EPFL SPACECRAFT TEAM

CHESS MISSION

Semester-Review 24.05.2023

Guidelines:

- Finish the report by the 19.05.2023
- This report is thought to be a support document to the PowerPoint presentation, meaning you can give more detailed descriptions
- For each important design decision, you took this year, provide a trade-off analysis
- Write whole sentences
- Minimum 1 page
- Feel free to include supporting Figures or Graphs

1. System Engineering

1.1. What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

Project Fall 2022: CHESS Spacecraft Systems Engineering Baselines for PDR by Samuel Frachebourg

Requirements Review

During the last year, a strong focus was set on reorganizing the requirements according to the in-house platform. The requirements are defined in 5 different levels (*Figure 1*). Each requirement is classified into one of the following types: Objective, Functional, Performance, Constraint, Interface, Environmental and Reliability. Until now, only the high-level requirements have been redefined and reviewed. They include the general project objectives (Level 0), the CHESS specifications (Level 1) and the CHESS Pathfinder 1 System requirements.

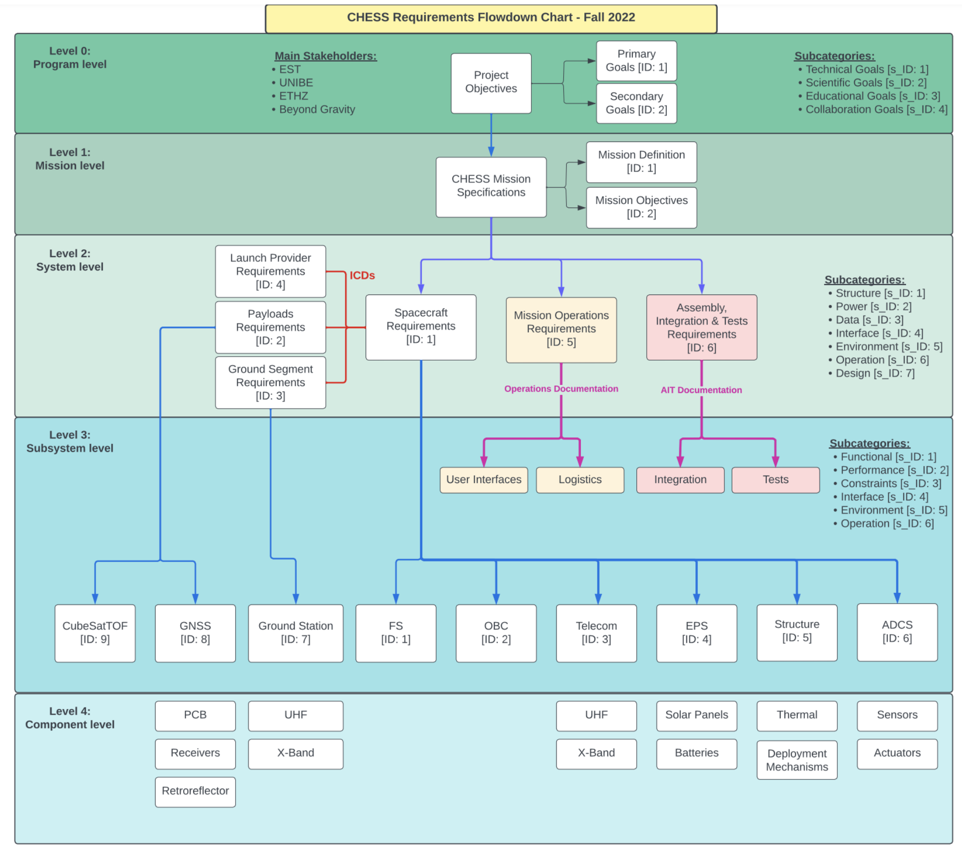
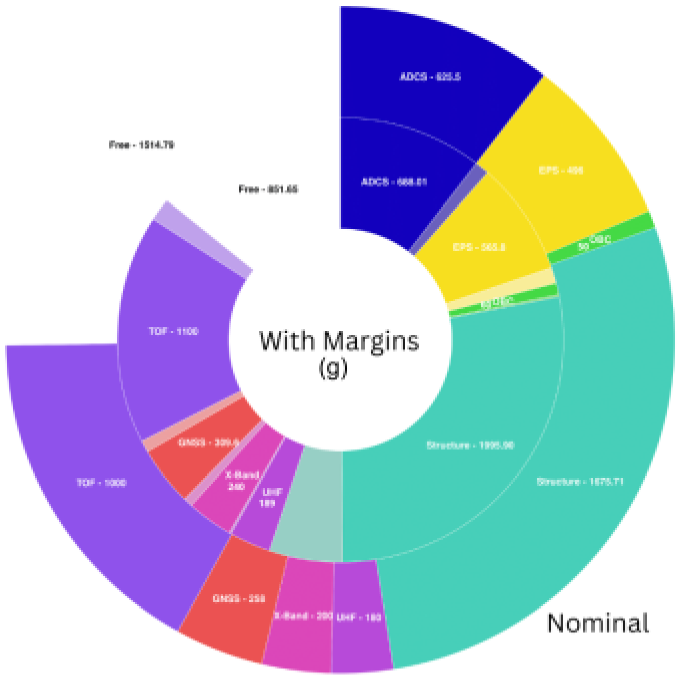


Figure 1: Requirements Flow down

Mass budget



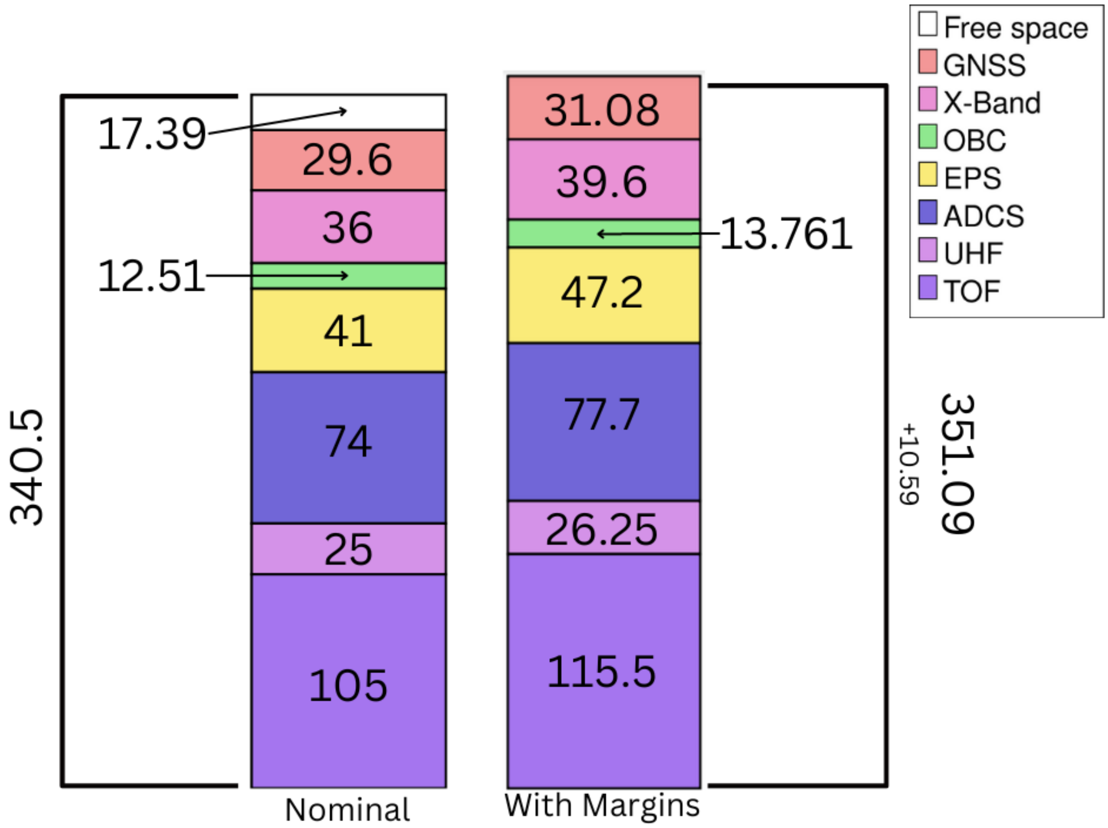
The mass budget had not been updated in very much detail for a while, so it was important that it was updated this semester. The mass budget, just like previous years, was capped at 6000 g, as is the standard for 3U CubeSats. As the diagram above shows, there were no issues with keeping to this limit, since, nominally, only 75% (4485.21 g) of the maximum allowed mass is used. With margins included for each subsystem, 86% (5148.35 g) of the 6000 g is used, leaving a good margin. Taking the extreme case of placing a plain 20% margin on the total mass, the maximum mass would equate to 5382.252 g, leaving 617.748 g to the 6000 g limit.

An issue with the mass budget as it is in the diagram is that the mass for the EPS PCB and the OBC had to be estimated using the old mass budget from the 2021 PDR. For the EPS PCB, the same mass as in the 2021 PDR was used, while the old HOBC mass (50 g) was used as an estimate for the OBC mass. In both cases, a 20% margin of error was applied to both components. Furthermore, there were some uncertainties in the team regarding the mass of the GNSS, for which the old value from the 2021 PDR was used as it was assumed that the mass of the GNSS would not have changed by too much. Also in this case a 20% margin was applied.

Some notable differences with the previous mass budget are the ADCS, the EPS batteries, structure, and the X-band transmitter. For ADCS, new parts are being used, resulting in a change in mass. New batteries are also being used. The great change in mass here has been hypothesised to have been due to the old batteries having shielding, increasing their mass. As for structure, it has to be kept in mind that the solar panels' mass are also included in the structure's mass, which they have not been before. Furthermore, the structure now has shielding, increasing its mass further. The change in mass for the X-band transmitter is simply because the part has a greater mass now.

Subsystem	Component	Mass (g)	Margin (%)	Total mass (g)	Total margin (%)	Total mass with margin (g)
CubeSatTOF		1000	10	1000	10	1100
UHF	Antenna	85	5	180	5	189
	Transceiver	95	5			
ADCS	CubeSense Sun	15	10	625,5	10	688,05
	CubeMag Deployable	14	10			
	CubeSense Earth	18	10			
	Computer/CubeDoor/CubeConnect	332,5	10			
	CubeWheels CW0017	180	10			
	Torquers CR0004	66	10			
EPS	Batteries	196	5	496	14,07	565,8
	PCB	300	20			
OBC	Board	50	20	50	20	60
X-Band	Antenna	50	20	200	20	240
	Transmitter	150	20			
GNSS		258	10	258	10	283,8
Structure	Bare Structure	370	20	1675,71	19,11	1995,90
	Shielding	826	20			
	Solar Panels	300	20			
	Solar Panel Deployment mechanisms	80	20			
	Solar Cells	99,71	5			
Total		4485,21	14,78			5148,35
Total +20% mass		4485,21	20			5382,26

Height budget



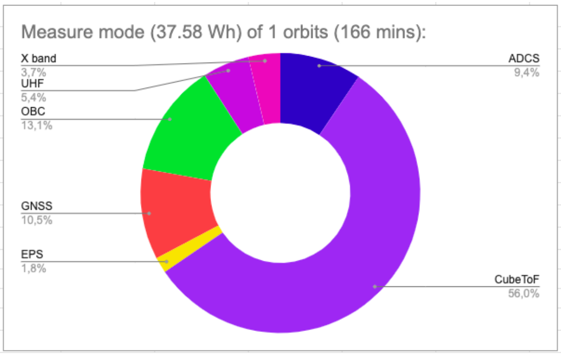
Subsystem	Components	Height (mm)	Margin (%)	Height with margin
CubeSat TOF		105	10	115,5
UHF	Antenna	4,5	5	4,725
	Cable	6,5	5	6,825
	Transceiver	14	5	14,7
ADCS		74	5	77,7
EPS	Board	21	20	25,2
	Batteries	20	10	22
OBC		12,51	10	13,761
X-Band	Antenna	8	10	8,8
	Cabling	10	10	11
	Transmitter	18	10	19,8
GNSS	Antenna	7	5	7,35
	Board	22,6	5	23,73
Total		323,11	8,53	351,01

Power budget

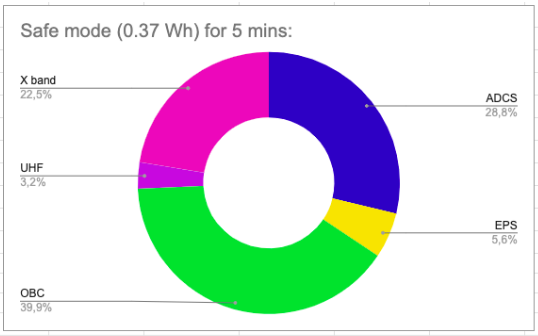
In the aim of fixing the power requirements for the EPS, a new power budget document with up-to-date values and traceability was created. In this document, only the battery output is

considered. The input and output are available on the mission design graphs. The updated values in this power budget are used for the mission design simulations.
The measure mode of 1 orbit considers that the CubeToF does a measurement of 1 orbit (1h50), the additional 56 minutes are required for conditioning, data transfer and standby.

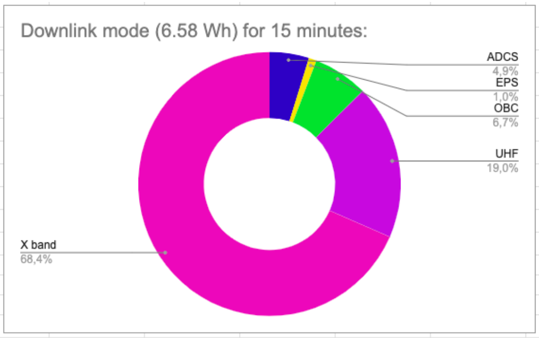
Measure mode 1 orbit		Total Energy		Voltage	Manufacturer
Component	Mode	Average	Unit		
ADCS	ON	3,54	Wh	3 or 3,3	CubeSpace
CubeToF	Measure op	21,05	Wh	12	UniBe
EPS	ON	0,69	Wh	-	EST
GNSS	ON	3,96	Wh	5	ETHZ
OBC	ON	4,91	Wh	3,3	EST
Structure	-	-	Wh	-	EST
UHF	idle	2,03	Wh	3,3	EST
X band	idle	1,39	Wh	12	EST
Total		37,58	Wh		
Number of orbits (N):	1				
Total Time (t):	166				



Safe mode: duration 5 mins		Total Energy		Voltage	Manufacturer
Component	Mode	Average	Unit		
ADCS	ON	0,11	Wh	3 or 3,3	CubeSpace
CubeToF	OFF	0,00	Wh	12	UniBe
EPS	ON	0,02	Wh	-	EST
GNSS	OFF	0,00	Wh	5	ETHZ
OBC	ON	0,15	Wh	3,3	EST
Structure	-	-	Wh	-	EST
UHF	idle	0,01	Wh	3,3	EST
X band	-	0,08	Wh	12	EST
Total		0,37	Wh		
Safe duration (t)	5				



Downlink mode duration t		Total Energy		Voltage	Manufacturer
Component	Mode	Average	Unit		
ADCS	ON	0,32	Wh	3 or 3,3	CubeSpace
CubeToF	OFF	0,00	Wh	12	UniBe
EPS	ON	0,06	Wh	-	EST
GNSS	OFF	0,00	Wh	5	ETHZ
OBC	ON	0,44	Wh	3,3	EST
Structure	-	-	Wh	-	EST
UHF	idle	1,25	Wh	3,3	EST
X band	-	4,50	Wh	12	EST
Total		6,58	Wh		
Downlink duration (t)	15				



Link budget
Insert Table

System Architecture
Another goal of this year was to freeze important parts of the systems' architecture. General focus was thereby set on the placement of the subsystems as well as the configuration of the solar panels. In order to make decisions, different trade-off analyses were carried out.

- **Solar panel configuration**
  Initially, the team had always planned to utilize a vertical solar panel configuration. However, concerns were raised by both payload providers regarding. In the vertical configuration, the solar panels would be positioned above the spectrometer's eye and at least one of the GNSS antennas. The main concern was that if the solar panels failed to deploy, the payloads could not operate. Consequently, the team conducted a thorough trade-off analysis to compare the vertical configuration with other

commonly used options for CubeSats. One of the main alternatives considered was the dove configuration. ….

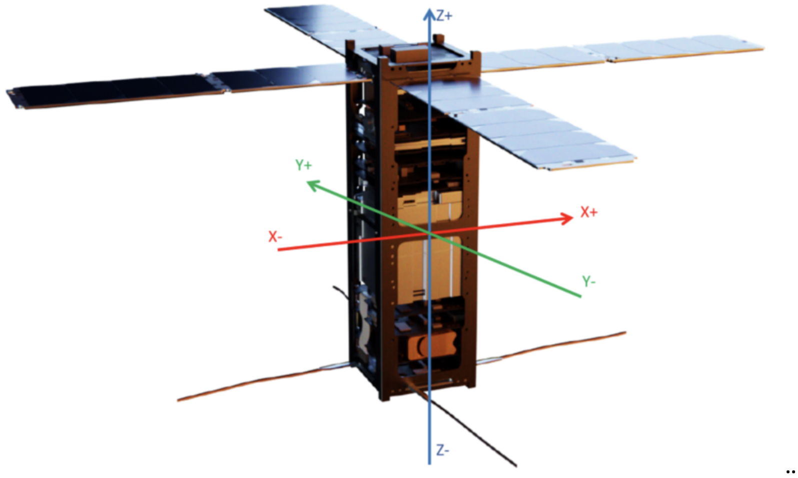
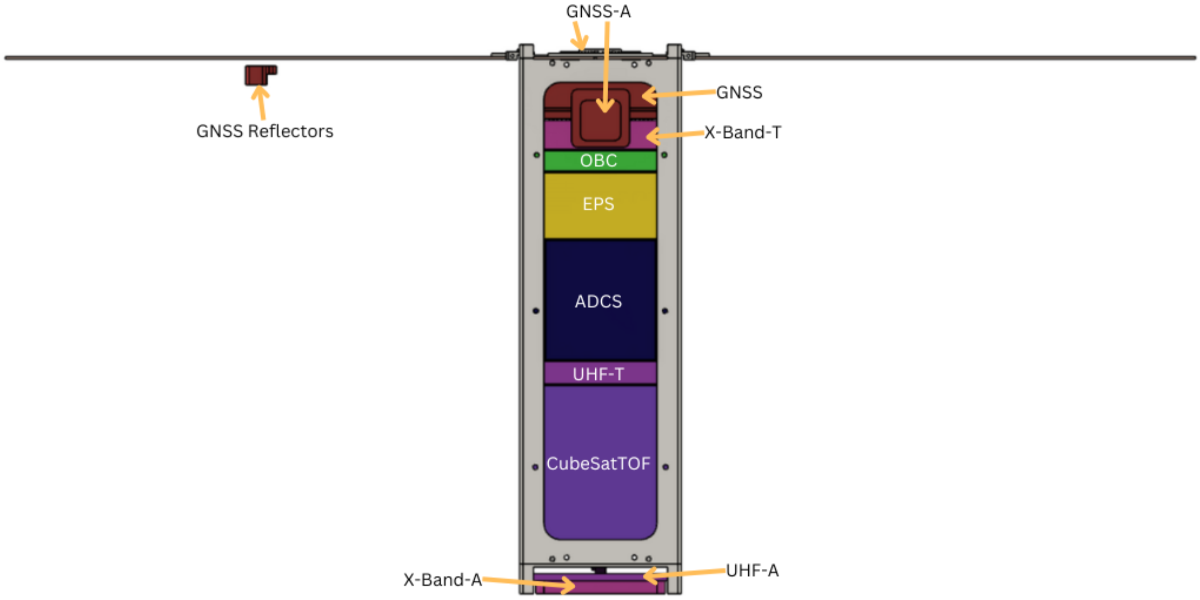


Figure 2: Vertical Solar panel configuration with axis convention

- **Subsystem placement**



1.2. What were some important lessons learned/challenges that came up?

Asymmetrical progress of Subsystems

One of the major challenges that the SE pole faced this year was that, since the change to the in-house platform, all subsystems were at early stages of development, meaning they were all moving forward with different speeds. It was therefore difficult to take design decisions, since a lot of information was either not yet available or dependent on the development of another subsystem.

Requirements Management

One important challenge that came up and is still not resolved is the management of the requirements. Previously, the platform Valispace was utilized for this purpose. However, due to the platform's complexity and the cancellation of student trainings provided by Valispace, the decision was made to discontinue its use and instead work with Excel. For the moment, given the relatively limited number of requirements, Excel proves to be a suitable program that everyone is familiar with. However, as the number of requirements increases in the future, there is a likelihood of losing the overall picture since Excel lacks the capability to effectively link requirements together. Therefore, it becomes crucial to consider either hiring a dedicated student that puts a lot of time in the management of Valispace or explore alternative platforms that are easier to use.

1.3. What are the goals for next semester/year?

PDR

In order to move to the next stage of the CHESS pathfinder 1 mission, the goal is to have a preliminary design review by the end of the fall semester 2023. Fundamentally, what the team hopes to gain from a PDR is a thorough evaluation of the design approach. Meaning a review of the current progress, risks, and compatibility of sub-systems with each other, and with the requirements. The operational effectiveness of the system shall be demonstrated by establishing a good configuration baseline compatible with the project’s objectives, schedule, and budget. The task of the SE pole will thereby be to provide the framework for the review. This will include:

- Requirements
- Interface control documents (ICD’s)
- Risk assessment
- CONOPS
- Projects time frame
- Mass budget, Height budget, Power budget, Link budget
- System's architecture

Level 3 Requirements

In order to successfully complete the PDR, the requirements have to be defined until subsystem level (Level 3). The work on redefining the requirements has already started in the spring semester 2023, however, a lot of technical details are still unknown from the subsystems, and therefore they cannot be finished yet.

2. Mission Design

2.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Notes: Show details from the thermal analysis: external temperatures from the orbits.
Structure will provide the subsystem level details.
Treat the satellite as a single homogenous object and let structure handle the detail.

2.2 What were some important lessons learned/challenges that came up?

2.3 What are the goals for next semester/year?

3. Structure

3.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

Notes: Mission design is providing details about the thermal environment: provide graphs relating to every subsystem and how do you plan to dissipate the heat. Is there any spacing needed and why: derive requirements from there.

To what extent can we push for the mech interfaces: mounting holes and connector. Spacers?

3.2 What were some important lessons learned/challenges that came up?

3.3 What are the goals for next semester/year?

4. EPS

4.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

4.2 What were some important lessons learned/challenges that came up?

4.3 What are the goals for next semester/year?

5. ADCS

5.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

Notes: Focus on the control algorithms and the design choices for the sensors – what is the overall precision

5.2 What were some important lessons learned/challenges that came up?

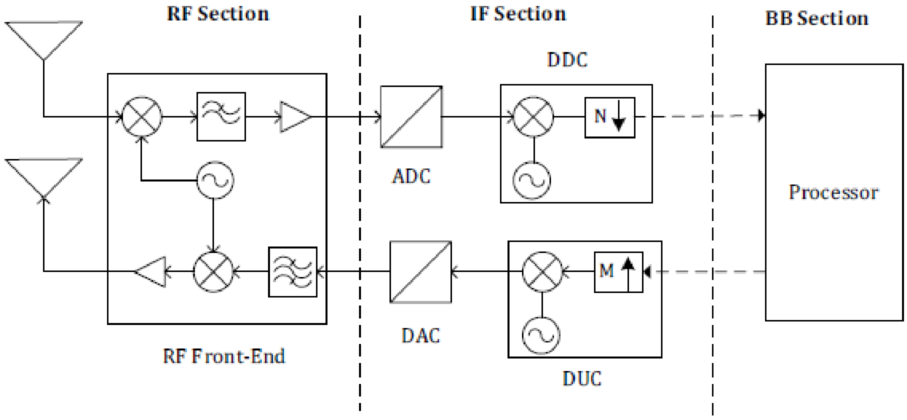
5.3 What are the goals for next semester/year?

6. Telecom

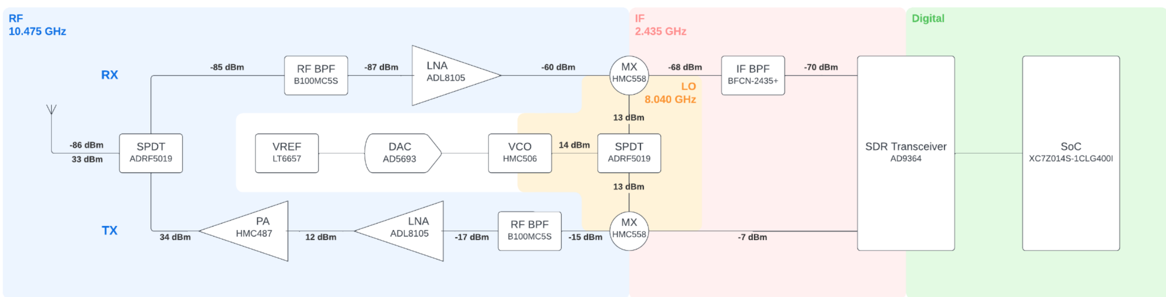
6.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Radio Jerry X-Band Transceiver

Since the transition to an in-house platform, the telecom subsystem saw the creation of a new component: a high-data-rate X-band transceiver. In the context of CHESS, this component will allow for fast downlinking of the data gathered by the scientific instruments of the CubeSats in the X-band amateur satellite frequency band at 10.45 to 10.50 GHz. The radio amateur spectrum was chosen to allow for a more flexible process in the frequency allocation process, circumventing the lengthy ITU frequency coordination process required for commercial X-band frequencies around 8 GHz. As no COTS components are readily available for the targeted frequency band, a fully custom solution is being developed.

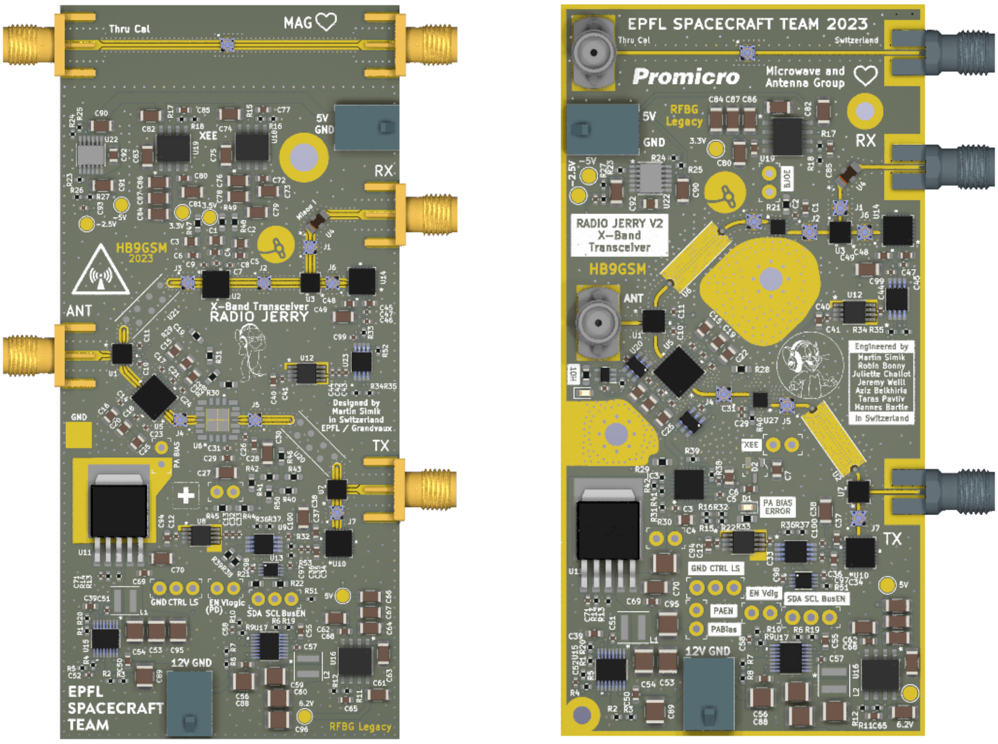


General hybrid receiver architecture block diagram



X-band transceiver block diagram, indicating power levels

The underlying architecture is designed to be modular and flexible, allowing for adaptation of the module for various use cases. At its core, a fully integrated software-defined radio (SDR) IC is used, linking the digital and analogue sections of the transceiver. On the digital side, a system-on-chip (SoC) interfaces with the transceiver and executes the necessary modulation/demodulation and coding/decoding algorithms. The radiofrequency front-end is customised for the targeted 10.45-10.50 GHz frequency band but could be easily adapted for other frequency bands. For prototyping and development purposes, the RF components are housed on the *Radio Jerry* PCB.



Radio Jerry RF front-end design iterations V1 & V2

On the software side, the necessary digital signal processing algorithms were developed, enabling the integration between the various components and ensuring communication with external subsystems. A standard quadrature amplitude modulation (QAM) scheme was chosen due to its widespread use in space systems. A ½ coder/decoder is added for error detection and correction, enabling highly reliable communication between space and ground.

6.2 What were some important lessons learned/challenges that came up?

The complexity of the transceiver was subdivided into multiple sections on multiple boards to allow for decoupled hardware and software development. This approach allowed for an iterative design philosophy of the RF front-end with rigorous testing at each iteration, converging at an optimised final design.

6.3 What are the goals for next semester/year?

In the near term, throughout the next months, the transceiver system shall be fully integrated, accommodating all sections on custom PCBs. In addition, the simulation and development of a matching antenna for the targeted frequency band shall be brought to a conclusion.

Regarding the telecom system in general, more focus shall be put on the UHF transceiver system. With the recent decision to use flight-proven COTS components in UHF, the necessary tradeoffs between different commercial components shall be made and the chosen transceiver and antenna be procured and tested.

7. OBC

7.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

Notes: Provide a detailed definition of the USB interface and what has been done with ethernet for TOF. How many USB devices can you handle, signal integrity checks, is there a need to protect the cables – shielding. Don't forget the UART link to UHF and solar deployment.

We need numbers on the data rates and their relation to the CONOPS: minimal time of data processing from TOF to the rest and if needed derive requirements on the preprocessing of the science data before reaching the OBC.

7.2 What were some important lessons learned/challenges that came up?

7.3 What are the goals for next semester/year?

8. Flight Software

8.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

//WIP TODO finish

Biggest milestones :
- Learn to use F’
- Yocto running on the dev board with F’ ref app running on top
- First definition of F’ topology for Lynx (will serve as basis for CHESS), to be confirmed once we have a prototype finished.
- Semester project (ongoing) on F’ with Xband module, general idea
    - Xband module expose a generic serial USB interface (hopefully recognized by generic drivers), HID or else (not sure)
    - when OBC estimate it should be in a communication window it sends a data packet to the Xband module and the Xband module confirms once it is sent.
- communication protocol with other subsystem will be defined more clearly later (and once we have done some experimentation with the Xband module) but the general idea stay the same : a serial communication where the OBC sends commands and the module respond (may add commands/events sent from the module if needed)
- are CONOPS defined somewhere if yes gimme
- dataflow diagram (TODO include topology diagram)
- packet size, will in more details how the F’ communication protocol works for a first estimation (more precise data once we finish the prototype I guess)

Notes: Don’t be stuck at the yocto definition : provide the protocols of communication with every subsystem (preliminary) and how do you want to treat them according to the CONOPS.
Provide a diagram that shows data flows from the acquisition to the downlink. No need to spend much time on the ground segment though, only focus on the state machine. Give a priori estimation of the file and command sizes because this is a limiting factor.

8.2 What were some important lessons learned/challenges that came up?

8.2.1 we need good documentation
8.2.2 pole lead = teacher for new member ?
8.2.3 getting new member up to speed takes time, specially when everybody is learning and there is no clear global picture
8.2.4 pole lead needs to be only pole lead
8.2.5 no time
8.2.6 working a little time each week is hard (forget from one time to another, summer “block” work will likely be more efficient)

8.3 What are the goals for next semester/year?

8.3.1 Goal for this summer

8.3.1.1 finish prototype of the software

8.3.1.2 write good documentation for new members + F’ crash course + git crash course ?

9. Ground Segment

9.1 What are the biggest milestones that have been achieved this year? (since going with an in-house platform)

Projects

9.2 What were some important lessons learned/challenges that came up?

9.3 What are the goals for next semester/year?