cutter	Review of the electric line and batteries
10	2nd event – line cutter igniter 1 ignition	Ignition of the line cutter	Review of the igniters
11	2nd event – line cutter igniter 2 ignition	Ignition of the line cutter	Review of the igniters
12	2nd event – reefing line cut	Reefing line cut by one or two line cutters	Increase the quatity of black powder/ Select a thinner reefing line
13	2nd event – central line released	Parachute unreefed	Change the reefing technique

3 TESTS RESULTS

N°	Criteria	Test 1	Test 2	Test 3	Test 4	Test 5
1	1st event – trigger sent by avionic to RAPTOR	PASS	PASS	PASS	PASS	PASS
2	1st event – RAPTOR igniter ignition	PASS	PASS	FAIL	FAIL	PASS
3	1st event – RAPTOR CO2 cartridge pierced	PASS	PASS	FAIL	FAIL	PASS
4	1st event – nose cone ejection	PASS	PASS	FAIL	FAIL	PASS
5	1st event – pilot parachute out of rocket body	PASS	PASS	FAIL	FAIL	PASS
6	1st event – no entanglement when pulling the drogue parachute	PASS	PASS	FAIL	FAIL	PASS
7	1st event – main parachute comes out of the deployment bag	PASS	PASS	FAIL	FAIL	PASS
8	1st event – no entanglement observed in the parachute lines	PASS	PASS	FAIL	FAIL	PASS
9	2nd event – trigger sent by avionic to line cutter	PASS	PASS	PASS	ABORT	PASS
10	2nd event – line cutter igniter 1 ignition	FAIL	-	-	-	-
11	2nd event – line cutter igniter 2 ignition	FAIL	PASS	PASS	ABORT	PASS
12	2nd event – reefing line cut	FAIL	FAIL	PASS	ABORT	PASS
13	2nd event – central line released	FAIL	FAIL	FAIL	ABORT	PASS
-	Adjustments for the next tests	Suppression of one reefing line cutter	Addition of an O-ring around line cutter's igniter	None	Increase trigger duration to 2 seconds	

4 CONCLUSION

Test1:

The ignition of the line cutter's igniter failed. Indeed, both igniters were wired in parallel with a single current source delivering 0.8A. Therefore, only 0.4A passed in each igniter which is not sufficient to trigger the ignition. The redundancy shall be implemented with two independent electrical circuits, or both igniter could be wired in serial. The event prior to the second event all passed.

Test 2:

This time, even if the igniter and the black powder of the line cutter successfully burned, the line passing through the line cutter wasn't cut. The reason is that a gap was still there at igniter's exit. The solution is to add an O-ring around the igniter's head just before starting to pass the igniter through the cap.

Test 3:

Due to an igniter failure, the CO2 cartridge wasn't pierced. Therefore, none of the subsystems were pushed out of the rocket body. This can happen statistically and it helps to understand the importance of redundancies.

Test 4:

Once again, the igniter failed to burn even though the electronics worked nominally. Two solutions can be applied: increase the current in the igniter and increase the timing during the current is sent to the igniter. For the next test, using 2 seconds instead of one shall be the first correction to implement.

Test 5:

Everything worked. The test is fully successful and the module is ready for the drop test.

TEST PROCEDURES

Title:	**Small Scale Module – Drop Tests**	Test Completed (Date) : 04.01.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0005_SMALL_SCALE_MODULE_DT_R02	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

In order to test the recovery system, the whole model has been tested thanks to a smaller scale module. The aim was to sort out the main issues before going to the normal scale system. Thanks to this approach several critical points were pointed out as vital for the final launch.

The following tests were performed on a 4 inches rocket tube. Their purpose was to test the full recovery system including the SRAD Recovery and the reefing mechanism. Prior to this test, several ground test were done to find the weaknesses of the module. As the last one was a full success, the module should now be tested outside in similar flight conditions.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the recovery module, including the ejection and the reefing mechanisms, is functional. The reefing is used during the first part of the descent between the apogee and the last part of the fall to limit the inflation of the canopy. The parachute is then unreefed and can fully open once the rocket is under 450m of altitude to slow down the chute to a speed smaller than 10 m/s.

2.2 Verification method

To test the reefing technique and subsystems, the rocket is thrown from a 30m height (100m for the Test 4) with a 1m diameter reefed parachute. The latter should inflate first and then be unreefed during the descent after the cut of the reefing line thanks to the line cutters. To validate this test, a significant inflation difference/ speed difference should be observed after the release of the reefing mechanism.

2.3 Test procedures

The test is performed throwing the rocket body from a defined height. The rocket is assembled according to the steps that should be tested.

The parachute is linked to the rocket body thanks to the electrical shock cord and reefed. The second event, which is the release of the reefing mechanism, is triggered thanks to the use of a timer with the SRAD recovery itself activated after the pression of a button.

2.4 Test conditions

Four tests were performed with a small scale model.

During the Test 1, the 2nd event was tested. As such the rocket is thrown with the main parachute already outside as if the 1st event had already occurred successfully. The step-by-step procedure for this test only includes steps 3; 5-6; 11-12; 14-15.

For Test 2, both events were tested. The parachute is linked to the rocket body thanks to the electrical shock cord and reefed. It is wrapped in the deployment bag which is attached to the pilot. The corresponding step-by-step procedure is 2-12; 14-15.

In Test 3, the pilot parachute is already out. The latter should pull out the main parachute located in the deployment bag. The aim of this test is to prove that arrangement of the different parachutes is working. The ejection mechanism isn't tested here and the main parachute is already unreefed. The corresponding step-by-step procedure includes steps 1; 7-9; 15.

During Test 4, the rocket is thrown from a 100m height. The rocket without the lower stage is thrown with the complete recovery module. Steps 1-15 are concerned in this test.

2.5 Test set-up and equipment

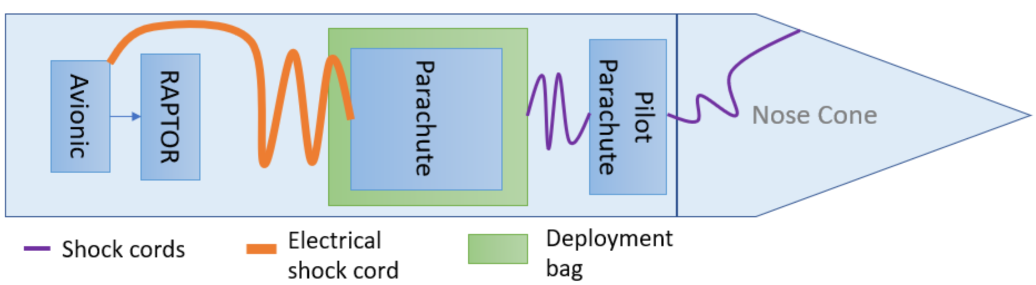


Figure 1 - Diagram of the Recovery Configuration in the Small Scale Module

As stated before, the recovery system is composed of a pilot parachute, a main parachute wrapped in a deployment bag, a reefing mechanism, an electrical shock cord, a RAPTOR and the SRAD Recovery's Avionics to trigger the events

The main parachute is linked to the rocket body thanks to the electrical shock cord. It is located in the deployment bag, itself attached to the pilot parachute located under the nose cone.

The reefing mechanism consists of one line cutter placed along a cord attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is set. Both events are tiggered thanks to a current of 0.8A applied during 2 seconds. This current should set the igniters which will light up the black powder.

The first trigger sent to the RAPTOR should ignite the black powder. This should throw the sharp metallic piece toward the oppercule of the CO2 caltridge. The subsystems located above should then be ejected out of the rocket.

During the second event, triggered by the SRAD recovery's avionics, the signal should ignite the black powder in the line cutters. The latters will then cut the reefing line.

2.6 Step-by-step testing procedure

1. Set a beep after 10 sec to announce the throw
2. Set up the RAVEN's trigger to be executed after 11 sec
3. Set up the line cutters' timer to 14 sec
4. Mount the RAPTOR
5. Follow the line cutter's filling procedure
6. Set up the reefing line on the parachute
7. Wrap the parachute
8. Put the parachute in the deployment bag
9. Attach the pilot parachute to the deployment bag and the nose cone
10. Connect the line cutters with the electrical shock cord
11. Insert the electrical shock cord, the parachute and the pilot in the rocket body
12. Close the rocket
13. Activate the timers
14. Throw the rocket with the right timing

2.7 Pass-fail criteria

N°	Criteria	PASS conditions	Implications if failure
1	1^{st} event – trigger sent by avionic to RAPTOR	Ignition of the RAPTOR	Review of the SRAD recovery
2	1^{st} event – RAPTOR igniter ignition	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
3	1^{st} event – RAPTOR CO2 cartridge pierced	Caltridge opened	Need for a better guiding system
4	1^{st} event – nose cone ejection	Nose cone and rocket body separation	Need for bigger CO2 caltridge
5	1^{st} event – pilot parachute out of rocket body	Pilot parachute going out of the rocket body	Review of the order of storage in the rocket body
6	1^{st} event – no entanglement when pulling the drogue parachute	No knot in the lines	Change in the folding procedure
7	1^{st} event – main parachute comes out of the deployment bag	Opening of the deployment bag	Openings in the deployment bag should be larger
8	1^{st} event – no entanglement observed in the parachute lines	No knot in the lines	Change in the folding procedure
9	2^{nd} event – trigger sent by avionic to line cutter	Ignition of the line cutter	Review of the electric line and batteries

10	2nd event – line cutter igniter ignition	Ignition of the line cutter	Review of the igniters
11	2nd event – reefing line cut	Reefing line cut by one or two line cutters	Increase the quatity of black powder/ Select a thinner reefing line
12	2nd event – central line released	Parachute unreefed	Change the reefing technique

3 TESTS RESULTS

N°	Criteria	Test 1	Test 2	Test 3	Test 4
1	1st event – trigger sent by avionic to RAPTOR	-	FAIL	-	PASS
2	1st event – RAPTOR igniter ignition	-	FAIL	-	PASS
3	1st event – RAPTOR CO2 cartridge pierced	-	FAIL	-	PASS
4	1st event – nose cone ejection	-	FAIL	-	PASS
5	1st event – pilot parachute out of rocket body	-	FAIL	-	PASS
6	1st event – no entanglement when the drogue parachute stretches the shock cord	-	FAIL	PASS	PASS
7	1st event – main parachute comes out of the deployment bag	-	FAIL	PASS	PASS
8	1st event – no entanglement observed in the parachute lines	-	FAIL	PASS	PASS
9	2nd event – trigger sent by avionic to line cutter	PASS	-	-	PASS
10	2nd event – line cutter igniter ignition	PASS	-	-	PASS
11	2nd event – reefing line cut	PASS	-	-	PASS
12	2nd event – canopy fully deployed	PASS	FAIL	PASS	PASS
-	Adjustments for the next tests	Testing of the 1st event	Addition of a buzzer to announce the throw	Test the full system	

4 CONCLUSION

Test 1:

Test fully successful. The reefing implementation, for this small-scale parachute, is operational. A more complete test can be performed.

Test 2:

The timing was wrong, the drop test was thrown 1 second too early compared to the required timer value. Therefore, the trigger was sent only after the module crashed on the ground. In conclusion, a buzzer was added to avoid future timing error.

Test 3:

The pilot parachute pulled the deployment bag out of the rocket body and the parachute out of the deployment bag. The parachute did fully deploy. The folding procedure seemed correct.

Test 4:

Test fully successful, dual event recovery using reefing has been successfully implemented on this small scale module.

TEST PROCEDURES

Title:	**Scale 1 Module – Drop Tests**	Test Completed (Date) : 05.21.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0006_DT_R01	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

After the battery of tests performed on the small scale rocket, the different subsystems should now be sized up to fulfil the same requirements but for the final rocket.

A scale one module was built, the latter has a 120mm diameter. Therefore, a PVC tube of this diameter is used to perform the tests.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the reefing system's implementation is functional considering that the rest of the subsystems are operational. The reefing is used during the first part of the descent between the apogee and the last part of the fall to limit the inflation of the canopy. The parachute is then unreefed and can fully open once the rocket is under 450m of altitude to slow down the chute to a speed smaller than 10 m/s.

2.2 Verification method

To test the reefing technique and subsystems, the rocket already opened is thrown from a 100m height with 4m diameter reefed parachute. The latter should inflate first, not fully, and then be unreefed during the descent after the cut of the reefing line thanks to the line cutters. To validate this test, a significant inflation difference/ speed difference should be observed after the release of the reefing mechanism.

2.3 Test procedures

The test is performed throwing the rocket body from a 100m height. The rocket is assembled without the lower stage. The payload is now present between the pilot parachute and the deployment bag.

The parachute is linked to the rocket body thanks to the electrical shock cord and reefed. The second event, which is the release of the reefing mechanism, is triggered thanks to the detection of the altitude with a barometer. The trigger is set to 40m above ground.

2.4 Test conditions

The tests presented here are performed with a real scale rocket body.

During Test 1, the pilot parachute and the payload were already out of the rocket body. The goal was to check that the parachute comes correctly out of the deployment bag and that the reefing is well implemented.

During test 2 and test 3, no payload, no nose cone nor pilot parachute were integrated, the goal was to gather data on the reefing, so the falling speeds and the acceleration when unreefed. They also permitted to confirm the implementation of the reefing.

2.5 Test set-up and equipment

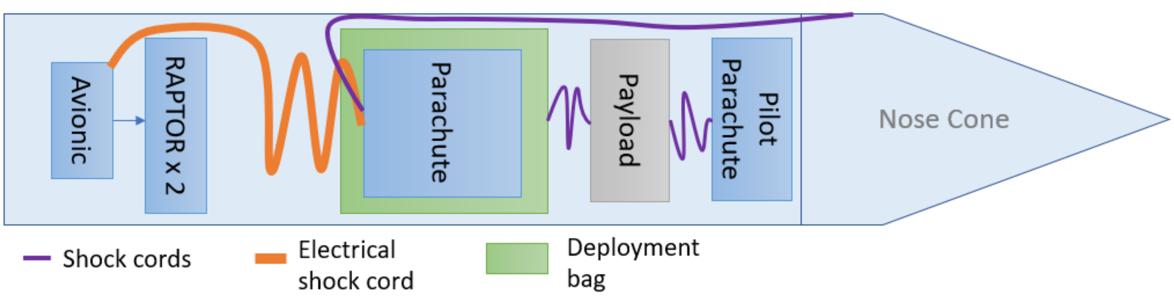


Figure 1 - Diagram of the recovery configuration in the scale 1 rocket

As stated before, the recovery system is composed of a pilot parachute, a main parachute wrapped in a deployment bag, a reefing mechanism, an electrical shock cord, a RAPTOR and the SRAD Recovery's Avionics to trigger the events.

Remark that the pilot is now pulling out the payload which is attached to the deployment bag.

The main parachute is linked to the rocket body thanks to the electrical shock cord. The reefing mechanism consists of to line cutters placed along the reefing line attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is set.

During the second event, the signal should ignite the black powder in the line cutter. The latter will then cut the reefing line.

2.6 Step-by-step testing procedure

1. Set up the SRAD recovery's avionics triggers to 40m
2. Follow the line cutter's filling procedure
3. Set up the reefing line on the parachute
4. Wrap the parachute
5. Put the parachute in the deployment bag

6. Attach the pilot parachute to the payload
7. Attach the payload to the deployment bag
8. Fold the pilot parachute
9. Connect the line cutters with the electrical shock cord
10. Insert the electrical shock cord, the parachute, the payload and the pilot in the rocket body
11. Close the rocket
12. Activate avionics
13. Throw the rocket

2.7 Pass-fail criteria

N°	Criteria	PASS conditions	Implications if failure
1	1st event – trigger sent by avionic to RAPTOR 1	Ignition of the RAPTOR	Review of the SRAD recovery
2	1st event – RAPTOR 1 igniter ignition	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
3	1st event – RAPTOR 1 CO2 cartridge pierced	Cartridge opened	Need for a better guiding system
4	1st event – trigger sent by avionic to RAPTOR 2	Ignition of the RAPTOR	Review of the SRAD recovery
5	1st event – RAPTOR 2 igniter ignition	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
6	1st event – RAPTOR 2 CO2 cartridge pierced	Cartridge opened	Need for a better guiding system
7	1st event – nose cone ejection	Nose cone and rocket body separation	Need for bigger CO2 cartridge
8	1st event – pilot parachute out of rocket body	Pilot parachute going out of the rocket body	Review of the order of storage in the rocket body
9	1st event – payload out of rocket body	Payload isn't stuck in the rocket body	Adjust payload size
10	1st event – no entanglement when pulling the drogue parachute	No knot in the lines	Change in the folding procedure
11	1st event – deployment bag comes out of the rocket body	Deployment bag is well pulled out of the rocket body	Change the folding procedure to obtain a thinner packed parachute
12	1st event – main parachute comes out of the deployment bag	Opening of the deployment bag	Openings in the deployment bag should be larger
13	1st event – no entanglement observed in the parachute lines	No knot in the lines	Change in the folding procedure
14	2nd event – trigger sent by avionic to line cutter	Ignition of the line cutter	Review of the electric line and batteries
15	2nd event – line cutter igniter ignition	Ignition of the line cutter	Review of the igniters

16	2nd event – reefing line cut	Reefing line cut by one or two line cutters	Increase the quantity of black powder/ Select a thinner reefing line
17	2nd event – central line released	Parachute unreefed	Change the reefing technique

3 TESTS RESULTS

N°	Criteria	Test 1	Test 2	Test 3
1	1st event – no entanglement when the drogue parachute stretches the shock cord	FAIL	-	-
2	1st event – deployment bag comes out of the rocket body	PASS	-	-
3	1st event – main parachute comes out of the deployment bag	PASS	-	-
4	1st event – no entanglement observed in the parachute lines	PASS	PASS	PASS
5	2nd event – trigger sent by avionic to line cutter	PASS	PASS	PASS
6	2nd event – line cutter igniter ignition	FAIL	PASS	PASS
7	2nd event – reefing line cut	FAIL	PASS	PASS
8	2nd event – canopy fully deployed	PASS	PASS	PASS
-	Adjustments for the next tests	Adjust shock cord integration	Shorten the central line	-

4 CONCLUSION

Test 1:

The nose cone’s shock cord got entangled with the upper part of the payload. From the parachute’s point of view this didn’t change its behaviour. The deployment bag was pulled out successfully and the parachute could deploy in reefed position successfully. However, the sewing of the shock cord’s loop at the parachute’s quick link got stressed in the wrong direction and broke. Therefore, the shock cord slipped through the parachute’s quick link in the direction of the nose cone, adding stress to the reefing electrical wires which broke the connection. This will be avoided by fixing the nose cone’s shock cord at one end of the rocket body with Velcro strap and roll the shock cord with a strong elastic in order to force it to fall directly on the side and not entangle with the upperpart of the payload. Furthermore, the shock cord’s loop will be sewed to support stress in both ways.

On the other hand, the reefing line was implemented using the wrong node. Therefore, it broke by itself and the parachute unreefed by itself. This will be corrected by using the fisherman’s knot.

Test 2:

The reefing implementation was successful, but the reefed position was too close in term of descent rate to the fully deployed position. Therefore, the central line shall be shortened to reef more the parachute.

Test 3:

Statistics are now very good for the reefing implementation. The reefing position seemed more correct, but a 100m fall is not sufficient to fully observe the different steps of the parachute inflation, falling speed stabilization…

TEST PROCEDURES

Title:	**Ground Tests**	Test Completed (Date) : 04.15.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0007_GT_R01	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

After the battery of tests performed on the small scale rocket, they now can be performed on the actual Matterhorn rocket used for the competition.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the ejection system is functional for the rocket used during the competition. Additionaly, the ejection should be performed using only one RAPTOR system to ensure the redundancy if two RAPTORs are used in the final rocket during the first battery of tests The other ones will be performed with two RAPTORs as set for the competition. Additionally, the pilot will be pulled out to check if there is any entanglement and if the parachute can be easily pulled out of the deployment bag.

2.2 Verification method

For the first tests the SRAD avionic is used to trigger the two recovery events, the last test was performed with the RAVEN simulator. The two RAPTORs will be set at the same time to test the redundancy.The two line cutters (one redundancy) will be triggered as well in parallel to test the whole system.

2.3 Test procedures

The test is performed on the ground. The rocket is assembled as for a launch without the motor. The main parachute of 4m in diameter is linked to the rocket body thanks to the electrical shock cord. It is wrapped in a deployment bag above which are located the payload and the pilot parachute.

The ejection is triggered by the used avionic.

2.4 Test conditions

The following tests were performed using the upper stage of the Matterhorn. The same configuration is used for the different tests. The latter is the same as the one used for the competition.

The Test 1 and 2 were performed using only one RAPTOR mechanism.

During Test 4, only one AEROCON line cutter was set.

2.5 Test set-up and equipment

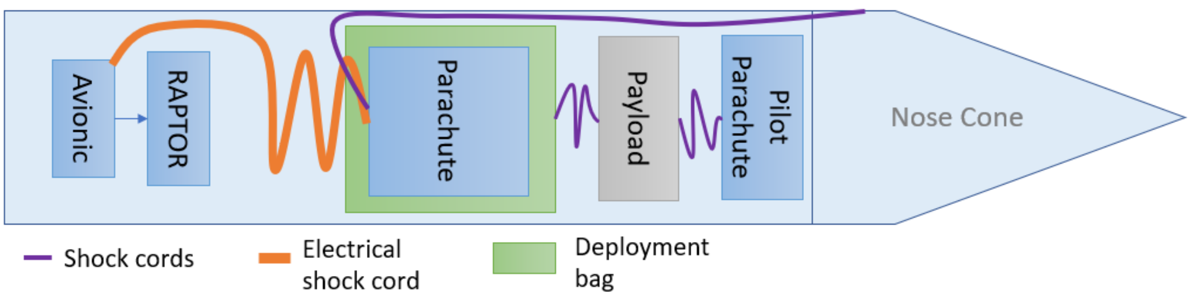


Figure 1 - Diagram of the recovery configuration in the scale 1 rocket

As stated before, the recovery system is composed of a pilot parachute, a main parachute wrapped in a deployment bag, a reefing mechanism, an electrical shock cord and custom avionic. The rocket body used is the upper stage of the Matterhorn rocket. The main parachute is linked to the rocket body thanks to the electrical shock cord. Remark that the pilot is now pulling out the payload which is attached to the deployment bag.

Additionally, a second RAPTOR is now placed on the recovery plate to test the final configuration of the recovery module.

The reefing line is attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is set.

The first trigger should activate the RAPTOR. In it, the black powder's explosion will push a sharp metal piece on the CO2 caltridge's operculum. The CO2 expelled will push the parachute in the deployment bag which will bring the pilot parachute and the nose cone out.

The second trigger activates the two AEROCON line cutters which should cut the reefing line.

2.6 Step-by-step testing procedure

1. Set up the SRAD Avionic's simulations / RAVEN simulation
2. Prepare the two RAPTORs
3. Follow the line cutter's filling procedure
4. Place the line cutters along the reefing line
5. Set up the reefing line on the parachute
6. Wrap the parachute
7. Put the parachute in the deployment bag
8. Attach the pilot parachute to the payload
9. Attach the payload to the deployment bag
10. Connect the line cutters and the nose cone with the electrical shock cord

11. Insert the electrical shock cord, the parachute, the payload and the pilot in the rocket body
12. Close the rocket with the nose cone
13. Launch simulation

2.7 Pass-fail criteria

N°	Criteria	PASS conditions	Implications if failure
1	1st event – trigger sent by avionic to RAPTOR x2	Ignition of the RAPTOR	Review of the COTS recovery
2	1st event – RAPTOR igniter ignition x4	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
3	1st event – RAPTOR CO2 cartridge pierced x2	Cartridge opened	Need for a better guiding system
4	1st event – nose cone ejection	Nose cone and rocket body separation	Need for bigger CO2 cartridge
5	1st event – pilot parachute out of rocket body and nose cone	Pilot parachute going out of the rocket body	Review of the order of storage in the rocket body
6	1st event – Payload out of the rocket body	Payload going out of the rcket body	Need for bigger CO2 caltridge
7	1st event – Deployment bag out of the rocket body	Deployment bag going out of the rocket body	Need for bigger CO2 caltridge/ Review of the folding procedure for the main parachute
8	1st event – no entanglement when pulling the drogue parachute	No knot in the lines	Change in the folding procedure
9	1st event – main parachute comes out of the deployment bag	Opening of the deployment bag	Openings in the deployment bag should be larger
10	1st event – no entanglement observed in the parachute lines	No knot in the lines	Change in the folding procedure
11	2nd event – trigger sent by avionic to line cutter x2	Ignition of the line cutter	Review of the electric line and batteries
12	2nd event – line cutter igniter 1 ignition	Ignition of the line cutter	Review of the igniters
13	2nd event – line cutter igniter 2 ignition	Ignition of the line cutter	Review of the igniters
14	2nd event – reefing line cut	Reefing line cut by one or two line cutters	Increase the quatity of black powder/ Select a thinner reefing line
15	2nd event – central line released	Parachute unreefed	Change the reefing technique

3 TESTS RESULTS

N°	Criteria	Test 1	Test 2	Test 3	Test 4	Test 5
1	1st event – trigger sent by avionic to RAPTOR	PASS	PASS	PASS	PASS	PENDING
2	1st event – RAPTOR igniter ignition	PASS	PASS	PASS	PASS	PENDING
3	1st event – RAPTOR CO2 cartridge pierced	PASS	PASS	PASS	PASS	PENDING
4	1st event – nose cone ejection> 300 mm	PASS	PASS	PASS	PASS	PENDING
5	1st event – pilot parachute out of rocket body/ nose cone	FAIL	PASS	PASS	PASS	PENDING
6	1st event – Payload out of the rocket body	-	FAIL	PASS	PASS	PENDING
7	1st event – Deployment bag out of the rocket body	-	FAIL	PASS	PASS	PENDING
8	1st event – no entanglement when pulling the drogue parachute	-	PASS	PASS	PASS	PENDING
9	1st event – main parachute comes out of the deployment bag	-	FAIL	-	FAIL	PENDING
10	1st event – no entanglement observed in the parachute lines	-	FAIL	PASS	PASS	PENDING
11	2nd event – trigger sent by avionic to line cutters	-	-	FAIL	PASS	PENDING
12	2nd event – line cutter igniter 1 ignition	-	-	FAIL	PASS	PENDING
13	2nd event – line cutter igniter 2 ignition	-	-	FAIL	-	PENDING
14	2nd event – reefing line cut	-	-	FAIL	PASS	PENDING
15	2nd event – central line released	-	-	FAIL	PASS	PENDING
-	Adjustments for the next tests	-	- Adjust plate sealing - Adjust deployment bag's elastic loops	- add damping capacitor	- adjust thedeployment bag's elastic loops	PENDING

4 CONCLUSION

Test 1:

A single 25g CO2 cartridge is sufficient to eject nose cone, so the deployment system is truly fully redundant. The pilot parachute stays in the nose cone during ground test. However, with the drop tests: small module, similar conditions proved that during a drop test the pilot does leave the inside of the nose cone.

Test 2:

The airtightness of the recovery plate wasn't optimal enough, so the nose cone was ejected but not the payload. This would not be critical since the payload's drogue would have pulled the payload out. But better sealing of the recovery plate resulted in the ejection of the payload with a single CO2 cartridge.
Once the deployment bag was pulled out of the rocket body, it did not open itself and the lines stayed entangled in it. Indeed, the closing part is too loose which resulted in undesired stress once the shock cord was fully stretched. The position of the closing loop of the deployment bag has been adjusted to the right position.

Test 3:

When the avionic sent the current to the 4 igniters of the 1st event, it triggers an undesired voltage. A large capacitor was added to absorb this drop of voltage and deliver the required current.

Test 4:

The deployment bag did release the parachutes lines but did not fully open and failed to let go the parachute. The loop closing the deployment bag still have too much lose and stay entangled as soon as stress is applied. The sewing of the loops shall be more adapted to avoid this entanglement.

TEST PROCEDURES

Title:	**In Flight Test – Integrated**	Test Completed (Date) : 05.01.2018
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_ TP_0008_INTEGRATED_R01	
Prepared by:	Grégoire Ferracci	
Checked by:	Malo Goury du Roslan	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This test was performed during the last in flight test. The rocket is mainly composed of the different subsystems used for the competition.

After the battery of tests performed on the small scale rocket, and on the scale 1 rocket, and the different lessons learned from them, this test should validate the work done up to today or give us a chance to proceed to the final adjustments.

2 VERIFICATION PROCESS

2.1 Verification objectives

The aim of this test is to prove that the whole recovery system is functional during an in-flight-test and in similar conditions as the ones of the competition. Every recovery subsystem has already been tested. This test should validate the integration with the other section’s systems in one rocket.

2.2 Verification method

For this test a RAVEN is used to trigger the second recovery events. As during the last ground test, the subsystems and redundancies will be triggered at the same time to maximize the chances of success.

2.3 Test procedures

The test is performed in flight. The rocket is fully assembled for the launch. The main parachute of 4m in diameter is linked to the rocket body thanks to the electrical shock cord. It is wrapped in a deployment bag above which are located the payload and the pilot parachute. The nose cone is disposed above it to close the rocket.

A trigger is sent to the four igniters of the RAPTORs during the first event to eject the parachute, located in the deployment bag, with the payload, the pilot and the nosecone.

A second signal is sent to the line cutters to cut the reefing line and unreef the parachute.

2.4 Test conditions

In-flight test performed with a scale 1 model.

2.5 Test set-up and equipment

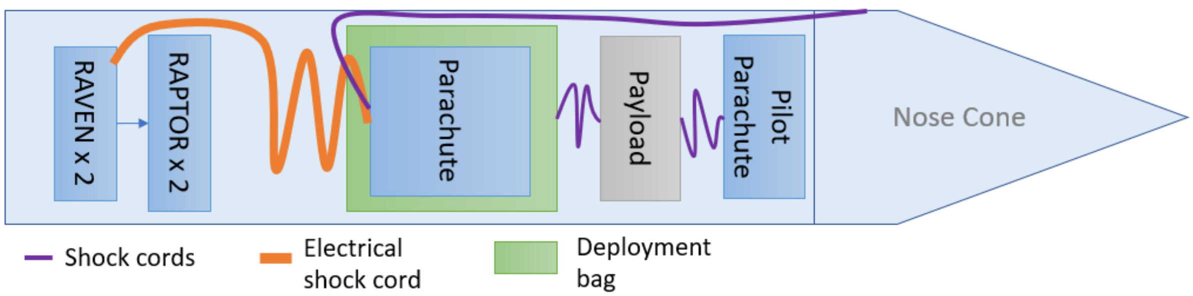


Figure 1 - Diagram of the recovery configuration in the scale 1 rocket

As stated before, the recovery system is composed of a pilot parachute, a main parachute wrapped in a deployment bag, a reefing mechanism, an electrical shock cord and is triggered by a RAVEN. The main parachute is linked to the rocket body thanks to the electrical shock cord. Remark that the pilot is now pulling out the payload which is attached to the deployment bag.

Additionally, a second RAPTOR is now placed on the recovery plate to test the final configuration of the recovery module.

The reefing line is as before attached between the canopy of the parachute and the end of the electrical shock cord. As such, it should limit the inflation of the canopy until the second event is set.

Both events will be tested and both the original subsystems and their redundancies will be triggered.

2.6 Step-by-step testing procedure

1. Set up the RAVEN's trigger to be executed at the apogee (add a timer to avoid any undesired event due to pressure variations)
2. Set up the line cutters' trigger to the last 300m
3. Prepare and arm the two RAPTORs
4. Follow the line cutter's filling procedure
5. Place the line cutters along the reefing line
6. Set up the reefing line on the parachute
7. Wrap the parachute
8. Put the parachute in the deployment bag
9. Attach the pilot parachute to the deployment bag
10. Fold the pilot parachute
11. Connect the line cutters with the electrical shock cord
12. Insert the electrical shock cord, the parachute and the pilot in the rocket body
13. Close the rocket

2.7 Pass-fail criteria

Criteria	PASS conditions	Implications if failure
1st event – trigger sent by avionic to RAPTOR x2	Ignition of the RAPTOR	Review of the SRAD recovery
1st event – RAPTOR igniter ignition x4	Ignition of the RAPTOR	Review of the igniters and of the filling procedure
1st event – RAPTOR CO2 cartridge pierced x2	Cartridge opened	Need for a better guiding system
1st event – nose cone ejection	Nose cone and rocket body separation	Need for bigger CO2 cartridge
1st event – pilot parachute out of rocket body	Pilot parachute going out of the rocket body	Review of the order of storage in the rocket body
1st event – Payload out of the rocket body	Payload going out of the rocket body	Need for bigger CO2 cartridge
1st event – Deployment bag out of the rocket body	Deployment bag going out of the rocket body	Need for bigger CO2 cartridge/ Review of the folding procedure for the main parachute
1st event – no entanglement when pulling the drogue parachute	No knot in the lines	Change in the folding procedure
1st event – main parachute comes out of the deployment bag	Opening of the deployment bag	Openings in the deployment bag should be larger
1st event – no entanglement observed in the parachute lines	No knot in the lines	Change in the folding procedure
2nd event – trigger sent by avionic to line cutter x2	Ignition of the line cutter	Review of the electric line and batteries
2nd event – line cutter igniter 1 ignition	Ignition of the line cutter	Review of the igniters
2nd event – line cutter igniter 2 ignition	Ignition of the line cutter	Review of the igniters
2nd event – reefing line cut	Reefing line cut by one or two line cutters	Increase the quantity of black powder/ Select a thinner reefing line
2nd event – central line released	Parachute unreefed	Change the reefing technique

3 TESTS RESULTS

CRITERIA	PASS / FAIL
1st event – trigger sent by avionic to RAPTOR	PASS

1st event – RAPTOR igniters ignition	PASS
1st event – RAPTOR CO2 cartridges pierced	PASS
1st event – nose cone ejection	PASS
1st event – pilot parachute out of rocket body	PASS
1st event – payload out of rocket body	PASS
1st event – deployment bag out of rocket body	PASS
1st event – no entanglement when pulling the drogue parachute	PASS
1st event – main parachute comes out of the deployment bag	FAIL
1st event – no entanglement observed in the parachute lines	-
2nd event – trigger sent by avionic to line cutter	PASS
2nd event – line cutter igniter ignition	PASS
2nd event – reefing line cut	PASS
2nd event – central line released	PASS
2nd event – canopy fully deployed	FAIL

4 CONCLUSION

The different electronic subsystems worked perfectly. The nosecone was correctly opened, and the payload was separated and recovered.

Unfortunately, the shock due to the inflation of the pilot parachute led to the tear of the strap located on top of the deployment bag. As such, no forces were exerted to pull the main parachute out of the bag and the rocket started to descent in pseudo-freefall.

A new deployment bag will be made, using different textile.

TEST PROCEDURES

Title:	**Acceptance Test, Deployment Bag**	Test Completed (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_RE_TP_0009_DEPLOYMENT_BAG_R01	
Prepared by:	Malo Goury du Roslan	
Checked by:	Guilain Lang	
Approved by:	Guilain Lang	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

After the result of the 2018_RE_TP_0008_INTEGRATED, a new deployment bag was manufactured, using a more rigid textile and stronger attach. Some features shall be tested for acceptance regarding the next flight.

2 DEFINITIONS AND ABBREVIATIONS

DB Deployment Bag

3 VERIFICATION PROCESS

3.1 Verification objectives

This test will check that the parachute comes out of the deployment bag smoothly enough and that the attach is sufficiently strong.

3.2 Verification method

The idea is to try to test this with similar behaviours than it will be in flight. The result of the test will be determined directly visually, checking that the attach is still intact after each load and that the parachute came systematically out of the DB.

3.3 Test procedures

Both the official DB and parachute are used. The rest are materials used only for this test.

3.4 Test conditions

In order to simulate the shock happening during a flight when the parachute is pulled out of the DB, the latter is attached high enough in order to let a mass fixed to the bottom of the parachutes lines fall and pull the parachute down. The shock produced once the parachute lines are fully stretched shall be similar than the one in flight. In flight, this force is produced by a drogue parachute such as the Iris Ultra 36'' from Fruity Chutes. Using their descent rate calculator, with a mass of a 4kg attached to it the descent velocity is 7 m/s. From this velocity the drag force can be computed and is equal to 60 N. Therefore, a mass heavier than 6kg shall be used. On the other hand, if in flight the DB struggles to open and it happens that the drogue is pulling the payload and the 14kg launch vehicle, this would correspond to a falling speed of 14m/s and a force of 240N. This gives the theorecally larger force that the attach of the DB shall withstand.

3.5 Test set-up and equipment

The deployment bag with the parachute inside is attached through a short strap to a small bridge. A 10kg mass is attached to the bottom part of the parachutes line. The control is done visually.

3.6 Step-by-step testing procedure

- Check bridge's height
- Fold the parachute
- Place it in DB
- Attach DB to bridge
- Attach mass to parachute lines
- Throw mass

3.7 Pass-fail criteria

Criteria	PASS conditions	Implications if failure
1st elastic opened	Lines out of the elastic loop	Change size of the loop
2nd eleastics opened x 2	Lines out of the elastic loop	Change size of the loop
3rd elastic opened x 2	Lines out of the elastic loop	Change size of the loop
Upper attach intact	Tensile and sewing not affected	Stronger Sewing
Parachute out of DB	DB is empty	Review of the order of storage in the rocket body

4 TESTS RESULTS

CRITERIA	PASS / FAIL
1st elastic opened	PASS
2nd elastics opened x 2	PASS
3rd elastics opened x 2	PASS
Upper attach intact	PASS
Parachute out of DB	PASS

5 CONCLUSION

The deployment bag did withstand the pulling shock, the parachute did correctly leave the deployment bag. The system is accepted.

3. Structure Subsystem

Documents regarding the manufacturing of the carbon fiber composite airframe:

- `2018_ST_PP_0004_TUBE_MANUFACTURING_PROCEDURE_R01`

Documents regarding presentation of extended rationales:

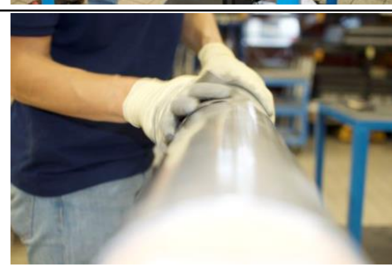
- `2018_ST_TN_0001_NOSE_CONE_RATIONALES1_R02`
- `2018_ST_TN_0002_COUPLERS_SIMULATION_RATIONALES_R04`
- `2018_ST_TN_0007_NOSE_CONE_RATIONALES2_R01`

Documents regarding test procedures are:

- `2018_ST_TP_0005_STRUCTURE_HEATING_R01`
- `2018_ST_TP_0006_NOSE_CONE_MOLD_R01`

Documents regarding simulations:

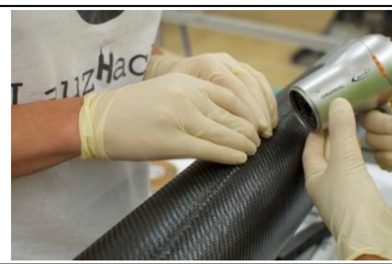
- `2018_ST_TN_0003_BOAT_TAIL_R01`
- `2018_ST_TN_0011_CARBON_AIRFRAME_R01`
- `2018_ST_TN_0012_THRUST_PLATE_ANALYSIS_R02`

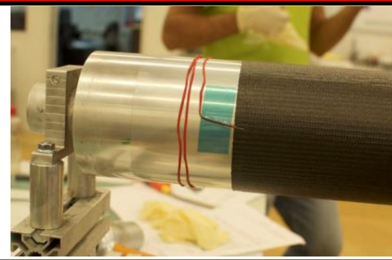
Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
1	07:45	Meeting main door				1	1	1	1	
	08:15	Gear Up		Put on protection shoes or protection shoe caps located in packing room closet next to break area.	Protection shoes or protection shoe caps	1	1	1	1	
	08:30	Get Jigs and molds		Get Jigs and molds located in Hanspeter Siegerist's workshop. Set molds on jig	Jigs and molds, tools to unscrew jig parts.	1	1			
	08:30	Take prepregs out of fridge		VERY IMPORTANT: don't forget to get the cut prepregs out of the fridge on the first day.	Prepregs			1		
	08:30	Prepare materials		Put useful materials for next step in plastic box.	sandpaper (240, 360, 400, 600, 800, 1000, 1200), polish paste, acetone, cleaning paper, cleaning cloth, gloves, breathing masks, small water bechers, clamps,				1	
	08:45	Start Sanding		Go through all sandpaper grits. Wash tube with acetone once and a while when to much wetted aluminum powder covers the mold.	sandpaper, acetone, paper	1	1	1	1	

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	11:30	Give sanded tube a final wash before polish		Rince tube well with acetone	acetone, paper	1	1	1	1	
	12:45	polish tubes		Apply polish paste on small area and rub until the surface has a mirror-like aspect.	polish paste, cleaning cloth	1	1			
	12:45	Prepare materials		Cut out any materials that can be cut in advance. E.g. breather, teflon cloth and vacuum bags. Identify ply numbers and directions. Write longitudinal center of each ply.	breather, teflon cloth, vacuum plastic, scisors			1	1	
	14:00	Apply tape to tube ends		So that the Frekote isn't applied to locations of the mold where the sealing tape is intended to stick, apply a width of tape to the circumference of the mold ends.	Blue transparent tape		1			

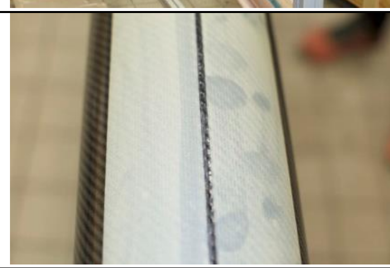
Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	14:15	Apply Frekote		Apply Frekote 770-NC according to product specifications or as described in procedures.	Loctite Frekote 770-NC	1				
	16:30	Clean up and store jigs and molds		Clean up workbench before leaving, put tools back to there places especially measuring instruments. Consider covering the jigs with plastic for storage. Make sure the plastic is clean.		1	1	1	1	
2	06:00	Meeting main entrance		Start laminating early so the tubes can be put in the autoclave the same day.		1	1	1	1	1
	06:15	Prepare workshop				1	1	1	1	1
	06:30	Lay layer one on tube	 	To apply first layer of prepreg to the tube, remove the green-side of the resin prepregs . Mark the tube in advance with two references indicating the position of the ply's center along it's width. Lay mat very gently taking special care that no creases or folds are created. Once mat is layed, press it against the tube with both hands aloong the whole length. Use a massaging motion to remove any air bubbles.	Prepregs, Jigs applied with Frekote	1	1	1	1	1

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	07:00	Remove white plastic on prepregs				1	1	1	1	
	07:10	Apply peel ply		The peel ply should be a little wider than the perimeter of the mold but shouldn't in any case wrap the tube more than once.	Peel ply	1	1	1	1	
	07:15	Apply breather		Wrap tube with breathing material, overlap is ok for this material. Tip: Use a lighter to slightly melt cloth in order to adhere pieces together. Tape is useless.	Breather	1	1	1	1	
	07:20	Apply vacuum bag		To slide the vacuum bag over the tube, it is necessary to unscrew it from its jig (at least for the first time). Make sure that tacky tape is appropriatly applied on every end of the vacuum bag that should be closed, before sliding it over the tube. Before closing the bag, screw on vacuum pump connector. A small cut must be made in the plastic at the location where the connector is screwed.	vacuum bag, tacky tape, vacuum pump connector	1	1	1	1	1

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
		Make bag airtight		Listen for any air leaks. Generally located in the tacky tape, push and pull on the sealings until they are air tight. If there is a hole in the plastic seal it with tape.	tape	1	1	1	1	1
		Flaten Vacuum bag		In order to reduce the number of wrinkles to a minimum, tug on the vacuum bag to flaten the plastic as much as possible.		1	1	1	1	1
	07:40	remove vacuum pump		Remove pump and open vacuum bag. If the bag is long enough, cut off one end with the tacky tape, new tape can be applied for the next layer. Keep the other end glued to the mold and carefully pull back the plastic to one end of the mold without taking it off the jig. Avoid piercing the plastic in the process.		1	1	1	1	
	07:45	Repair wrinkles		Wrinkles are bound to appear in the process. At each layer, push them back in by applying pressure with fingertips. Use a hair drier to fluidify the resin.	hair drier	1	1	1	1	1
	08:00	Repeat layup process for second Layer		Lay prepregs, apply teflon cloth, breather, vacuum bag, possibly new tacky tape, vacuum and remove wrinkles.		1	1	1	1	1

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	09:45	Thermocouple		On the middle layer (second in this case) setup a thermocouple ~5mm inside the composite tube. Wrap the rest of the cable around the tube. This is important for the autoclave.	Thermocouple	1	1			
	09:50	Repeat layup process for third layer		Lay prepregs, apply teflon cloth, breather, vacuum bag, possibly new tacky tape, vacuum and remove wrinkles.		1	1	1	1	1
	10:00	Cut out remaining materials		Have two people cut out the lubriglas and cut out and prepare the final vacuum bag made out of heavier duty plastic and already formed into a tube. Prepare the bag with tacky tape too at the ends.	Lubriglas, vacuum bag	1	1			
	11:30	Vacuum last layer and go eat				1	1	1	1	1
	12:30	Lay last layer				1	1	1	1	1
	12:50	Apply lubriglas	 	Take care when applying the lubriglas so that it is as parallel as possible to the tube. Massage the lubriglas onto the tube to remove all air bubbles	Lubriglas	1	1	1	1	1

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	13:10	Setup breathing material		For the last vacuum, breathing material isn't layed onto the fiber but rather around it as in the picture. This setup allows for the vaccuum to travel from the pump to the rest of the tube and at the same time allow to better eliminate any wrinkles on the tube.	Breather	1	1	1	1	
	13:30	Apply vacuum bag		As for the previous one remove the mold from the jig to slide on the vacuum bag. Vacuum connectors are installed on both sides of the tube this time. Make sure to screw them on before sealing the bag.	Vacuum bag with tacky tape installed, vacuum pump connectors	1	1	1	1	
	13:45	Proceed to final vacuum		Make absolutely sure that the bag is totally air-tight. Take time trying to set the plastic as flat as possible against the lubriglas.		1	1	1	1	1
	15:00	Last deadline to bring tubes to autoclave		At this time, most techniciancs start thinking about going home. This leaves about 30 min to have someone help put the tubes in the autoclave and start the machine.		1	1	1	1	1
	15:10	Put jigs in autoclave		Unscrew wheels under the rolling jig, remove any wooden rings from the tubes or any other material susceptible to burn at 140°C before placing the jig in the autoclave. Let the technician take care of connecting the vacuum tubes and thermocouples.	6mm Allen wrench	1	1			

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	15:20	Maximize sealing		Work on seals until the pressure at both connectors reaches acceptably low levels (according to technician).		1	1	1		
	15:30	Close her up		The autoclave has an electrical closing system, but the door has to be helped out for the last centimeters.		1	1	1		
		Fiesta!				1	1	1	1	1
3	07:00	Meeting main entrance				1	1	1		
	07:20	Get Jigs out of autoclave and unpack the tubes		Carefuly unpack the tubes without scratching the mold or the composite tube.	cutter	1	1	1		
	07:45	Clean lubriglas joint		Tape both sides of lubriglas joint location where the finish isn't as nice as the rest of the tube. Sand the joint with 240 grit paper and finish with finer 800 grit.	tape, 240 grit and 800 grit sandpaper	1	1	1		

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	08:15	Clean mold ends		Thoroughly clean both ends of mold with acetone. Any particles that might slide between the tube and the mold will signifcantly hinder the unmolding process.	acetone and absorbing paper	1	1	1		
	08:20	Unmold		Remove mold from jig. One person should pull on the mold, another on the tube while the third makes sure the tube isn't being excessively bended.		1	1	1		
	08:30	Clean Jigs		Clean jigs with paper and acetone	acetone and absorbing paper	1	1			
	08:30	Prepare bubble plastic to store molds		Cut out buble plastic to tube length				1		
	08:45	Wrap molds with bubble plastic				1	1	1		
	09:00	Store jigs		Put wraped molds back on to jigs and store them where indicated (last time was in the archives)		1	1	1		
	09:30	Cut tubes to length		Use circular cutter to cut the blades to length. Insert a wooden ring on one side of the tube which fits snuggly such that it can be used as a reference for a flat and perpendicular tube end. When cutting, rotate the tube to cut the whole circumference and have people make sure the tube is well against the guide and the stopper.	Technical drawings of rocket airframe.	1	1	1		

Timing		Task	Picture	Description	Materials	Occupied				
Day	Time					1	2	3	4	5
	10:30	Clean and pack tubes		Clean inside of tubes with dry paper tissues and wrap them in bubble plastic.	Bubble plastic	1	1	1		

TECHNICAL NOTES

Title:	**Nose Cone specifications**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0001_NOSE_CONE_R01	
Prepared by:	Emilien Mingard	
Checked by:	Maxime Eckstein	
Approved by:	César	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The nose cone is a major part which doesn't sustain that much load compared to the thrust plate or the coupler. The other aspect concerning the nose cone are its shape and its material. Both are decided based on flight simulations and manufacturing processes that the team is able to perform at school. Both subjects are presented in the current technical document.

2 DEFINITIONS AND ABBREVIATIONS

OD	Outer Diameter
IN	Inner Diameter
ST	Structure
FDM	Filament deposition method
3D	Usually reference to 3D printing manufacturing processes

3 CONCEPT EXPLANATION

3.1 Nose Cone

The part will be made out of composite materials. The high strength and the low weigth are advantages that confirm our choice. Plastic injection implies metal mold and injection device which cost to much. 3D deposition methods such as plastic FDM or metal powder allows wide range of shape and complex internal structure. As the Nose Cone is a shell, 3D deposition methods doesn’t suite very well.

The chosen composites material is glass fibers with epoxy matrix as carbon based composites do not allow radio wave to be transmitted through. The fibres are chosen such that they can be shaped to double curvature mold. Both the resin and the fibers come from Swiss-Composites [1]compagny.

Figure 1 presents the used textile, which is an Atlas type. It allows wide range of curvature and are providen with finish agent which improve matrix adhesion. Figure 2 presents the Epoxy matrix chosen. It can be used for 90 min before any reaction. It allows us enough time to work with it. The

Figure 1 Atlas Glass Fiber, 300g/m²

Figure 2 - Epoxy Resin L+EPH161

resin is chosen such that is can sustain a temperature up to 80°C which is the upper bound considered for the New-Mexico desert.

The dimensions were set using OpenRocket based on a altitude sensitive analysis. We end up with an ogive as the best shape for the cone within shapes we are able to manufacture at EPFL. The shoulder OD is 117.5 +- 0.1mm and the ogive length is 500 mm. The ogive OD should be at 120+2x1.2 = 122.4 +- 0.4 mm which is compatible with the airframe dimensions ID 120+-0.4mm, OD 122.4+-0.4mm. The shoulder length is 120mm as asked by the rules (Shoulder = 1xID).

3.2 Mold

[1] https://www.swiss-composite.ch

The nose cone is composed of an ogive and a shoulder and thus, a positive mold can not be used. It is decided to create a negative mold made of two halfs. It is made out of MDF wood cover by varnish. Many layer are applied to obtain a smooth surface. A wax released agent is applied to the surface to provide release assistance.

The final results are presented in Figure 6, the two halfs bodies are varnished. The mold is closed

Figure 6 Vernished Mold

Figure 4 Mold Manufacturing

Figure 5 Wax Release Agent

Figure 3 Standard Wood Varnish

using M8 screws positionned everywhere. Figure 4 illustrates the manufacturing process. It is made by a 3 axis CNC machine. A 6 mm ball end mill is used to provide the best surface approximation. Figure 3 presents the standard varnish used to smooth the surface. Figure 5 presented th release agent.

4 CONCLUSION

This report talk about a first attempt to produce a home made nose cone. The nose cone V1 was produced in January 2018. Figure 7 illustrates the result from first test. Despite the fact that the produced nose cone isn't at the right dimensions, all the rationales were initially thank for the final nose (Such as material & dimensions). A second Technical Note will discuss more in details what happened from january to june 2018.

Figure 7 Nose Cone V1, sits in final cone mold

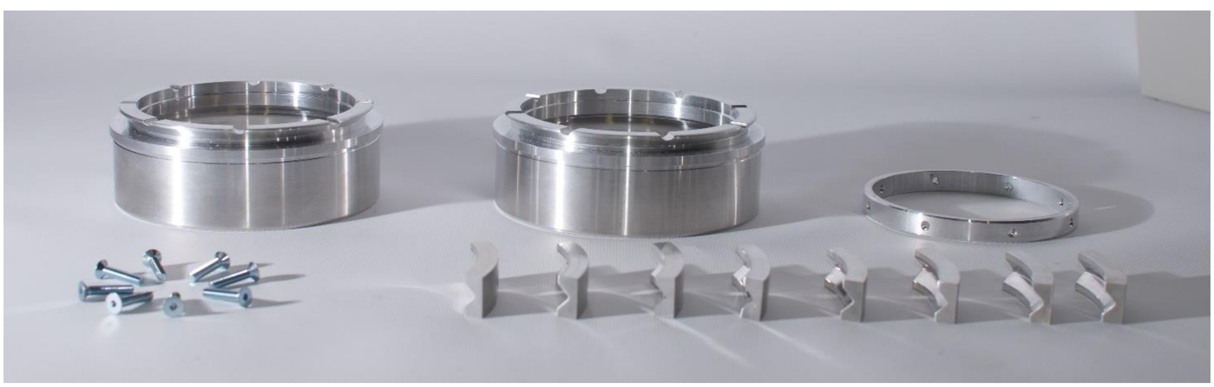
TECHNICAL NOTES

Title:	**Technical notes, Coupling mechanism**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0002_COUPLERS_SIMULATION_RATIONALES_R04	
Prepared by:	Eckstein Maxime	
Checked by:	Héloïse Boross	
Approved by:		Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The goal of this document is to show that the student designed and developed coupling system for rocket Matterhorn proposed by the ERT Rocket Team of EPFL in Switzerland is safe and reliable. This system is meant to be used on various parts of the rocket requiring coupling. During the flight, it will secure two air-frame parts together while allowing easy access to the inside of the rocket during assembly. Furthermore it will provide fixation points inside the rocket for the thrust plate and the recovery. A highly conservative hypothesis is considered on the loading case to dimension the parts and prove that even under extreme stresses the system will maintain the integrity of the rocket.



2 CONCEPT EXPLANATION

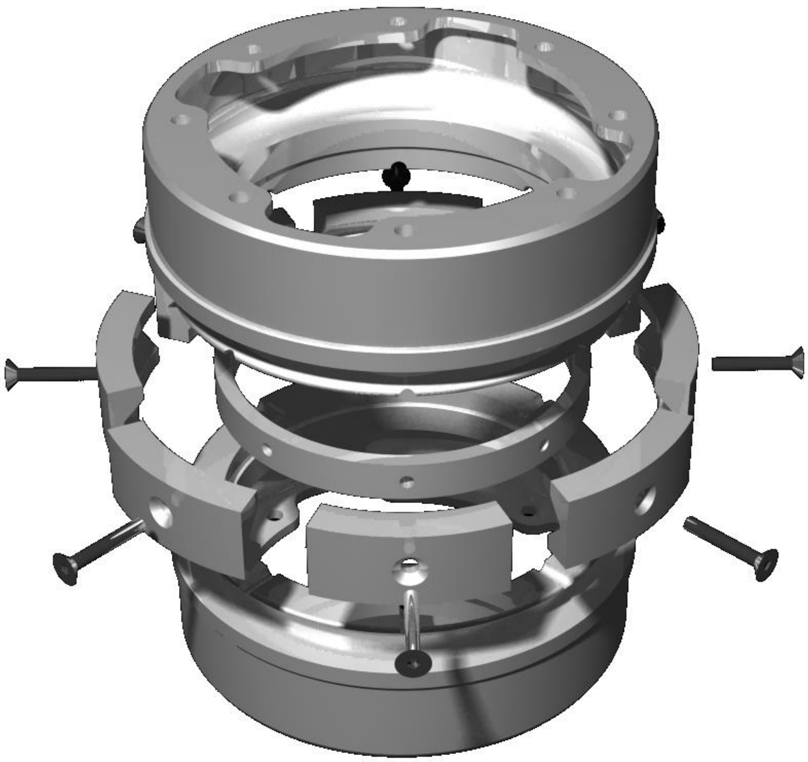


Figure 1 : Coupler exploded assembly view

2.1 Design

The coupler consists of 4 different parts :

- Two cylindrical parts that are glued in the air-frame
- An inner ring
- Eight wedges
- Eight screws

The exploded view of the assembly is presented in Figure 1.

In the following sections we will first determine the maximal force that may arise in a catastrophic event in order to size :

- The area needed for the lap joint between the air-frame tubes of the rocket and the coupling cylinders,
- The overall dimension of the wedges and screws.

With this analysis we will show the safety of our system in all possible flight configurations.

2.2 Maximal load analysis

The maximal traction force on the coupling system will arise when the main parachute opens see Figure 2. To represent the worst case scenario we will take the following hypothesis:

- Mass of the rocket at burnout $m_b = 20$kg
- Velocity at main parachute opening based on IREC's rules $V_o = 46$m/s
- Desired velocity when touchdown $V_t = 5$m/s
- Density of air is constant up to main opening altitude $\rho = 1.225$kg/m^3
- Typical coefficient of drag $C_x = 2.2$ (Fruity Chutes Iris Ultra)
- Length of the chute shock cord $l = 25$m
- Rigidity of the shock cord $E_c = E_{nylon} = 3$GPa
- Section of the shock cord $S = 25 \cdot\ 2 = 50$mm^2
- All the mass of the rocket will be loaded onto one coupler only.

The last hypothesis is obviously wrong and will oversize the whole mechanism, as some of the weight of the rocket will be located above the coupler and the attach point of the parachute shock cord. But if we can show that it the mechanism will withstand it we can ensure that this critical part will not fail.

To evaluate the maximal traction force on the shock cord two different conservative approach are used. The first one is based on the energy of the system and consider that all the energy required to slow down the rocket will be at first stored in the elongation of the shock cord which will act like a spring. The second idea is to calculate the maximal drag that will produce the parachute if we could open it instantaneously at a velocity V_o.

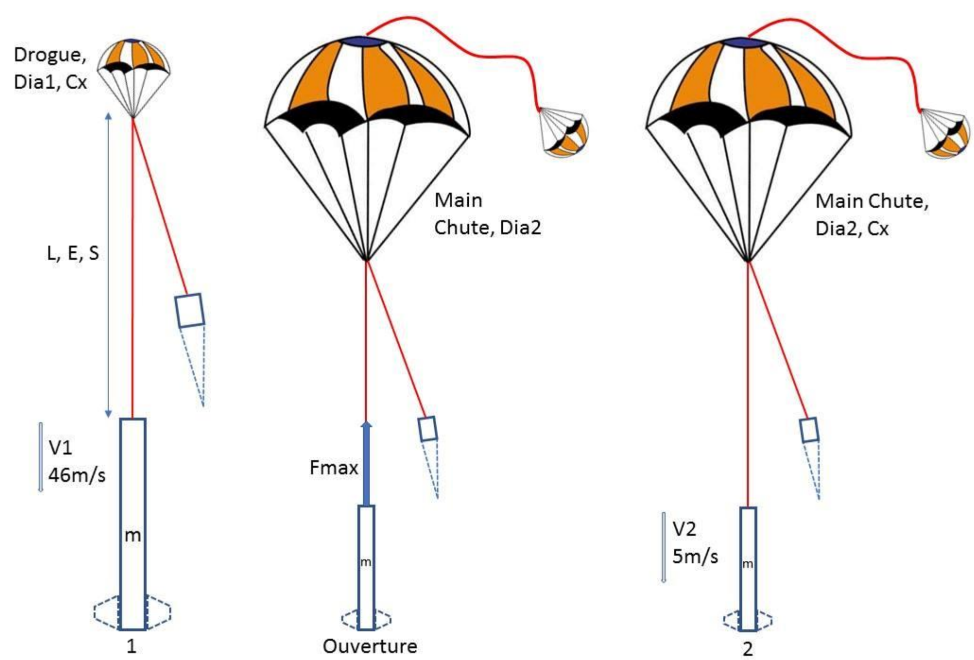


Figure 2 : Main loading event

2.2.1 Energy method

We will modelize the cord as a spring in an oscillator and deduce the maximal force that will be produced on the rocket. By assuming an instantaneous stop of the parachute and conserving mechanical energy:

$$\frac{1}{2}\,m_b(V_o^2 - V_t^2) = \frac{1}{2}F_{max}\,\Delta l$$

$$\Delta l = l \cdot \epsilon = l\,\frac{F_{max}}{SE}$$

$$F_{max} = \sqrt{\frac{m_b(V_o^2 - V_t^2)SE}{L}} \approx\ 15.85kN$$

2.2.2 Drag force method

Here we will only consider the maximal drag force from the parachute if it could manage to open instantaneously. First of all the size of the chute is decided in order to achieve a touchdown velocity of approximately 5m/s. This personal choice will provide us reasonable chances to recover a rocket in decent conditions.

$$S_p\ = \frac{2m_b g}{\rho C_x V_t^2} \approx\ 5.8m^2$$

We can then estimate the maximal drag force that the parachute can create.

$$F = \frac{1}{2}\rho S_p C_x V_o^2 \approx\ 16.6kN$$

2.3 Lap joint design

Material	Modulus	Poisson ratio	Yield strength
Aluminum 6082	68 GPa	0.3	240 MPa
Epoxy	5 GPa	0.35	10 MPa

Considering a maximal traction force of 16kN we want to ensure that the mean shear stress in the joint doesn't exceed 5MPa. The security factor of 2 takes into account imperfections in the glueing process. We also consider the Poisson effect for the tubes being in traction. The radial deformation of the tube due to the traction is given by :

$$\epsilon_{rr} = -\frac{\nu\sigma_{zz}}{E_a} = -\frac{\nu\,F/A}{E_a} = \ -1.26 \cdot\ 10^{-4}$$

Using Tresca, maximal shear, criterion we can then calculate the effective stress into the glue as the sum on the shear and normal stresses due to traction and Poisson effect respectively.

$$\tau_{max}\ = \sqrt{\frac{\sigma_{rr}^2}{4} + \tau^2} \leq\ 5MPa$$

$$\tau = \sqrt{\tau_{max}^2 - \frac{\sigma_{rr}^2}{3}} = 4.99MPa$$

We can see that the limiting factor, as expected for a lap joint is only due to the shear forces. We can then calculate the length of glued part needed by assuming τ is constant inside the joint.

$$l = \frac{F}{\pi d \tau} = 8.5mm$$

Having a design with a length of 30mm at the moment, we ensure that even without taking into account the edges effects, the lap joint will not fail during traction.

2.4 Numerical results

Finally we evaluated the stresses in the material using the finite element method. The intention of the document is not to provide a full report on the analysis so only the method and results will briefly be explained.

The coupler was tested in traction with a force of 16kN. A small preloading was applied to the screws to ensure good alignment of the two parts and also prevent them from separating if a small traction during handling is applied. Implicit dynamic integration and simulation of contact forces was used to predict the deformation of the wedges and thus smaller contact regions during the shock. Once again, the forces applied are largely above what could happen during flight and therefore the results will show overestimated values.

The results shows some discontinuities at the screw's edges (see Figure 3), but generally stress values are below the yield stress in both materials (Figure 3 and Figure 4). And inserts made of steel might be added afterwards for the threads in the inner ring to prevent them from failing.

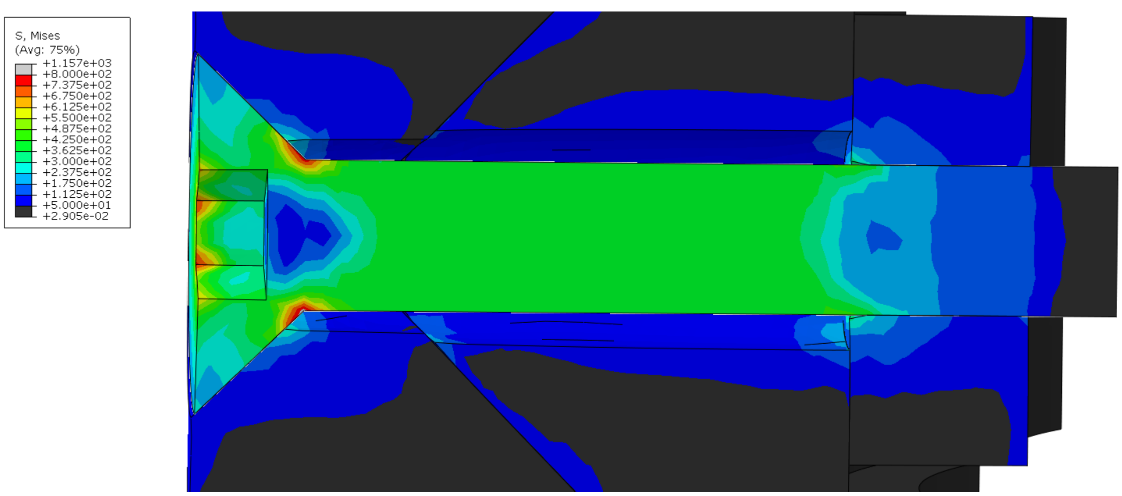


Figure 3 : Von Mises stress in the steel screw

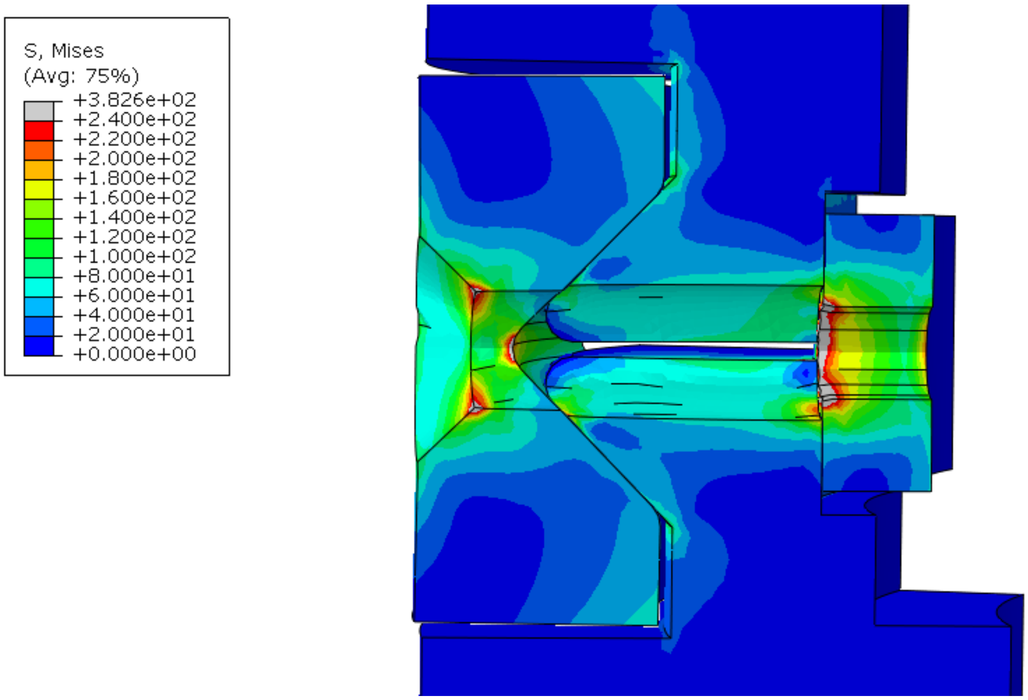


Figure 4 : Von Mises stress in aluminium parts

2.5 Preloading effect

When the parachute traction is applied, the wedge whants to move radialy outward and to open vertically. This effect increase the stresses in the inside of wedge where the stress is concentrated by the geometry, leading to values triggering plasticity of the parts as we can see in Figure 4.

By applying a preloading to the assembly, we can reduce the radial motion of the parts under traction and thus reduce this concentration effect. A sensivity analysis has been made with different preloading on the screw. The results show an interesting effect with the maximal stresses under traction going from the external wedges to the inner ring when increasing the preloading. They also clearly show that the maximal stress is reaching a minimal value inbetween the two configurations. Therefore we can improve the results presented in Figure 4 by applying a greater preloading as shown in Figure 5

Knowing the stress inside the screew after the preloading phase can help us determine the torque that need to be applied when assembling the couplers by calculating the traction force F. The optimal preloading is taken at 80 Mpa, as we have to take into account uncertainties on the friction factor as well as the torque applied. Two different formulas are known to calculate the thorque required to apply a desired preload to the assembly, both will be used and we will use the average value as our final torque to apply. The friction factor between aluminium and steel is taken to be $f_f = 0.2$

$$\sigma = 80\ MPa \Rightarrow \quad F = \sigma * S_{eq} = 700N$$

$$T = \left(0.16p + 0.583 f_f * d_2 + 0.5\ f_f * D_m\right) * F = \ 787\ Nmm = 0.79\ Nm$$

$$T = \left(\frac{d_2}{2}\tan(\delta' + \alpha_2) + D_m * \frac{f_f}{\cos(45)}\right) * F = \ 0.41\ Nm$$

$$0.41\ Nm \leq T \leq 0.79\ Nm \ \rightarrow T_{used} = 0.6\ Nm$$

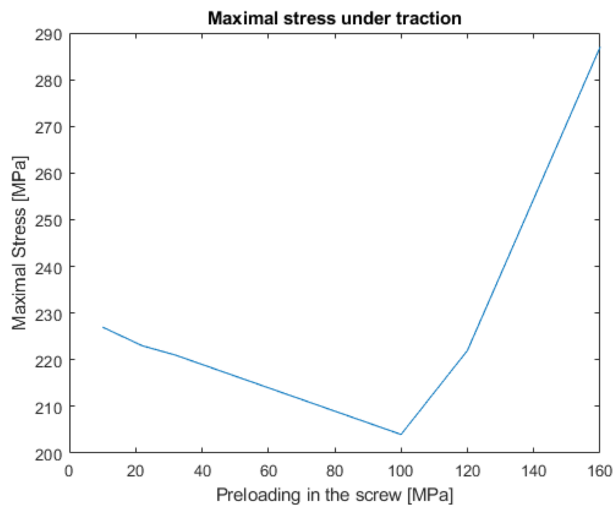


Figure 5 : Maximal stress in the aluminium parts under traction

3 ADDITIONAL LOAD CASES

In this section, better approximation on the load cases are used and therefore the traction force at the parachute opening has been divided by 4 using more precise models. We solved the second order differential equations of motion to determine precisely the acceleration that the drag force will create on the rocket and found a value of 8.5G's for the dereefing phase. A conservative result of 20G will nonetheless be used to directly add a security factor greater than 2 for this critical part of the flight. This value is twice the one experienced at takeoff and gives a traction force of 4kN in the shock cord. This is four time less than the previous assumption, but it takes into account the elongation of the shock cord, the time needed for the parachute to inflate during which the drag will gradually increase. For the thrust plate the worst case is applied. That means that we considered the higher maximal thrust available in aerotech 75mm motors and did the simulation with this value even if it doesn't reflect the actual motor we will be using at the competition.

3.1 Parachute fixation

The parachute shock cord is attached to two eybold located on top of the recovery plate. The load is then transmited to the coupling system throught two 8mm rods threaded at both end. This section will present the results of numerical analysis on the fixation plate inside the coupling systems.

The load case considered is the dereefing of the main parachute witch is likely to induce a 20G's acceleration to the bottom part of the rocket. Given an empty mass of less than 20kg, the actual force created by the shock cord on the eybolt is around 4000N. To prevent any failure possibilities, it is considered that all the load is transferred through only one of the two rods. This accout for a shorter link on one side that will concentrate the load into one metal rod if the shock cord is not folded properly and even any failure that may arise.

The numerical analysis results presented in Figure 6 shows some discontinuities in all the sharp angles. But is is due to the numerical instabilities that such angles creates and therefore those high concentrated value don't have any physical meaning. A threshold was intentionnaly fixed at 240MPa which is the lowest yield strength for the aluminimum 6082-T6 we are using.

A quick look shows that a 1.5 security factor remains even when all the load is concentrated into one fixation. The real flight condition thus are likely to present a 2.5-3 security factor.

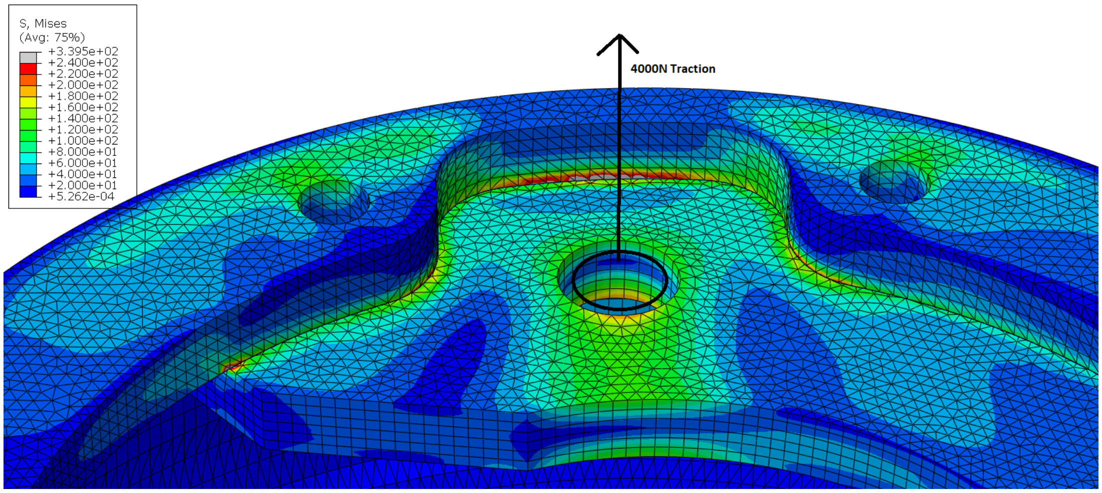


Figure 6 : Von Mises Stress due to parachute traction

3.2 Thrust plate

The thrust plate analysis was made using the most powerful motor in the 75mm range, and a detailed report on the simulation can be found in the following document:

- 2018_ST_TN_0002_THRUST_PLATE_ANALYSIS_R01

4 CONCLUSION

The structural integrity of the coupling system as well as its adherence to the air-frame under extreme loads has been demonstrated. The two techniques used to evaluate the maximal traction force are based on two different approaches that greatly overestimate the real conditions. The relatively high values used for the analysis comfort us in the idea that the drogue parachute should keep the descending speed of the rocket under 30m/s, which will drastically decrease the resulting forces.
Considering adaptations that have been made on the hypothesis, such as rocket mass reduction (-10kg on the system) and the drogue velocity (25m/s) as weel as a better simulation of the forces acting at the parachute opening, the resulting force has already been lowered by a factor 4. Therefore final simulations showed a greater margin that the results presented in this report. Furtermore, this report has also shown that the coupling system can also withstand the additional loads and therefore will serve as a reliable attachment point for all the internal subsystems.

TECHNICAL NOTES

Title:	**Nose Cone Rationals**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0007_NOSE_CONE_RATIONALES2_R01	
Prepared by:	César Toussaint	
Checked by:	Emilien Mingard	
Approved by:	Maxime Eckstein	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The rocket's nose cone is major part of the aerostructure that predetermines strongly the flight but does not sustain much stress compared to the lower assembly. The determinant aspects of the nose cone are it's shape, materials and their judicious choice to meet our needs. Our design has a modulable design adaptable to different mission goals, and all of it will be presented in the current technical document.

2 CONCEPT EXPLANATION

2.1 Nose Cone

The nose cone is made out of composite materials. The high strengh and the low weight of fibreglass are significant advantages that confirm our choice. Moreover, we chose glass fibers with an epoxy matrix since carbon-based composites do not allow radio wave to pass through, and our telemetry antenas are situated in the nose cone.

The fiberglass we chose is an Atlas type wich allows a wide range of curvature and are provided with a finish agent wich improves matrix adhesion. The laminate is based on existing products. The epoxy matrix we chose is the Epoxy resin L+EPH161 wich can be manipulated for 90 minutes before

Figure 1- Epoxy Resin L+EPH161

Figure 2- Atlas Glass Fiber, 300g/m²

reaction and can sustain a temperature up to 120°C wich is 40° over the upper bound we considered for the New-Mexico desert.

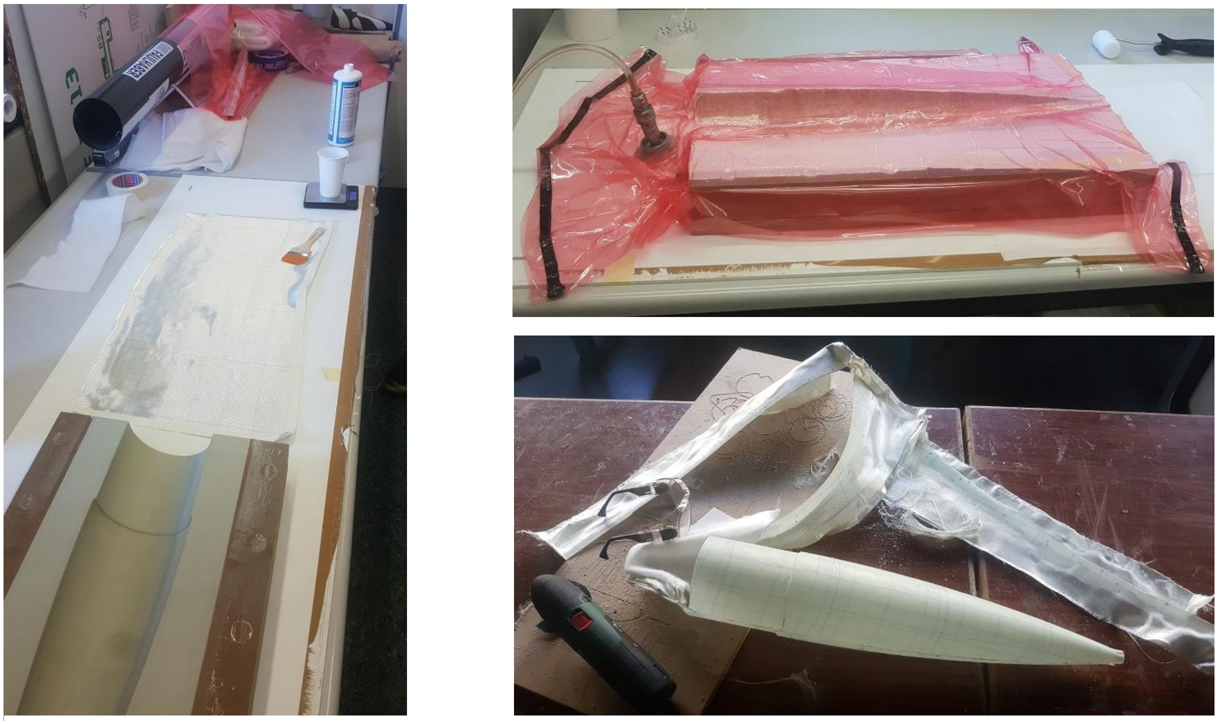


Figure 3 Production of the Nose cone halves

2.2 Tip Insert

For the nose cone tip, we chose to have a modulable insert system, wich simplifies our work and allows us to change the tip depending on the mission goal or in case of damage.

After the two halfs of the nose cone are joined and cured, the tip in truncated so we never have to bother about drapping the fiber in a tight space. We then glue an aluminium insert with a threaded hole. Therefore, we can then screw a solid plastic tip or a hollowed one with a pito tube for avionic mesurements.

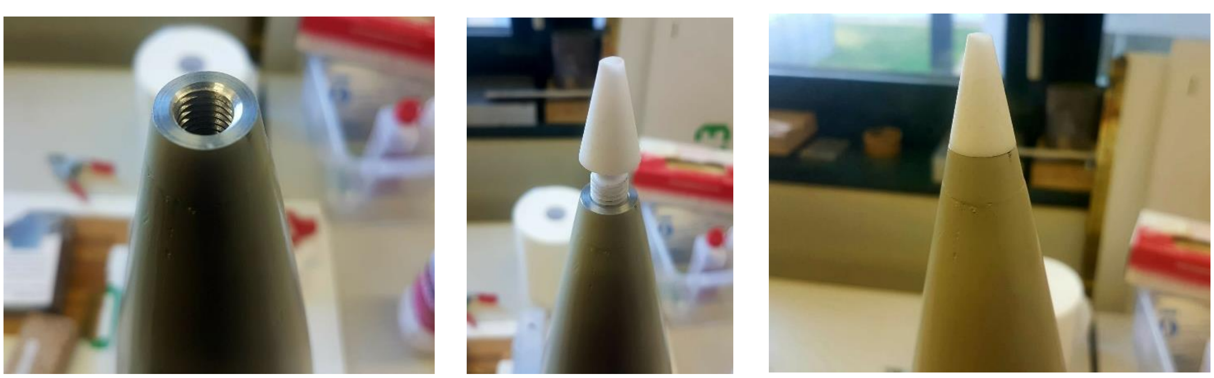


Figure 4 Tip Insert Assembly

3 CONCLUSION

As of now, beginning of april 2018, we have produced a functioning prototype of the nose cone and are about to finish the production of a second one for testing purposes.

TEST PROCEDURES

Title:	**Epoxy Resin & Glue heating test**	Test Completed (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TP_0005_STRUCTURE_HEATING_R01	
Prepared by:	Emilien Mingard	
Checked by:	César Toussaint	
Approved by:	César Toussaint	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

As the competition of interest is in a desert, the environnemental conditions may not be as in Switzerland. The temperature and the sun radiation are going to be high, near critical value when few calculations are made (Natural Convection, Radiation, Sun, Ambiant temperature). The test should prove that temperature isn't higher than all various epoxies limits.

2 NORMATIVE AND REFERENCE DOCUMENTS

Table 2-1 Normative Documents

Ref	Description	Doc. Number	Issue
[ND01]	Verification (17 November 1998).pdf	ECSS-E-10-02A	

Table 2-2 Reference Documents

Ref	Description	Doc. Number	Issue
[RD01]	Acceptance REDV test procedure.pdf	S3-D-SET-1-2	1.0

3 DEFINITIONS AND ABBREVIATIONS

ER	Epoxy Resin
EG	Epoxy glue
T	Temperature

4 VERIFICATION PROCESS

4.1 Verification objectives

Few thermosensitive patchs will be placed in the structure. The coupling system, the carbon tube, the fins module, the fins and the nose cone are considered as important locations as they all contain ER or EG. The test should prove that any increasing of temperature may not be critical. A location is critical when T reach the theoretical limit. Those limits are given in 4.7.

4.2 Verifcation method

One must check the position of each thermosensitive patch.

4.3 Test procedures

The rocket must be sat horizontaly in an open space. This is the worst case that can arise in the desert.

4.4 Test conditions

Only environnemental conditions are in our interest:

- No wind.
- Clear blue sky to reduce sun radiation absorbtion.
- Sun at vertical angle (10 a.m to 3 p.m) maximize heat transfer through atmosphere.

The test should be as long as possible, as sun reduce in intensity from 3 p.m, the test can be performed for 4 hours.

The test was performed on the 18th of april 2018, Outside temperature of 23°C without wind. The test took place on the EPFL Roof.

4.5 Test set-up and equipment

The thermosensitive patch are presented in appendix, it records only the highest T achieved, even if T cool down afterwards. The chosen one are the TERMAX LEVEL 8 A and TERMAX LEVEL 8 B. The temperature range (37 -> 110°C) is large enough to test surface heating. It has been estimatied to 60°C in the desert of New-Mexico. All EG and ER were designed for an absolut T of 80°C.

4.6 Step-by-step testing procedure

1. Environment preparation
   1.1. Check if all conditions are okey
2. Sensors installations
   2.1. Apply all the patchs, Figure 1 shows all the locations where sensors must be placed. The sensors must be apply inside if enough place allows it.

Figure 1 Patch Positions Chart

3. Setup positioning
   3.1. Lie down the rocket on 2 supports, the patch must be on the top of the rocket, where radiation come normally to the surface.

4. Measuring phase
   4.1. Unpatch the sensors, read the value and save data.

4.7 Pass-fail criteria

If a patch has higher T than allowed, the test fails. The following table gives us the critical value per location:

Location	T limit [°C]	Epoxy type
Fins	180	RUAG Suppliers, Autoclave
Fins Module	120	RUAG Suppliers, Autoclave
Coupling system	80	R&G 90min, Oven
Central Upper Airframe	80	R&G 90min, Oven
Nose Cone	120	L+EPH161, Oven

5 TESTS RESULTS

CRITERIA	PASS / FAIL
Fins 60°C	PASS
Fins Module 60°C	PASS
Coupling System 44°C	PASS
Central Upper Airframe 50°C	PASS
Nose Cone 36°C	PASS

6 CONCLUSION

The temperature never reach critical value for any parts of the rocket. The outside surface heats up close to 60°C, which can be dangerous as the desert in New-Mexico will be hotter.

7 APPENDIX

TMCHallcrest

Surface Temperature Monitoring System

THERMAX®

Irreversible Temperature Sensitive Products

IRREVERSIBLE LABELS

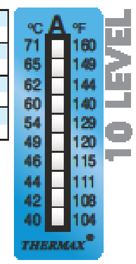
A fast, simple temperature monitoring system based on Proprietary colour change technology

- Inexpensive and Easy to Use
- Immediate Response
- Permanent Record of Highest Temperature
- Oil, Water and Steam Resistant
- Accuracy Tolerances
  29°C to 99°C is +/-1°C
  100 to 154°C is +/-1.5°C
  160°C to 290°C +/- (1%+1°C)
- Temperature range 29-290°C
- Labels or Strips
- Silver to Black Colour Change
- Last Black Event is the highest temperature achieved

THERMAX 10 LEVEL STRIPS

A	°C	40	42	44	46	49	54	60	62	65	71
	°F	104	108	111	115	120	129	140	144	149	160
B	°C	77	82	88	93	99	104	110	116	121	127
	°F	171	180	190	199	210	219	230	241	250	261
C	°C	132	138	143	149	154	160	166	171	177	182
	°F	270	280	289	300	309	320	331	340	351	360
D	°C	188	193	199	204	210	216	224	232	241	249
	°F	370	379	390	399	410	421	435	450	466	480

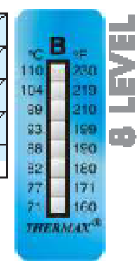
Specifications:
Size: 51 x 18mm (2.00" x 0.7")
Type: Vertical, Self adhesive.
Scale: °C and °F
Range: (Sold in units of 10)



THERMAX 8 LEVEL STRIPS

A	°C	37	40	43	46	49	54	60	65	
	°F	99	104	109	115	120	129	140	149	
B	°C	71	77	82	88	93	99	104	110	
	°F	160	171	180	190	199	210	219	230	
C	°C	116	121	127	132	138	143	149	154	
	°F	241	250	261	270	280	289	300	309	
D	°C	160	166	171	177	182	188	193	199	
	°F	320	331	340	351	360	370	379	390	
E	°C	204	210	216	224	232	241	249	254	260
	°F	399	410	421	435	450	466	480	489	500

Specifications:
Size: 51 x 18mm (2.00" x 0.7")
Type: Vertical, Self adhesive.
Scale: °C and °F
Range: (Sold in units of 10)



THERMAX 6 LEVEL MINI STRIPS

1	°C	29	33	34	37	40	42
	°F	84	91	93	99	104	108
2	°C	44	46	49	54	60	62
	°F	111	115	120	129	140	144
3	°C	65	71	77	82	88	93
	°F	149	160	171	180	190	199
4	°C	99	104	110	116	121	127
	°F	210	219	230	241	250	261
5	°C	132	138	143	149	154	160
	°F	270	280	289	300	309	320
6	°C	166	171	177	182	188	193
	°F	331	340	351	360	370	379
7	°C	199	204	210	216	224	232
	°F	390	399	410	421	435	450
8	°C	241	249	254	260	280	290
	°F	466	480	489	500	536	554

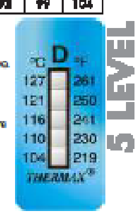
Specifications:
Size: 12 x 32mm (0.47" x 1.26")
Type: Horizontal, Self adhesive.
Scale: °C and °F
Range: (Sold in units of 10)

THERMAX 5 LEVEL STRIPS

A	°C	37	40	*43	*46	*49
	°F	99	104	109	115	120
B	°C	49	54	60	65	71
	°F	120	129	140	149	160
C	°C	77	82	88	93	99
	°F	171	180	190	199	210
D	°C	104	110	116	121	127
	°F	219	230	241	250	261
E	°C	132	138	143	149	154
	°F	270	280	289	300	309
F	°C	160	166	171	177	182
	°F	320	331	340	351	360
G	°C	188	193	199	204	210
	°F	370	379	390	399	410
H	°C	216	224	232	241	249
	°F	421	435	450	466	480
I	°C	249	254	260	280	290
	°F	480	489	500	536	554
S	°C	29	33	34	37	40
	°F	84	91	93	99	104

Specifications:
Size: 39 x 18mm (1.53" x 0.7")
Type: Vertical, Self adhesive.
Scale: °C and °F
Range: (Sold in units of 10)

(*Please note that the temps on the 5A may be subject to change due to ongoing development)



Thermax irreversible temperature strips and indicators provide a permanent record that an item has exceeded its rated temperature and can be used in most applications where temperature is a concern.

TEST PROCEDURES

Title:	**Nose cone manufacturing and mold test**	Test Completed (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TP_0006_NOSE_CONE_MOLD_R01	
Prepared by:	César Toussaint	
Checked by:	Emilien Mingard	
Approved by:	Emilien Mingard	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The nose cone is an important part of the rocket, and although it does not sustain a lot of constraints, it must be sturdy enough to whistand the landing.
In this document, we will be discussing the first production of a nose cone and the mold.

2 DEFINITIONS AND ABBREVIATIONS

ND	Normative Document
RD	Reference Document
MDF	Medium Density Fibreboard

3 VERIFICATION PROCESS

3.1 Verification objectives

The objectives of the test are:
- Quality of the surface obtained on the nose cone
- Precision of the dimensions of the nose cone
- Feasibility of the mold
- Easiness of mold removal
- Price of prouction

3.2 Verifcation method

Respectively:
- Comparison with commercialy bough nose cones
- Fitting the nose cone in a rocket and comparing with the orginal nose cone
- Time of production
- Removal without damage and/or excessive constraints
- Comparison with commercialy bough nose cones

3.3 Test procedures

The mold is made under normal production procedure, but scaled down approximately by half.

We then apply epoxy resin on the mold and fiberglass.

Finally, we demold the two halfs and assemble them with more resin and fiberglass.

3.4 Test conditions

The tests were made under simplified conditions: the vacuum pump was not used to press the fibers and the resin; we used sand in a fabric bag to have uniform pressure.

The resin was modified with 220 microns carbon powder for additional strength.

3.5 Test set-up and equipment

No peculiar set-up was needed since the point of the test is to build the mold for the nose cone and then build a nose in it.

3.6 Step-by-step testing procedure

1. Mold manufacturing
   1.1. CNC machining of the two 22mm thick MDF boards to make half a mold (so 4 MDF boards for this nose cone)
   1.2. Assembly of the two boards with M5 threaded rods, nuts and washers.
   1.3. Varnishing the molds (9 layers)
   1.4. Waxing the mold with 3 layers of Mold Release

2. Fiberglass application
   2.1. Application of our carbon modified epoxy resin on the mold using a paint roller
   2.2. Application of the fiberglass
   2.3. Second layer of epoxy resin to drape the fibreglass in the mold
   2.4. Second layer of fiberglass
   2.5. Third layer of epoxy resin
   2.6. Application of cellophane on all of the surface
   2.7. Uniform pressure application using a fabric bag full of sand and three 2kg aluminium weights
   2.8. 24h cure time

3. Demolding
   3.1. Removal of the weights, sand bag and cellophane.
   3.2. Demolding the half-cones with medium consistent force
   3.3. Cutting the excess fiberglass with a Dremel tool

4. Nose cone assembly
   4.1. Smoothing of the edges
   4.2. Provisional assembly of the nose cone using duct tape on the exterior surface
   4.3. Application of epoxy resin and a fiberglass strip on the inside of the nose cone
   4.4. 24h cure time
   4.5. Removal of the duct tape and smoothing of the whole surface

5. Metal Point assembly
   5.1.

3.7 Pass-fail criteria

Respectively:
- The surface is excessively rough, has holes or fibers coming trough
- The nose cone does not fit
- The mold is not feasible
- The nose cone or the mold breaks or is fragilized
- The price of production exceeds by far the price of a commercially bought nose cone

4 TESTS RESULTS

CRITERIA	PASS / FAIL
Surface	Pass
Nose cone fits	Pass
Mold feasible	Pass
Nose cose doesn't break	Pass
Price lower than market	Pass

5 CONCLUSION

The small scale test is a full success. Following these results, manufacturing of final mold has been started. If 2 nose cone are produced with every stuff bought, then the price would be excessively lower than market. The main advantaged of this method is the dimensions personalization.

TECHNICAL NOTES

Title:	**Technical notes on Boat Tail**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0003_BOAT_TAIL_R01	
Prepared by:	César Toussaint (ST)	
Checked by:	Emilien Mingard	
Approved by:	Maxime Eckstein	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The boat tail is an important part of the rocket's aerodynamic design and structural design. It has two major functions: closing the airflow behind the rocket and absorbing a maximum of damage during landing to spare the fins and motor. It's shape was determined based on flight simumlations.

2 CONCEPT EXPLANATION

2.1 BOAT TAIL

The part will be made out of 1mm thick folded and welded aluminium sheet. Alumium's relatively low weight with good stenght and ability to deform plastically under constraints confirms our choice. Steel is to heavy and bittle, plastics ans composite would melt under the high heat of the motor's burn. We chose welding because it is much cheaper than machining a whole cylinder of aluminium and the boat tail is considered as a consumable.

The dimensions were set using OpenRocket, a flight simulation software, based on an altitude sensitive analysis. We ended up with a truncated cone of 122,68mm in diameter and a tip angle of 23,43° truncated at a height of 49mm.

Figure 1 Folding Process For The Aluminum Sheets

Figure 2 Final Product and Test-fitting On Our Carbon Tubes

2.2 FIXATION INSERTS

With the dimensions of the Boat Tail, we can acces the whole with an Allen key to assemble it. The Boat tail is held in place with 3 M3 screws and 3 inserts in the fins module. They are made out of PMMA since it has a good resistance to heat for a polymer and is lightweight.

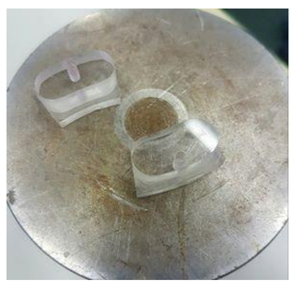


Figure 3 PMMA Inserts

3 CONCLUSION

As of today, march 2018, we have our final Boat Tail and some prototype PMMA inserts that might be replaced by circular aluminium ones.

TECHNICAL NOTES

Title:	**Carbon Airframe Analysis**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0011_CARBON_AIRFRAME_R01	
Prepared by:	Emilien Mingard	
Checked by:	Maxime Eckstein	
Approved by:	Maxime Eckstein	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

This documents talks about the simulations regarding the carbon airframe. Compression, traction and buckling are considered.

2 NORMATIVE AND REFERENCE DOCUMENTS

Table 2-2 Reference Documents

Ref	Description	Doc. Number	Issue
[RD01]	2018_ST_PS_0009_EHKF_PREPREG_R01	0009	1.0
[RD02]	2018_ST_PP_0004_TUBE_MANUFACTURING_PROCEDURE_R01	0011	1.0
[RD03]	2018_ST_PS_0012_Prepreg_C2947009_KSP_001_05_R01	0012	1.0

3 DEFINITIONS AND ABBREVIATIONS

ID	Inside diameter
OD	Outside diameter
LA	Lower Airframe BOM: 11501
UA	Upper Airframe BOM: 11601
UC	Upper Coupler BOM: 11301
LC	Lower Coupler BOM: 11301

4 CONCEPT EXPLANATION

4.1 Airframe Manufacturing

The both carbon tubes were manufactured in RUAG Space, using professional infrastructures such as autoclave, diamond saw, vacuum pomp etc… [RD02] and space graded carbon/epoxy prepreg [RD01]. Two similar rockets were produced and no major differences were observed.

4.2 Load Cases

4.2.1 Lower Airframe

As the lower airframe is at the back of the rocket and located behind the thrust plates, the frame is under traction at any moment of the flight. This is true for initial acceleration and both parachute inflation events.

All the load carried by the LA comes from the lower coupler (Connected to the fins module BOM: 11400), it should pull the fins module and its own mass. The initial acceleration has a maximum at 10g. Chute inflation also has deceleration of about 10g. One simulation will be performed for both load cases.

When chute opens, the burned motor is also maintain by the lower airframe. The parachute attach is located on the UC. Then the total mass suspended is:

$$m_{tot} = m_{finsmodule} + m_{motorcasing} + m_{LA} = 5\ kg$$

It is considered as the worst case. The total force becomes approximately: $F = ma = 500\ N$. It is transmitted to the LA through the LC, which is glued inside the tube. We consider a shear stress, applied over the glue contact area, of about:$\tau = \frac{F}{Area} = 0.088\ [MPa]$. The contact surface is given by th ID multiplied by the coupler length (h = 30mm): $Area = \pi IDh$. Figure 1 illustrated the lower airframe body of the rocket, The UC and the LC are indicated. Everything below the LC are parts of the fins module. The thrust plate is linked to the UC such that it pull everything at initial acceleration and at chute inflation.

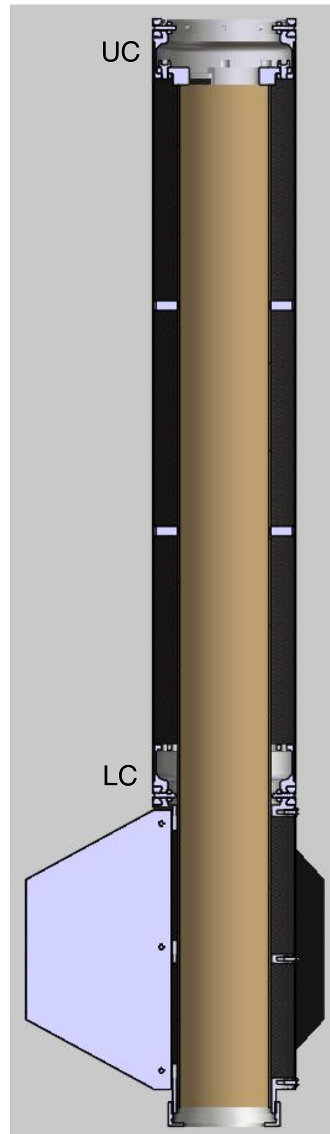


Figure 1 Lower Airframe cut view

4.2.2 Upper Airframe

The upper airframe has a different purpose. It contains all subsystems such as the payload, the avionics and the recovery. The load path is such that only payload and nose cone avionics are carried by the UA. Figure 2 presents the UA configuration. It sits on the UC and hold the nose cone. On the top of UA is glued a protective ring which prevent from delamination. The load from the nose cone is transmitted through the protective ring.

We supposed that all the mass carried is sitted on top of the tube such that is is the worst case.The total mass is:

$$m_{tot} = m_{nosecone} + m_{upperavionic} + m_{ring} + m_{payload} = 6.5\ kg$$

Again, an acceleration of 10g for both cases induces a force of about: $F = 650\ N$. As the UA works in compression, we must consider the buckling effect.

4.3 Analytical Solution

An stress estimation isn't difficult to provide in the case of tension/compression. We can show that rough results can bw provided:

$$\sigma = \frac{F_{transmit}}{Area_{cross}}$$

The transmitted force is either 500N for the LA or 650N for the UA. The cross area is given by:

$$Area_{cross} = \frac{(OD-ID)\pi ID}{2}$$

In this case, the stress are roughly estimated to:

$$\sigma_{LA} = 1.1\ MPa$$

$$\sigma_{UA} = 1.43\ MPa$$

We see the results to be very small. A quick FEM simulation with full material properties confirmed those value. Thus it makes no sens to perform complete FEM simulations on compression, traction. The both frames sustain their relative load. When we look to the strength of the material [RD03], the ultimate strength is given to 500 MPa. The security factor is way to big for both airframes.

Figure 2 Upper Airframe cut view

4.4 Finite Element Simulations

ABAQUS is used to performed a buckling analysis. We only simulate the UA as it is the only one to work in compression. We suppose no internal ring and the load to be applied on the protective ring (Top of UA). The mass is again 6.5 kg which is transformed into a shear stress applied by the protective ring. The contact glued surface is given by:

$$Area = ID\pi h$$

Where h = 10mm (Protective Ring height, BOM: 11602). The shear stress applied is: $\tau = 0.171\ MPa$. We wish to check the security factor to the buckling failure.

We performed a convergence analysis to ensure reliable result. Tableau 1 lists the outcome of the analysis. The value is in fact the security factor. It is the amount the applied force need to be multiplied by to reach the first mode of buckling failure. For any element size, the value stay around 38. The deviation is small and an error of few percents is true for these results.

Anyway, the UA seems to sustain buckling failure by a security factor of at least 37.

Tableau 1 Convergence Analysis

Element Size	# Node	Value
20	1102	37.910
10	4332	37.599
5	17252	39.328
3	47502	39.860

5 CONCLUSION

In conclusion, the design was made such that the frame is overestimated. The manufacturing occurs really early in the process of design. Simulations were performed afterward to prove the design. The carbon used is of high quality and resin is cured in autoclave to provide high quality results. As analysis and simulations prove it, the integrity of the rocket is confirmed at burn time and chute inflation, considered as the two worst events.

TECHNICAL NOTES

Title:	**Thrust plate under initial acceleration**	Procedure Applied (Date) :
Project:	IREC SA CUP 2018 Team Lausanne – MATTERHORN	
Filename:	2018_ST_TN_0012_THRUST_PLATE_ANALYSIS_R01	
Prepared by:	Emilien Mingard	
Checked by:	Maxime Eckstein	
Approved by:	Maxime Eckstein	Responsible signature

TABLE OF CONTENTS

1 INTRODUCTION

The thrust provided by the motor need to be transmit to the main aiframe. In our design, the total force generated by the motor is transmit to upper and lower aiframes through the coupling system. In order to have contact between the motor casing and the coupler, an added part is needed. This part is critical in a way that if it breaks, then motor casing can slide in the tube through the coupling mechanism and eventually destroy all sub-system placed in the upper aiframe.
We use Finite Element Method to estimate the failure of such a part, designed to fit in a given coupling mechanism (Geometry is under given constraint).

2 DEFINITIONS AND ABBREVIATIONS

MD	Motor diameter
FCD	Free coupler diameter
NT	Nominal Thrust

3 CONCEPT EXPLANATION

3.1 Motor Assumptions

In rocketery motor, the grain is is placed within an aluminium tube called a Motor Casing. It is used to sustain high load occurring during burn and ensure the motor system integrity. Figure 1 illustrates our used motor casing. The main assumption is that the whole load is carried by the motor casing and transmit by the forward enclosure. The motor push the rocket using a so called "Obstacle Shoulder", the obstacle is in fact the thrust plate presented in section 3.2.

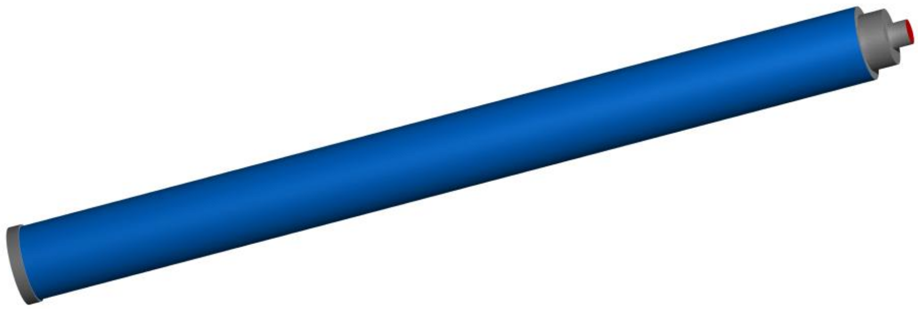


Figure 1 AeroTech RMS 75/6860 Motor Casing

3.2 Part presentation

To sustain the load and ensure connection between the motor casing and the coupling mechanism, an added part is needed because the MD < FCD. Figure 2 represents half of the thrust plate. It is cut in two pieces because it needs to by slided in the coupler.

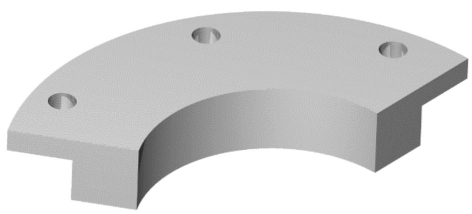


Figure 2 Thrust Plate

The whole system (Motor Casing, Thrust Plate & Coupler) is presented in Figure 3. As we can see, the casing pushes the thrust plate which is hold in place relative the the coupler using screws. As the coupler is glued to both aiframe, thrust at burn time is provided to the whole rocket.

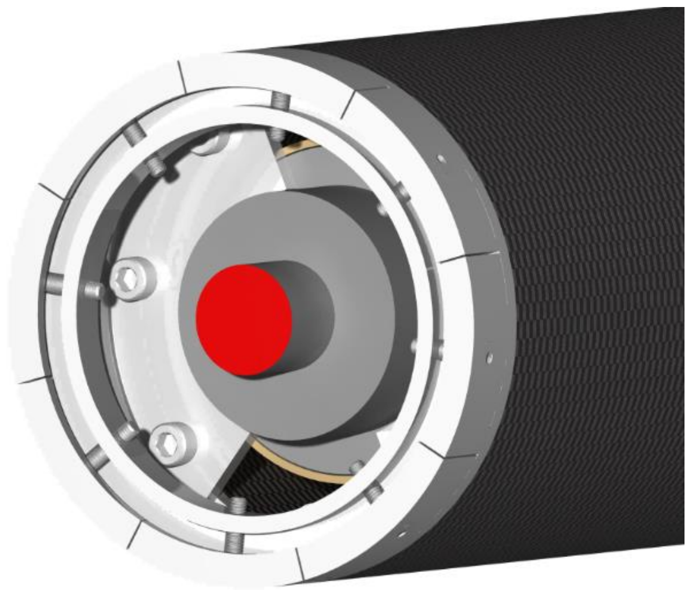


Figure 3 Thrust Plate in action

The part is made out of aluminium 6082 T6. It is 5 mm thick and is holded in place using 6 M6x14 12.9 quality screw.

3.3 Load Case

The load case is in fact not that difficult. The maximum thrust is provided as a data linked to the motor. As it is ensure to have an error lower than 20%, The maximal force applied is therefore 1.2*NT. As the mass of the rocket isn't perfectly define, we don't know what motor is used. Let's assume to use the worst case of all motor available in 75 mm catergory. So, NT = 4489 N corresponding to motor Aerotech M1850W.

3.4 FEM Assumptions

As FEM isn't perfect, we will discuss each discountinuity and its effects on the results. Each screw will be defined as radial and z blocking constraint. The motor will push on a ring of diameter MD.

We assume small displacements and linear elasticity behaviour. Thus, the material properties are:

- Poisson Ratio 0.34 [-]
- Young Modulus 69000 [N/mm^2]
- Yield Strenght 240-350 [N/mm^2]

The load cases is then 1.2*NT = 5386.8 N separated in two because of the two thrust plates. We have then 2693.4 N applied as a pressure on a surface of 491.14 mm^2. Thus the pressure to apply is P = **5.48 MPa**.

3.5 Results

The FEM isn't precise as already told in this report. To counterfact it, we can proceed to a convergence analysis. It means that different meshs are tried, the results are plotted and the convergence of the results is observed. When singularity occurs, the stress is observed at integration points, which may smooth the value. Figure 4 and Figure 5 presented the results when right mesh is used (Small for convergence and big enough to avoid singularities). The mesh size is 3 [mm] and the element type are C3D20R and C3D15. Singularities can be observed around the screws.

3.6 Discussion

In overall, when the worst motor is used, even with 20% more thrust, the thrust plate sustain such a load. The maximum value shows a stress of 150 [MPa], when we look at integration points, the maximum is 126 [MPa]. If we reduce the element size, this stress increases. In reality phenomena such as plasticity would releases some stress in case of very high local stress.

Still the order of magnitude is lower than 240 [MPa], so that no failure is possible for the parts.

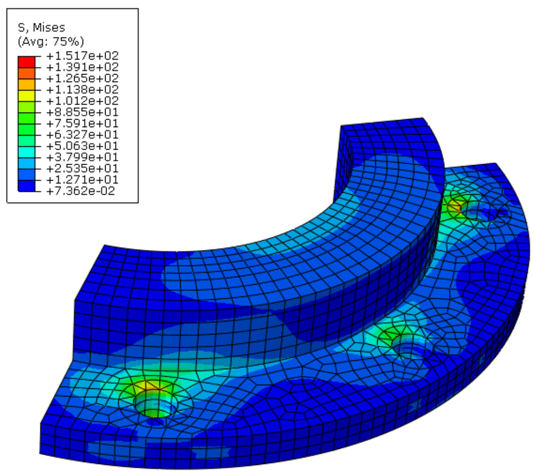


Figure 4 Thrust Plate back view

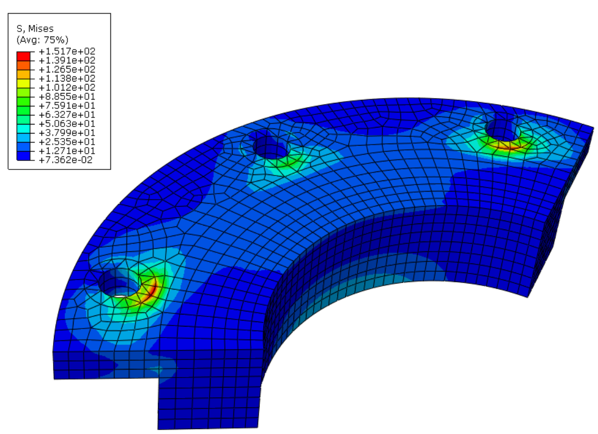


Figure 5 Thrust Plate upper view

4 CONCLUSION

4. System Engineering

The complete project specifications and BOM are presented in the following documents:

- `2018_SE_MS_0001_SPECIFICATIONS_R04`
- `2018_SE_MS_10000_BOM_SUMMARY_R04`

SPECIFICATIONS

Title: General specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been done and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
GE-FP01	Reach the apogee	Altitude	3048 m	+/-600	IREC	Simulations and flight test	The flexibility is chosen by SE in order to score points		■
GE-FP02	Remain stable during flight without ACS implemented	Stability	stable	0	IREC	Simulations and flight test	Need not be stable without the required payload mass on-board		■
GE-FP03	Contains a payload	Mass	3.992 kg	0/-1	IREC	Mass budget and weighting of the prototype	The flexibility is chosen by SE		■
GE-FP04	Carry a payload to the target apogee	Altitude	3048 m	+/-600	IREC	ConOps and payload design	The flexibility is chosen by SE in order to score points		■
GE-FP05	Recover safely	number of deployment event	2	0/+2	IREC	Recovery design review	The flexibility is chosen by SE, recovered bodies whose apogee is not anticipated to exceed 457 m AGL are exempted, and may feature only a single/main deployment event. Riefing could be seen as a dual deployment event		■
GE-FP06	Recover independently of any active or passive payload function	dependencies to payload	0	0	IREC	Design of the recovery system	-		■
GE-FC01	Weight optimization	Mass	23.6 kg	maximum	SE	Mass budget at system and subsystem level and prototype weighting	Mass budget of the subsystems are made by each concerned subsystem		■
GE-FC02	Size optimization	Length	3000 mm	-700/+200	SE	Volume budget at system and subsystem level and prototype measuring	Volume budget of the subsystems are made by each concerned subsystem		■
GE-FC03	Size optimization	Inner diameter	120 mm	0	SE	Control of the design of each subsystem, considering their attachement in the airframe	-		■
GE-FC04	Costs constraints	CHF	25'000	-5'000 to +5'000	TR	Money budget	This number is more an indication of the total cost of the rocket. Each subsystem will have to deal with it's own money budget.		■
GE-FC05	Choice of recovery method	Conventional	Parachutes	yes	SE	Recovery design review	Teams exploring non-parachute or parafoil based recovery methods shall notify ESRA of their intentions at the earliest possible opportunity, and keep ESRA apprised of the situation as their work progresses.		■
GE-FC06	Access of all energetic device arming features	accessibility	externally accessible/ controllable	0	IREC	design review	This does not preclude the limited use of access panels which may be secured for flight while the vehicle is in the launch position		■
GE-FC07	Location of all energetic device arming features to ensure security of personnel arming them	Location	on airframe, for from armed device	0	IREC	design review	For example, the arming key switch for an energetic device used to deploy a hatch panel shall not be located at the same airframe clocking position as the hatch panel deployed by that charge		■
GE-FC08	Stability control to mitigate the small perturbations which affect the trajectory of a stable rocket which implements only fixed aerodynamic surfaces for stability	ACS	not implemted	yes	SE	Simulations and tests	LV active flight control systems shall be optionally implemented strictly for pitch and/or roll stability augmentation, or for aerodynamic "braking"		■
GE-FC09	Launch elevation	angle	84°	-1° to +1°	IREC	-	Competition officials reserve the right to require certain vehicles' launch elevation as low 70° if possible flight safety issues are identified during pre-launch activities. The launch azimuth is determined by competition officials		■

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
GE-FC10	Departure velocity to ensure the LV will follow a predictable flight path	min rail departure velocity	30.5 m/s	if stability proven	IREC	Simulations and tests	Alternatively, the team may prove stability is achieved at a lower rail departure velocity (a velocity greater than 15.24 m/s) either theoretically (eg computer simulation) or empirically (eg flight testing)		■
GE-FC11	Ascent stability	entire ascent of the LV	stable	0	IREC	Simulations	Stable is defined as maintaining a static margin of at least 1.5 to 2 body caliber regardless of CG movement due to depleting consumables and shifting CP location due to wave drag effects (which may become significant as low as 0.5 M). Falling below 1.5 BC will be considered a loss of stability.		■
GE-FC12	Stability	Avoid becoming over-stable	During the ascent	0	IREC	Simulations	A LV may be considered over-stable with a static margin significantly greater than 2 body calibers (eg. 6 BC). As long as the simulations prove the good functionning, the static margin can be over 2 body calibers.		■
GE-FC13	Launch support equipment portability	man-portable over a short distance	if possible	-	IREC	Estimation	-		■
GE-FC14	Fitting on the launch rails provided by IREC (5.5m in length)	fit	if possible	-	SE	Design review	Team provided launch rails shall implement the nominal launch elevation specified in Section 8.1 of the IREC specs document and, if adjustable, not permit launch at angles either greater than the nominal elevation or lower than 70°		■
GE-FC15	Assembly of the subsystems in the rocket	orientation	horizontality	yes	SE	Writing the assembling procedure	It'll permit to have an easier access to the different subsystem of the rocket		■
GE-FC16	Internal disposition of the subsystems	order of SS	most fragile part in the top	yes	SE	Internal drawing of the rocket	This requirement shall not lead to a non-sens in the dispostion of the elements		■
GE-FC17	Abillity to sustend accelerations	g	18.5	minimum	SE	simulations and flight test	The given value has been estimated by simulations		■
GE-FC18	Launch preparation	time	1 hour	-1 to +1	SE	Rewiew of the launch preparation process and practicing	The time of this process can be efficiently decreased if a checklist is properly done		■
GE-FC19	Shipping preparation	time	2 hours	-1 to +1	SE	Rewiew of the shipping preparation process and practicing	The time of this process can be efficiently decreased if a checklist is properly done		■
GE-FC20	Thermal resistance	temperature range	-20 to +80°C	-	SE	Prototype building	The dilatation at the interfaces has to be taken in account, electronic components must be chosen adequatly as well as the selected glues for the structure.		■
GE-FC21	Sand and dust resistant	Seals at interfaces	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functionning of any mechanism		■

SPECIFICATIONS

Title: Structure specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
ST-FP01	Ensure ascent stability	entire ascent of the LV	stable	0	IREC	Simulations and wind tunnels for aerodynamic tests	Stable is defined as maintaining a static margin no less than 1 body caliber regardless of CG movement due to depleting consumables and shifting CP location due to wave drag effects (which may become significant as low as 0.5 M). The wind tunnel could be the same as 2017.		■
ST-FP02	Ensure stability	Avoid becoming over-stable	During the ascent	0	IREC	Simulations	A LV may be considered over-stable with a static margin significantly greater than 2 body calibers. (As long as the simulations prove the good functionning, the static margin can be over 2 body calibers)		■
ST-FP03	Ensure accessibility to the inside	time to open/close	5 minutes	-4 to +1	SE	Writing assembling/disassembling procedure	-		■
ST-FP04	Holding subsystems	adapted casing	Prevent free movements of SS	-	SE	Prototype building	-		■
ST-FC01	Weight optimization	Mass	7 kg	maximum	SE	Mass budget and weighting of the prototype	It's the total mass (all subparts and inner structure included)		■
ST-FC02	Size optimization	Inner diameter	120 mm	0	SE	Volume budget and weighting of the prototype	This is fixed in order to reuse the already existing "mandrin"		■
ST-FC03	Size optimization	Length	3000 mm	-700 to +200	SE	Volume budget and prototype measuring	This value is flexible for now but will be defined more precisely in october		■
ST-FC04	Costs constraints	CHF	15'000	-	TR	Money budget	-		■
ST-FC05	Prevent unintended internal pressure to develop during flight	adequate venting	implemented	0	IREC	Design according to ECSS standards: ECSS-E-20-01A(5May2003)	Typically, a 3.175 to 4.7625 mm hole is drilled in the booster section just behind the nosecone or payload shoulder area		■
ST-FC06	Whistanding the operating stresses and retain structural integrity	retain structural integrity	under conditions encountred during handling and flight	0	IREC	Simulations and flight test	Thermal and dynamical environement have to be considered.		■
ST-FC07	Materials used in load bearing structure	PVC, Public Missile Quantum Tube, Stainless steel	not allowed	0	IREC	Make an exhaustive BOM	-		■
ST-FC08	Use of load bearing eye-bolts	type	closed-eye forged or U-Bolts	0	IREC	Make an exhaustive BOM	Not the open-eye/bent-wire type		■
ST-FC09	Sizing of the coupling tubes	extension (length)	no less than one body caliber on either side of the joint	yes	IREC	Design review	It is measured from the separation plane. Flexibility given by SE after a clarification given by the competition officials by email. Couplers can be shorter it an analyse shows they do not allowed significant bendig at interfaces		■
ST-FC10	Prevention of bending of the airframe joints	quality	stiff	0	IREC	Writing tests procedures	eg RADAX or other join types.		■
ST-FC11	Clear identification of the LV	Project name and academic affiliation	Clearly identified on airframe	0	IREC	Design review	-		■

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
ST-FC12	Clear identification of the LV	Team ID	Prominen-tly displayed on airframe	0	IREC	Design review	Preferably on the 4 quadrants of the LV. The team ID is assigned by ESRA prior to the IREC		■
ST-FC13	Access to the arming device	accessibility	externally accessible	0	IREC	Design review	This does not preclude the limited use of access panels which may be secured for flight while the vehicle is in the launch position		■
ST-FC14	Mechanical attachments of launch lugs (rail guides) and their fastening to the main structure	Strength	Sufficient to be able to lift the rocket vertically from the bottom lug	0	IREC	Prototype building	The design should remain functionnal and allow a proper clearing of the launch tower.		■
ST-FC15	Mechanical attachments of launch lugs	"hard-point"	implemented	0	IREC	Design review, sizing	These hardened/reinforced areas on the vehicle airframe, such as a block of wood installed on the airframe interior surface where each launch lug attaches, will assist in mitigating lug "tear outs" during operations		■
ST-FC16	Inside thermal resistance	Motor temperature resistance	145 °C	minimum	PR	Refering to the datasheets of COTS components holding the motor. Testings for SRAD components	This given temperature is the highest around the casing. So if needed ST could add insulation around it.		■
ST-FC17	Outside thermal resistance	Temperature range	-10 to +80°C	0	SE	testing	Cold and hot environement during transport, handling,...Take the expansion in consideration		■
ST-FC18	Inside thermal control	Temperature range	-5 to +50°C	minimum	SE	Calculations and testing	This is fixed in order to protect the most sensitive parts of the rocket and the payload.		■
ST-FC19	Access of all energetic device arming features	accessibility	externally accessible/ controllable	0	IREC	Design review	This does not preclude the limited use of access panels which may be secured for flight while the vehicle is in the launch position		■
ST-FC20	Location of all energetic device arming features to ensure security of personnel arming them	Location	on airframe	0	IREC	Design review	For example, the arming key switch for an energetic device used to deploy a hatch panel shall not be located at the same airframe clocking position as the hatch panel deployedby that charge		■
ST-FC21	Fitting on the launch rails provided by IREC (5.5m in length)	fit	if possible	yes	SE	Design review	Team provided launch rails shall implement the nominal launch elevation specified in Section 8.1 of the IREC specs document and, if adjustable, not permit launch at angles either greater than the nominal elevation or lower than 70°		■
ST-FC22	Assembling of the subsystems in the rocket	orientation	horizontality	yes	SE	Writig the assembling procedure	It'll allow to have an easier access to the different subsystem of the rocket		■
ST-FC23	Internal disposition of the subsystems	order of SS	most fragile part in the top	yes	SE	Internal drawing of the rocket	This requirement shall not lead to a non-sens in the dispostion of the elements		■
ST-FC24	Ensure stability considering airbreaks	Stability	stable	0	SE	Simulations and testings	-		■
ST-FC25	Sand and dust resistant	Seals at interfaces	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functionning of any mechanism		■
ST-FC26	Whistanding the operating stresses and retain structural integrity	Axial stress	2018_AS_TN_AIRFRAME_ANALYSIS	2018_AS_TN_AIRFRAME_ANALYSIS	SE	Simulations and prototype testing	Thermal and dynamical environement should be considered. The document mentioned in "level" gives a detailed explanation of what is expected regarding this criterion.		■
ST-FC27	Whistanding the operating stresses and retain structural integrity	Shear stress	2018_AS_TN_AIRFRAME_ANALYSIS	2018_AS_TN_AIRFRAME_ANALYSIS	SE	Simulations and prototype testing	Thermal and dynamical environement should be considered. The document mentioned in "level" gives a detailed explanation of what is expected regarding this criterion.		■
ST-FC28	Whistanding the operating stresses and retain structural integrity	Bending stress	2018_AS_TN_AIRFRAME_ANALYSIS	2018_AS_TN_AIRFRAME_ANALYSIS	SE	Simulations and prototype testing	Thermal and dynamical environement should be considered. The document mentioned in "level" gives a detailed explanation of what is expected regarding this criterion.		■
ST-FC29	Abilility to sustend accelerations	g	18.5	minimum	SE	simulations and flight test	The given value has been estimated by simulations		■

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
ST-FC30	Whistanding the operating moments and retain structural integrity	Nm	2018_AS_TN_AIRFRAME_ANALYSIS	2018_AS_TN_AIRFRAME_ANALYSIS	SE	Simulations and flight test	The document mentioned in "level" gives a detailed explanation of what is expected regarding this criterion.		■
ST-FC31	Material for load-bearing eyebolt or U-Bolts	material	steel	-	IREC	Design review	Not stainless. For any bolt and eye-nut assembly used in place of an eyebolt.		■
ST-FC32	RF transparency	RF window	implemented	some IREC team	IREC	Design review	Transparent windows at the top of the motor mount and near the greatest concentration of payload mass. (Our team hasn't been notified yet to implement this)		■
ST-FC33	Airframe marking	color	lighter tinted or white	yes	IREC	Design review	eg. Yellow, red, orange to mitigate some of the solar heating		■
ST-FC34	Airframe marking	patterns	implemented	yes	IREC	Design review	eg. High visibility schemes (high contrast black, orange, red etc) and roll patterns (contrasting strips, "V" or "Z" marks) may allow ground-based observers to more easily track and record the LV's trajectory with high power optics		■

SPECIFICATIONS

Title: Propulsion specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
PR-FP01	Provide Thrust	Thrust average	2414.1 N	-10% to +10%	SE	Control of the datasheet of the chosen COTS motor	The flexibility is fixed regarding the uncertainties when buying a solid motor		■
PR-FP02	Provide Isp	Isp	Maximum 40,960 Ns	-10% to +10%	IREC	Control of the datasheet of the chosen COTS motor	The flexibility is fixed regarding the uncertainties when buying a solid motor		■
PR-FP03	Provide enough departure velocity	departure thrust	2418 N	-10% to +10%	SE	Control of the datasheet of the chosen COTS motor	This value consider a 26 kg rocket		■
PR-FC01	Weight optimization	Mass	6 kg	maximum	SE	Control of the datasheet of the chosen COTS motor	The attachements to integrate the motor in the structure have to be taken in account. The tank as well		■
PR-FC02	Size optimization	Length	1800 mm	-500 to +50	SE	Control of the datasheet of the chosen COTS motor	The attachements to integrate the motor in the structure have to be taken in account. The tank as well		■
PR-FC03	Size optimization	Outer diameter	120 mm	maximum	SE	Control of the datasheet of the chosen COTS motor	The attachements to integrate the motor in the structure have to be taken in account. This specification is not only the size of the motor grain		■
PR-FC04	Propellant type used	toxicity	not toxic	0	IREC	Control of the datasheet of the chosen COTS motor	Ammonium perchlorate composite propellant (APCP), potassium nitrate and sugar (aka "rocket candy"), nitrous oxide, liquid oxygen (LOX), hydrogen peroxide, kerosene, propane and similar, are all considered non-toxic		■
PR-FC05	Costs constraints	CHF	1'500	-	TR	Money budget	-		■
PR-FC06	Sand and dust resistant	Seals	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functionning		■

SPECIFICATIONS

Title: Avionic specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Notes: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.
In the document irec-design-test-evaluation-guide, two chapters could be useful for the avionics design:
APPENDIX B: SAFETY CRITICAL WIRING GUIDELINES
APPENDIX C: FIRE CONTROL SYSTEM DESIGN GUIDLINES

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
AV-FP01	Tracking the rocket	carry a radio beacon or similar transmitter	aboard each indepen-dently recovered assembly	0	IREC	Design review	Tracking systems using the Global Positioning System (GPS) and an automatic packet reporting system (APRS) are highly encouraged		◘
AV-FP02	Controlling the altitude	COTS barometric pressure altimeter with on-board data storage	carry minimum 1	0	IREC	Design review	Will provide an official log of apogee for scoring		◘
AV-FP03	Signifying that the arming of the rocket is working	indication of working	signal	0	IREC	Writing tests procedures	-		◘
AV-FP04	Arming all upper-stage (aka air-start)	mean	launch detection	0	IREC	Design review	eg accelerometers, zero separation force [ZSF] electrical shunt connections, break-wires, or other similar methods		◘
AV-FP05	Enabling an ignition signal to ignite the propellant	ignition	permitted	0	IREC	Design review	a software-based control circuit that automatically cycles through an "arm function" and an "ignition function" does not satisfy the arming requirement. This problem may be avoided by including a manual interrupt in the software program.		◘
AV-FP06	Triggering the primary recovery event	altitude	at apogee	near apogee	IREC	Writing tests procedures and testing	-		◘
AV-FP07	Monitoring	implementation	optional	-	SE	Design review	Even if not implemented, the architecture of the avionics has to be modular enough in order to add it easily		◘
AV-FP08	Control vertical stability	implementation	optional	-	SE	Design review	Even if not implemented, the architecture of the avionics has to be modular enough in order to add it easily		◘
AV-FP09	Control rotation	implementation	optional	-	SE	Design review	Even if not implemented, the architecture of the avionics has to be modular enough in order to add it easily		◘
AV-FP10	Deployement of the drogue parachute	Altitude	At apogee	0 to 3 seconds	IREC	Writing tests procedures and testing	-		◘
AV-FP11	Deployement of the main parachute	Altitude	457 m AGL	-100 to +0	IREC	Writing tests procedures and testing	Flexibility given by SE. However it has to reduce the LV's descent rate enough to prevent excessive damage upon impact with ground (ie 9 m/s))		◘
AV-FC01	Weight optimization	Mass	4.5 kg	maximum	SE	Mass budget and weighting of the prototype	Including aerobreaks		◘
AV-FC02	Size optimization	Outer diameter	90 mm	maximum	SE	Design review and prototype building	In order to be able tos slide through couplers		◘
AV-FC03	Size optimization	length	380 mm	maximum	SE	Design review and prototype building	Including aerobreaks		◘
AV-FC04	Official altitude logging system mounting	Location	in LV (not PL)	0	IREC	Design review	-		◘
AV-FC05	Data used for telemetry	source sensor	same as the onboard data-log	0	IREC	Design review	if telemetry implemented		◘

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
AV-FC06	Locking of the control actuator system whenever either an abort signal is received for any reason	state	neutral	0	IREC	Design review	neutral means: doesn't apply any moments to the LV (eg aerodynamic surfaces not deflected, gas jets off, etc). Any reasons means: primary system power is lost, or the launch vehicle's attitude exceeds 30° from its origin)		◘
AV-FC07	Electronic redundancies for recovery system	redundancies	implemented	0	IREC	Design review	including sensor/flight computer and electric initiators		◘
AV-FC08	Electronic redundancies for recovery system	COTS computer	implemented	minimum 1	IREC	Design review	This flight computer may serve as the official altitude logging system. (There are advantages to using dissimilar primary and backup systems). Eg. Stratlogger, G-Wiz, Raven, Parrot, Eggtimer, AIM, EasyMini, Telemetrum, RRC3. Flight computer kits are permitted and considered COTS		◘
AV-FC09	Cable management of all safety critical wiring: prevention of tangling and excessive free movement of significant wiring/cable lengths due to expected launch loads	cable management solution (e.g. wire ties, wiring, harnesses, cable raceways)	implemented	0	IREC	Design review and prototype building	This requirement is not intended to negate the small amount of slack necessary at all connections/terminals to prevent unintentional de-mating due to expected launch loads transferred into wiring/cables at physical interfaces		◘
AV-FC10	Preventing demating of critical wiring/cable connection due to expected launch loads	connections	Sufficiently secure	0	IREC	"Tug test": the connection is gently but firmly "tugged" by hand to verify it is unlikely to break free in flight	-		◘
AV-FC11	Arming of energetic devices	energetic device until launch position	safe	0	IREC	Design review	An energetic device is considered safed when two separate events are necessary to release the energy. An energetic device is considered armed when only one event is necessary to release the energy		◘
AV-FC16	Thermal resistance	Temperature range	-10 to 65°C	minimum	SE	Refering to the datasheets of COTS components and testing of SRAD components	Take in account the possibility of cold environement too (during transportation, etc). And the thermal expansion		◘
AV-FC17	Costs constraints	CHF	3'000	-	TR	Money budget	-		◘
AV-FC18	Electronically operated SRAD launch control systems	ignition switches type	momentary, normally open (aka "dead-man")	0	IREC	-	The idea is to have the signal removed when the switches are released. The ESRA provided a launch control system. Mercury or "pressure roller" switches are not permitted anywhere in team provided launch control systems.		◘
AV-FC19	Electronically operated SRAD launch control systems	removable safety interlock	implemented in series with the launch switch	0	IREC	-	That permits the system to be at least single fault tolerant.The ESRA provides a launch control system. (i.e. a jumper or key to be kept in possession of the arming crew during arming is the interlock)		◘
AV-FC20	Electronically operated SRAD launch control systems	Having a maximum operational range - distance	no less than 610 m from the launch rail	0	IREC	-	The ESRA will provide a launch control box that can supply a 12V, 15A signal. Connection is by free wire ends from the launch vehicle into screw binding posts on terminal boxes located at the launch rails. Launch vehicles requiring more signals may be accommodated by reallocating terminal boxes from adjacent rails provided that the total current requirement does not exceed 15A at any given moment in time		◘
AV-FC21	Can stand accelerations	g	18.5	minimum	SE	prototype testing	-		◘
AV-FC22	Powering the whole system	Hours	5	minimum	SE	Power budget and prototype testing	The rocket could stay a very long time on the launch pad before beeing launched. Different operating modes could be defined in order to help to save power and a remote controller for switching the mode		◘

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
AV-FC23	Enabling the central power system	powering on when the rocket is completely mounted	possible	0	SE	Design review	This will allow to turn on the rocket on when it'll be already on launch pad		▣
AV-FC24	Sounds feedback dynamic	different feedbacks	coordinated	0	SE	-	The beeps have to be clearly differentiable together regarding their mode (rythm and note). The beeps have to be not non-stop beeps.		▣
AV-FC25	GPS/trackers autonomy	hours	7	minimum	SE	tests in different conditions	The time before recovering the rocket can be long. This doesn't mean that a separated battery has to be dedicated to this task		▣
AV-FC26	Temperature sensor with logging capabilities	integrated	if possible	-	SE	design review	-		▣
AV-FC27	Pressure sensor with logging capabilities	integrated	if possible	-	SE	design review	-		▣
AV-FC28	Sand and dust resistant	Protection on sensitive components	implemented	-	SE	Design review	All the electronic component could be exposed to desert conditions		▣
AV-FC29	Aerobrakes reactivity	Time to open completely	1s	maximum	SE	prototype testing	-		▣
AV-FC30	Aerobrakes prescision	Error in position	0.5% of the max. opening	maximum	SE	prototype testing	-		▣
AV-FC31	Emplacement of the pitot-tube	location	in the nose cone	no	SE	Design review	If pitot-tube used		▣
AV-FC32	Aerobrakes reversibility	possibility to stop breaking	enabled	-	SE	Design review and flight test	-		▣
AV-FC33	Aerobrakes maneuvrability	steps	small	-	SE	prototype testing	-		▣
AV-FC34	Abilility to sustend accelerations	g	18.5	minimum	SE	simulations and flight test	The given value has been estimated by simulations		▣
AV-FC35	Connector identification	writing of them	every connectors	-	SE	Prototype inspection	This will ensure the knowledge of the task of each connector and where they have to be plugged		▣
AV-FC36	Battery type	Same as PL and GS	if possiblie	-	SE	Design review	Easier for charging station management and spare parts management		▣
AV-FC37	Data send to GS	battery status	implemented	no	SE	tests in different conditions	Having too low batteries is a criteria to abort a flight		▣
AV-FC38	CAS (control actuator system) locking	position	in neutral state	-	IREC	Design reviwe	Has to remain locked until the mission's boost phase has ended, or the LV has crossed the point of max. aerodynamic pressure in its trajectory, or the LV has reached an altitude of 6'096 m.		▣
AV-FC39	active flight control energetic devices	general energetic devices requirements	comply with	-	IREC	Design review	-		▣

SPECIFICATIONS

Title: Recovery specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
RE-FP01	Control descent speed	velocity	23-46 m/s	0	IREC	simulations, reach terminal velocity in test (if possible)	-		▣
RE-FP02	Control arrival speed	velocity	9 m/s	maximum	IREC	simulations	The arrival speed will be reduced as much as possible under this limit as long as it's still complyant with the allocated mass/volume budget		▣
RE-FP03	Recovery of body with apogee above 475m AGL	Operation concept	dual-event	0	IREC	ConOps for the recovery system (taking all parts of the rocket in account, except PL)	Initial deployement event followed by a main depolyement event. Riefing is considered as a dual-event operation concept.		▣
RE-FC01	Weight optimization	Mass	3 kg	maximum	SE	Mass budget and weighting of the prototype	-		▣
RE-FC02	Size optimization	Outer diameter	120 mm	maximum	SE	Volume Budget, design review and prototype building	Taking in account the attachement parts inside of the rocket		▣
RE-FC03	Size optimization	length	450 mm	maximum	SE	Volume budget, design review and prototype building	-		▣
RE-FC04	Costs constraints	CHF	5'000	-	TR	Money budget	-		▣
RE-FC05	Protection of retaining chords, parachutes and other vital components (against ejection gases if implemented, causing burn damages)	Adequate protection	Implemen-ted	0	IREC	Design review	Eg: fire resistant material, pistons, etc...		▣
RE-FC06	Recovery system mechanism testing	Rules, regulations, and best practices imposed by the authorities at our chosen test location(s)	Comply with	0	IREC	Writing tests procedures and testing	Could be done horizontally on a highway. ESRA recommends teams complete these tests by 01 April 2018.		▣
RE-FC07	Recovery system mechanism testing	verification testing of all recovery system	Sucessfully	0	IREC	Writing tests procedures and testing	Can be done by flight testing (implementing the same major subsystems component, as flight computer and parachutes as will be integrated into the LV intended the IREC), or through one or more ground tests of key subsystems		▣
RE-FC08	Capability of withstanding a wind drift of the main recovery event	wind drift	23 - 46 m/s	0	IREC	Simulations	-		▣
RE-FC09	Deployement stage characterization	Color of the chutes	Dramatically different	0	IREC	Control of the "order component" list when buying chutes. Design review and tests in case of riefing	Having colors fitting with our logo could be nice. In case of riefing an other method has to be implemented in order tobe able to differentiate the 2 states (half vs completely open) of the parachute from the ground.		▣
RE-FC10	Thermal resistance	Temperature range	-10 to 65°C	minimum	SE	Refering to the datasheets of COTS components and testing of SRAD components	Take in account the possibility of cold environement too (during transportation, etc). As the thermal expansion		▣
RE-FC11	Safe deployement of parachutes	Opening while the rocket is spinning	works	4'000	SE	Design review	Even if a spin control of the rocket could be implemented later, we want to be able to flight without it as well		▣
RE-FC12	Can stand vibrations	vibrations	From motor	minimum	SE	Prototype testing	Recommandation: designing with a security factor of 3		▣

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
RE-FC13	Abilility to sustend accelerations	g	18.5	minimum	SE	simulations and flight test	The given value has been estimated by simulations		☐
RE-FC14	Distance of separation during ejection	diameters	2	minimum	SE	Prototype testing	This has to be measured with the rocket layed horizontally at maximum 10 cm upper the ground level.		☐
RE-FC15	Redundancy on each ejection mechanism	redundancy	implemented	0	SE	Design rewiew	-		☐
RE-FC16	Sand and dust resistant	Seals at interfaces	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functionning of any mechanism		☐
RE-FC17	Parachute caracteristic	Made by	SRAD	if possible	SE	Design review	This could give us a better score at the competition		☐
RE-FC18	Recovery system rigging	siwel links	implemented at connection	-	IREC	Design review	To relieve torsion as the specific design demands. Mitigate the risk of torque loads unthreading bolted connections		☐

SPECIFICATIONS

Title: Payload specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
PL-FP01	Detect muons	number of events	3	minimum	PL	prototype testing	it has to ensure to not detect false positives		☐
PL-FP02	functionnality	not boiler-plate	encouraged	no	IREC	Design review	Creative scientific anxperiment and technology demonstration. Flexibility given by SE to not have to comply with boiler-plate PL requirements and to participate in SDL challenge.	27.02.2018	☒
PL-FC01	Weight optimization	Mass	3.992 kg	-5% to +0%	IREC	Mass budget, design review and weighting of the prototype	The upper flexibility is given by SE. But for the competition officials any weight greater than the specified minimum is acceptable. The lower one is the limit to not get penalties		☐
PL-FC02	Size optimization	System Length	300 mm	maximum	SE	Volume Budget, design review and measure of the prototype	The payload recovery system is taken in account in this length. The supporting structure of the payload can be longer if useful to the rocket's configuration.		☐
PL-FC03	Size optimization	Outer diameter	117.5 mm	maximum	SE	Volume budget, Design review and measure of the prototype	In order to be able to slide in the upper rocket tube.		☐
PL-FC04	Independency	connection to other component	not inextricably	-	IREC	Design review	Weight PL independant of all launch vehicle associated systems prior to flight.	27.02.2018	☒
PL-FC05	Composition of the PL	live, vertebrate animal	excluded	0	IREC	Design review	-	27.02.2018	☒
PL-FC06	Composition of the PL	lead and hazardous materials	not significant quantities	0	IREC	Design review	-		☐
PL-FC07	Independant recovery of depoyable PL	max velocity at 457.2 m AGL	9 m/s	0	IREC	Simulations	If a parachute or parafoil based recovery system is implemented, the PL recovery systme isn't required to comply with the dual-event requirement		☐
PL-FC08	Cable management of the recovery system of a deployable PL : prevention of tangling and excessive free movement of significant wiring/cable lengths due to expected launch loads	cable management solution (e.g. wire ties, wiring, harnesses, cable raceways)	implemented	0	IREC	Design review and prototype building	This requirement is not intended to negate the small amount of slack necessary at all connections/terminals to prevent unintentional de-mating due to expected launch loads transferred into wiring/cables at physical interfaces		☐
PL-FC09	Preventing demating of critical wiring/cable connection due to expected launch loads	connections	Sufficiently secure	0	IREC	"Tug test": the connection is gently but firmly "tugged" by hand to verify it is unlikely to break free in flight	-		☐
PL-FC10	Integration of the payload	Geometry	Preferably CubeSat Standard	yes	IREC	Design review	fitting in the CubeSat standard (1U, 2U, etc but not smaller) would give 50 bonus points to the team.		☐
PL-FC11	Recovery mechanism testing	verification testing of all recovery system	Sucessfully	0	IREC	Writing tests procedures	Can be done by flight testing (implementing the same major subsystems component, as flight computer and parachutes as will be integrated into the LV intended the IREC), or through one or more ground tests of key subsystems		☐
PL-FC12	Arming of energetic devices	state of energetic device until launch position	safe	0	IREC	Design review	An energetic device is considered safed when two separate events are necessary to release the energy. An energetic device is considered armed when only one event is necessary to release the energy	27.02.2018	☒

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
PL-FC13	Electronic of the PL recovery system	electronic, sensors/ flight computers and electric initiators	redundant	0	IREC	Design review	electric initiator is the device energized by the sensor electronics, which then initiates some other mechanical or chemical energy release to deploy its portion of the recovery system (i.e. electric matches, nichrome wire, flash bulbs, etc...)		■
PL-FC14	Flight computer of the redundant recovery system	Type	at least 1 COTS	0	IREC	Design review	-		■
PL-FC15	Thermal resistance	Temperature range	-10 to 65°C	minimum	SE	Refering to the datasheets of COTS components and testing of SRAD components	Take in account the possibility of cold environement too (during transportation, etc). As the thermal expansion. The payload has to work inside and outside of the rocket		■
PL-FC16	Costs constraints	CHF	10'000	-	TR	Money budget	-		■
PL-FC17	Abilility to sustend accelerations	g	18.5	minimum	SE	simulations and flight test	The given value has been estimated by simulations		■
PL-FC18	TOF above 2km AGL	minutes	5	minimum	SE	Descente velocity calculations and flight test	This is to ensure to have sufficient events	27.02.2018	■
PL-FC19	Can stand vibrations	vibrations	From motor	minimum	ST	Vibration tests	-		■
PL-FC20	Sand and dust resistant	Seals at interfaces	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functioning of any mechanism		■
PL-FC21	Autonomy	battery life	4 hours	minimum	SE	Testings	The rocket can stay for a long time on the launch pad waiting a launch window		■
PL-FC22	Recovery on ground	distance from launch area	16 km East	maximum	SE	Simulations	This is in order to not land in the forbidden area. This implies implementing a simulation able to determine the maximum opening altitude AGL for the parachute and having a possibility to reconfigure easily the PL at the last minute considering winds. If the PL arrives in the WSMR, it'll have to be abandoned or recover at the team's own expenses	27.02.2018	■
PL-FC23	Battery type	Same as AV and GS	if possiblie	-	SE	Design review	Easier for charging station management and spare parts management		■
PL-FC24	Recording recocket separation from the inside	video	optional	-	SE	Design review	The video could be sent to the ground sation to see live events		■
PL-FC25	Shape and dimensions	CubeSat standard	if possible	tuna box	IREC	Design review	For a boiler plate PL, the requirement is min 3U (non other shape is admitted). Flexibility is given by SE. Teams which adopt the CubeSat standard will be awarded bonus points		■
PL-FC26	Mass repartition in non-boiler plate PL	boiler plate mass	1/4th	maximum	IREC	Design review	Not counting the associated support structure for the functionnal part of the PL		■
PL-FC27	Ejection	risk	low	minimum	SE	Payload Design review	The risks linked to the ejection of the payload regarding the success of the mission shall be kept to a minimum (e.g the payload ejection shall not be critical to the nominal deployment of the main parachute)	27.02.2018	■
PL-FC28	Ejection	direction	away from rocket and parachute	none	SE	Payload Design review	The ejection system shall be designed in such a way that the payload is ejected away from the rocket.	27.02.2018	■
PL-FC29	Ejection	time	at apogee	none	SE	Payload Design review	The payload shall be ejected at apogee.	27.02.2018	■
PL-FC30	Ejection	redundancy	redundant	none	SE	Payload Design review	Any process necessary to ejection shall be redundant, hence shall be duplicated. If the system was not tested in advance, the redundancy shall be done using two systems based on different principles.	27.02.2018	■

SPECIFICATIONS

Title: Ground Station specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been proceed and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
GS-FP01	Receive data from the rocket	operating range	0 to +10 km	minimum	SE	Design review, ground test and flight test	Distance chosen in order to be able to communicate with the rocket during its ascent in all the IREC categories. Radio beacons could be used as well. Having different antennas for different launch parameters could be an option. Changing the antenna used depending of the communication range is acceptable as long as the GS remains the same.		■
GS-FP02	Send data to the rocket	operating range	0 to +2 km	minimum	SE	Design review, ground test and flight test	The control of the rocket during its ascent is prohibited. Changing the antenna used depending of the communication range is acceptable as long as the GS remains the same. (this doesn't mean that the actual competition rocket will have a receiver implemented but we want to have this capability)		☐
GS-FP03	Display the rocket's location	Displaying system	implemented	-	SE	Design review	If a screen is implemented, more than one information can be displayed on the same device (unlike, sounds,...)		■
GS-FP04	Display the rocket's altitude	Displaying system	implemented	-	SE	Design review	If a screen is implemented, more than one information can be displayed on the same device (unlike leds, sounds,...)		■
GS-FP05	Data logging	Relation time-rocket's location	implemented	-	SE	Code review	-		■
GS-FP06	Display of main events	Displaying system	implemented	-	SE	Design review	The kind of events could be: main parachute deplyed, burnout, landed, etc		■
GS-FC01	Weight optimization	mass	5 kg	if heavier, must have wheels	SE	Mass budget and weighting the prototype	Easy to transport and to ship		■
GS-FC02	Volume optimization	volume	80 dm^3	maximum	SE	Volume budget and measuring the prototype	Easy to transport and to ship. A suitcase could be a solution		■
GS-FC03	Battery autonomy	time	5 hours	minimum	SE	Power budget and testings	-		■
GS-FC04	Cost Constraints	Money	3'000	maximum	TR	Money budget	-		■
GS-FC05	Sand and dust protected	seals	implemented	-	SE	Design review	The competition takes place in the desert		■
GS-FC06	Thermal resistance	Range of temperature	-10 to +50°C	minimum	SE	Design review and test of the prototype	Considering the shipping condition as the competition conditions. The GS could be used during in Switzerland as well		■
GS-FC07	Water resistance	Water resistant materials	optional	-	SE	Design review and test of the prototype	If the system isn't, a water resistant box could be aquired to protect it		■
GS-FC08	Transportation easyness (walking with it)	nb of people needed	1	-	SE	Test of the prototype	It's possible to require a second person for carrying the antenna even if it isn't prefered		■
GS-FC09	Accuracy in localization	distance to target	70 m	minimum	SE	Test of the prototype	Radius around the target		■
GS-FC10	Signalization of the established contact with the rocket	Continuous information	implemented	-	SE	Design review	If light is implemented, it has to be visible outside during a sunny day		■
GS-FC11	General informations display	Pressure	optional	-	SE	Design review	Records of the launch site conditions are very interesting in case of hybrid rocket launch		■

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
GS-FC12	General informations display	Temperature	optional	-	SE	Design review	Records of the launch site conditions are very interesting in case of hybrid rocket launch		■
GS-FC13	General informations display	Actual time	implemented	-	SE	Design review	-		■
GS-FC14	General informations display	GS battery level	implemented	-	SE	design review	-		■
GS-FC15	General informations display	GS on/off	implemented	-	SE	design review	If the GS is foldable (suitcase style, etc), this information have to be visible even if the GS is closed		■
GS-FC16	Internal compenents accessability	use of non-permanent binding system	as much as possible	-	SE	Design review and prototype building	This specification is settled only in case a defective component has to be changed. During a normal use of the GS, nobody should access to its interior even to charge the batteries or access to the aquired datas. Si it has to be closed properly		■
GS-FC17	Data storage capability	Number of 10min flights	10	minimum	SE	Design review	Even in the situation of the GS directly connected with a computer, all the aquired data have to be stored inside the GS itself.		■
GS-FC18	Display rocket's velocity	Display device	optional	-	SE	Design review	-		■
GS-FC19	Charging station for external device	charging port	optional	-	SE	design review	If implemented, this will be used only for the rocket itself or the payload if none other power source is available at that time. Note that large batteries can't be taken on board a plane or even in checked-in luggage		■
GS-FC20	Connectivity with a computer	port	implemented	-	SE	design review	It's purpose is to access to the aquired datas and debug		■
GS-FC21	Dependency to a computer	existance	none	-	SE	Design review	To limit the risks, the GS has to work independently of other systems as computer, etc. If the GS needs a calibration it has to be feasible without external computer		■
GS-FC22	Data rate	time between each uptade of all the channels	1s	maximum	SE	Data budget and design review	-		■
GS-FC23	Signalization of data aquisition	Display device	implemented	-	SE	Design review	-		■
GS-FC24	Data storage redundancy	redundant	1	minimum	SE	Design review	If the data storage is done with a revmovable memory card, a second one has to always be in the non-accessible part of the GS as a backup		■
GS-FC25	Launch preparation and packing	assembling	not needed	-	SE	Prototype building	The only part which can be disassembled from the GS is its antenna		■
GS-FC26	Used bandwidth	frequency	legal	no	SE	Design review	In CH and in the USA		■
GS-FC27	General informations display	speed	optional	-	SE	Design review	-		■
GS-FC28	General informations display	altitude	optional	-	SE	Design review	-		■
GS-FC29	General informations display	acceleration	optional	-	SE	Design review	-		■
GS-FC30	Use Bandwidth with as little users as possible	frequency	other than 900 MHz	-	SE	Design review	900Mhz is the most used frequency in the US because it's the long range mode of the xbee pro.		■
GS-FC31	Battery type	Same as AV and PL	if possiblie	-	SE	Design review	Easier for charging station management and spare parts management		■
GS-FC32	Receive and display data	video	optional	-	SE	Design review	Video could be taken by payload		■
GS-FC33	General informations display	Rocket batteries level	implemented	no	SE	Tests in multiple conditions	Having too low batteries is a criteria to abort a flight		■

SPECIFICATIONS

Title: Hybrid Propulsion specifications
Project: IREC SA CUP 2018 Team Lausanne – MATTERHORN
Filename: 2018_SE_MS_0001_SPECIFICATION_R04
Responsible: Héloïse (SE)

Note: When a test or other verification steps has been done and the system complies to its specifications, the "validation" box has to be filled with a cross. The date and the name of the responsible of the verification will be written next to the corresponding box as well.

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
PRH-FP01	Provide Thrust	Thrust	2414.1 N	-10% to +10%	SE	Simulations and prototype building	-		■
PRH-FP02	Provide Isp	Isp	Maximum 40,960 Ns	-10% to +10%	IREC	Simulations and prototype building	-		■
PRH-FP03	Venting or offloading of all liquid and gaseous propellants	Control	remote controlled	0	IREC	Design review and testing of the prototype	Will be used in the event of a launch abort		■
PRH-FP04	Arming of all upper-stage (aka air-start) propulsion systems	Mean	launch detection	0	IREC	Design review	eg of launch detection : accelerometers, zero separation force [ZSF] electrical shunt connections, break-wires, or other similar methods. The AV team takes care of the arming part		■
PRH-FP05	Provide enough departure velocity	departure thrust	2418 N	-10% to +10%	SE	Simulations and prototype building	-		■
PRH-FC01	Weight optimization	Mass	10 kg	-9 to +2	SE	Design review and weighting of the prototype	-		■
PRH-FC02	Size optimization	Length	750 mm	-200 to +200	SE	Design review and measure of the prototype	-		■
PRH-FC03	Size optimization	Outer diameter	130 mm	yes	SE	Design review and measure of the prototype	-		■
PRH-FC04	Costs constraints	CHF	12'000	-	TR	Money budget	-		■
PRH-FC05	Propellant type used	toxicity	not toxic	0	IREC	Control of the datasheet of the chosen COTS motor	Ammonium perchlorate composite propellant (APCP), potassium nitrate and sugar (aka "rocket candy"), nitrous oxide, liquid oxygen (LOX), hydrogen peroxide, kerosene, propane and similar, are all considered non-toxic		■
PRH-FC06	Complete a propellant loading and off-loading test in "launch-configuration"	test result	Sucessful	0	IREC	Writing test procedures	This test may be conducted using either actual propellant(s) or suitable proxy fluids. ESRA recommends teams complete these tests by 01 April 2018		■
PRH-FC07	Romplete an instrumented (chamber pressure and/or thrust), full scale (including operating time) static hot-fire test	test result	Sucessful	0	IREC	Writing test procedures	ESRA recommends teams complete these tests by 01 April 2018		■
PRH-FC08	Relief device for pressure vessels, set to open at no greater than 1.5 times the maximum expected operating pressure	status	implemented	0	IREC	Calculations	SRAD (including modified COTS) rocket motor propulsion system combustion chambers are exempted from this requirement		■
PRH-FC09	Security factor of SRAD pressure vessels constructed entirely from isentropic materials (eg metals)	burst pressure	2 times the maximum expected operating pressure	not less than	IREC	Calculations	The maximum operating pressure is the maximum pressure expected during pre-launch, flight, and recovery operations		■
PRH-FC10	Security factor of SRAD pressure vessels constructed entirely from non-isentropic materials, or implementing composite overwrap of a metallic vessel	burst pressure	3 times the maximum expected operating pressure	not less than	IREC	Calculations	eg fiber reinforced plastics; FRP; aka composites, composite overwrapped pressure vessels; COPV		■

ID	Function	Criterion	Level	Flexibility	Source	Validation method	Comments	Validation Date	Validation
PRH-FC11	Security factor for tests of SRAD pressure vessels and rocket motor propulsion system combustion chambers	pressure	1.5 times the maximum expected operating pressure	without significant anomalies	IREC	Prototype building and test procedure writing	Although there is no requirement for burst pressure testing, a rigorous verification & validation test plan typically includes a series of both non-destructive, proof pressure and destructive, burst pressure tests. A series of burst pressure tests performed on the intended design will be viewed favorably; however, this will not be considered an alternative to proof pressure testing of the intended flight article.		◘
PRH-FC12	Material selection for propulsion system combustion chamber	PVC components	not used	0	IREC	Design review	-		◘
PRH-FC13	Thermal resistance	range of temperature	-10 to 65°C	minimum	ST	Writing test procedures and testing, material choice review	Cold and hot environement during transport, handling,...Of course, the motor will have to be able to withstand the temperature it produces while functionning as well.		◘
PRH-FC14	Sand and dust resistant	Seals	implemented where needed	-	SE	Design review	The sand shouldn't prevent any assembly or good functionning		◘
PRH-FC15	Tunnable valve for flow rate	implementation	optional	-	SE	Design review	This could permit to choose the burn time and the thrust to do testings		◘

10000_BOM_SUMMARY_R04

CAD Identifier				TITLE	Qty	Material	Status
x0000	xx000	xxx00	xxxxx				
10000				**Project Matterhorn (System)**	1	-	i.e. in production
	11000			**Structure**	1	-	
		11100		**Nosecone**	1		
			11101	Nosecone	1	Fiberglass	manufactured
			11102	Insert tip	1	PE	manufactured
			11103	Hole tip	1	PE	manufactured
			11105	Cone connector support	1	PVC	manufactured
		11300		**Coupler**	3		manufactured
			11301	Tube ring	1	Aluminum 6082	manufactured
			11302	Bague interne	1	Aluminum 6082	manufactured
			11303	Bague	8	Aluminum 6082	manufactured
			11304	M4x20 tête fraisée	8		bought
		11400		**Fins module assembly**	1		manufactured
			11401	Upper ring	1	Aluminium 6082	manufactured
			11402	Middle ring	1	Aluminium 6082	manufactured
			11403	Lower ring	1	Aluminium 6082	manufactured
			11404	Aft enclosure	1	Aluminium 6082	manufactured
			11405	Fins v1	3	Swiss-Composite CFRP Plates h = 3mm	manufactured
			11406	Motor tube	1	Kraft Cardboard, Public Missiles	bought
			11408	Third of panel	3	CFRP EHKF PrePreg	manufactured
			11409	Sandwich centering ring	2	Swiss-Composite, aramid-carbon sandwich	manufactured
			11411	M4x10 tête ronde	27		bought
			11412	M4x20 6 pan creux	12		bought
			11413	Ecrou locking M4	12		bought
			11414	Insert boat tail	3		manufactured
			11415	Boat tail	1	PVC	manufactured
		11500		**Lower tube assembly**			
			11501	Lower airframe	1	CFRP EHKF PrePreg	manufactured
			11502	Thrust plate	2	Aluminium 6082	manufactured
			11503	M6x10 6 pan creux	6		bought
			11504	Lower airframe glue	1	Swiss Composite, 90 min epoxy, heat resistant	bought
		11600		**Upper tube assembly**	1		
			11601	Upper frame	1	CFRP EHKF PrePreg	manufactured
			11602	Bague renfort	1	Aluminum 6082	manufactured
			11603	Rail triangle	1	Aluminium 1xxx	bought
			11604	Liste thin	2	Aluminium 1xxx	manufactured
			11605	Liste thick	2	Aluminium 1xxx	manufactured
			11606	M6x10 Low Profile Socket Head S	6		bought
			11607	M8x1.25 Nylon Insert Flange Lockn	4		bought
			11608	Recovery Coupling Rings	2	Aluminium 6082	manufactured
			11609	Rondelles Ressort	2		bought
	12000			**Recovery**	1	-	
		12100		**Structure**	1	-	
			12101	Recovery Plate	1	Aluminium 6082	manufactured
			12102	M8 Structural Shaft	2	Titan	manufactured
			12103	M8 Eyelet	2	Zinc plated Steel	bought
			12104	M8 Upper Nut	2	Chromated Steel	bought
			12105	Top Male Connector	2	Brass (chrome or nickel plated)	bought
			12106	Bottom Male Connector	2	Brass (chrome or nickel plated)	bought
			12107	Female Connector	4	Brass (chrome or nickel plated)	bought
			12108	Bottom Spacer	2	Rubber or soft plastic	manufactured
			12109	Top Spacer	2	Rubber or soft plastic	manufactured
		12200		**Parachute Chain**	1	-	
			12201	Parachute	1		manufactured
			12202	Quick link	1		bought
			12203	Electrical Shock Cord	1	Kevlar, 4 conductors	manufactured
			12204	Body Harness	1	Kevlar	manufactured
			12205	Kevlar Strap	1	Kevlar	bought
			12206	Deployment Bag	1		manufactured
		12300		**Reefing Module**	1	-	
			12301	CentralLineShort	1		manufactured
			12302	CentralLineLong	1		manufactured
			12303	ReefingBody	1		manufactured
			12304	LineCutterCap	2		bought
			12305	LineCutterORing	2		bought
			12306	LineCutterSpike	2		bought
			12307	LineCutterBody	2		bought
		12400		**Raptor C02 Deployment System**	2		
			12401	Raptor Base	2		bought
			12402	Raptor Bolt	2		bought
			12403	Pyro Housing	2		bought
			12404	Puncture Spring	2		bought
			12405	Puncture Piston	2		bought
			12406	Puncture Piston O-ring	2		bought
			12407	System Cap	2		bought
			12408	Cap O-ring	2		bought
			12409	CO2 Cartridge Adapter	2		bought
			12410	CO2 Cartridge	2	Aluminum	bought

10000_BOM_SUMMARY_R04

CAD Identifier				TITLE	Qty	Material	Status
x0000	xx000	xxx00	xxxxx				
10000				**Project Matterhorn (System)**	**1**	-	i.e. in production
	13000			**Propulsion**	**1**	-	
		13100		**Motor**	**1**	-	
			13101	Aerotech - M1850W	1		selected
		13200		**Motor Casing**	**1**	-	
			13201	Casing tube	1	Aluminum	bought
			13202	Aft Closure	1	Aluminum	bought
			13203	Front Closure	1	Aluminum	bought
	14000			**Avionics**	**1**	-	
		14100		**Central Avionics**	**1**	-	
			14101	Sliders	1	PVC	manufactured
			14102	Support plate Control Panel	1	Fiberglass	manufactured
			14103	Support plate raven	1	Fiberglass	manufactured
			14104	LFP battery	1		bought
			14105	Slider Control Panel	1	PVC	manufactured
			14106	Control Panel	1	Fiberglass, 4 anti-vibration switches	manufactured
			14107	9V battery	2		bought
		14200		**Cone Avionics**	**1**	-	
			14201	PCB Main	1		manufactured
			14202	PCB power	1		manufactured
			14203	Entretoise M3x7	6	Stainless Steel	bought
			14204	11.1 V LiPo Battery	1		bought
			14205	Sandwich plate	1	Swiss-Composite, aramid-carbon sandwich	manufactured
			14206	Guide	2	Aluminum	manufactured
			14207	Nose top ring	1	PE	manufactured
			14208	Nose bottom ring	1	PE	manufactured
			14209	Entretoise M3x15	4		bought
			14210	Guide power	2		bought
			14211	GNSS antenna	2		bought
			14212	Telemetry antenna	2		bought
			14213	Tige	2	Aluminum	manufactured
		14300		**COTS Avionics**	**2**	-	
			14301	Raven	1		bought
		14400		**Control Panel**	**1**	-	
			14402	Switch body	4		bought
		14700		**Cables & Connectors**			
			14701	Nosecone - Nosecone	1	4 conductor, LEMO connectors: FAG.0B.304.CLA, EGG.0B.304.CLL	bought
			14702	Nosecone - Central body	1	4 conductor, LEMO connectors: FAG.0B.304.CLA, EGG.00.304.CLL	bought
			14703	Central body - Airbrake	1	8 conductor, LEMO connector: FP6.1B.308.CLAD62	bought
			14704	Recovery reefing connector	1	4 conductor, LEMO connectors: FGG.00.304.CLAD35, EGG.0B.304.CLL	bought
			14705	Recovery ejection connector	1	6 conductor, LEMO connectors: FGG.0B.306.CLAD42, EGG.0B.306.CLL	bought
			14706	Central body serial connector	1	4 conductor, LEMO connector: EGG.00.304.CLL	bought
			14707	Central body airbrake connector	1	8 conductor, LEMO connector: EGG.1B.308.CLL	bought
	15000			**Airbrakes**	**1**	Aluminum	
		15100		**Drive Train - Shuriken**	**1**	-	
			15101	Servo	1	NA	bought
			15102	Servo srews	4	Steel	bought
		15200		**Mechanism - Shuriken**	**1**	-	
			15201	Main gear	1	Aluminum 6082	manufactured
			15202	Geared wings	3	Aluminum 6082	manufactured
			15203	Wing bearings	6	Steel	manufactured
			15204	Wing axles	3	Steel	manufactured
		15300		**Module - Shuriken**	**1**	-	
			15301	Upper plate	1	Aluminum 6082	manufactured
			15302	Lower plate	1	Aluminum 6082	manufactured
			15303	Bolts	3	Steel	bought
	16000			**Ground station**	**1**	-	
		16100		**Hardware**	**1**	-	
			16101	Pelican Air 1615 Casing	1		bought
			16102	LiFePO4 12V/20Ah battery	1		bought
			16103	High Brightness LCD	2		bought
		16200		**Electronics**	**1**	-	
			16201	Up Board CPU	1		bought
			16202	Raspberry Pi	1		bought
			16203	Transceivers	2		bought
	17000			**Payload**	**1**	-	
		17100		**Structure**	**1**	-	
			17101	Disc	2	Steel	manufactured
			17102	Sheet Large	2	Steel	manufactured
			17103	Sheet Narrow	2	Steel	manufactured
			17104	Rail	2	Steel	manufactured
			17105	Braket	4	Aluminium	manufactured
			17106	Teflon Skate Long	4	PTFE	manufactured
			17107	Teflon Skate Short	4	PTFE	manufactured
			17108	Foam Scotch Long	4	Foam	bought
			17109	Foam Scotch Short	4	Foam	bought
			17110	Electronic Support	1	Steel	manufactured
			17111	Fiberglas Sheet	1	Fiberglas	manufactured
			17112	Spring Steel Sheet	2	Steel	manufactured
			17113	Ballast	0-8	Steel	manufactured
			17114	M4x20 Socket Head Screw Hex Dr	6	Steel	bought
			17115	M4x10 Socket Head Screw Hex Dr	8	Steel	bought
			17116	M3x8 Flat Head Screw Hex Drive	0-16	Steel	bought
			17117	M3x6 Flat Head Screw Hex Drive	40	Steel	bought
			17118	M4_Locknuts	8	Steel	bought
		17200		**Parachute**	**1**	-	
			17201	Parachute	1		bought
			17202	Shock Cord	1		bought
			17203	Hardware	1		bought