DJIBOUTI SPACE PROGRAM

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PAPER

The Republic of Djibouti has decided to set up a space program. The objective of this program is twofold: Take benefit from transfer of technology to Djibouti in the field of nanosatellites & develop concrete applications in the framework of the protection of Djibouti environment preventing impacts of climate changes and developing the national economy.

Following a partnership signed with the University of Montpellier, ten Djiboutian students were sent for training to acquire the knowledge and know-how of space systems. After graduating, the students joined the University of Montpellier Space Center (CSUM) to design a 1U Cubesat Space Mission. Phase O and A were run from March to July 2021. Then, an engineering model of DJIBOUTI-1A, a 1U type nanosatellite was assembled, based on the CSUM 1U platform and a payload developed by Expleo group. The project is currently in phase C/D, flight model being expected very soon.
As for the Mission Control Center in Djibouti, it is already operational.
The launch of DJIBOUTI-1A should take place in Q4(2022) or Q1(2023). In the process, a second 1U type cubesat is scheduled for launch in 2023.
The primary mission objective consists in collecting climatology data from ground terminals in store and forward mode.
In the future, other 1U cubesats and larger nanosatellites (3U, maybe 12U type) should be launched for much larger applications such as quality imagery.

1. The DECISION, the MOTIVATIONS and the STAKES

In January 2020, the decision was taken to launch a Djiboutian space program.
At the origin of this decision, there are:
• An awareness that the costs of these technologies are now affordable, even for a small country
• A desire of the Head of State to provide Djibouti with all the technologies that can contribute to its development
• A desire to acquire complete knowledge and know-how (from the definition of a space mission to the production of CubeSats) and not the commercial acquisition of satellites
• A desire to exploit the pool of skills within the University of Djibouti and the Center for Study and Research of Djibouti.

Figure 1. Kick-off meeting at the Presidency of the Republic

The challenges of launching a space program:

1 - Between skepticism and pragmatism:
• To test technologies and take advantage of them for economic development: space must be a development tool and not an end in itself.
• To demonstrate the useful spin-offs to put an end to skepticism (encourage the adhesion, the collaboration of public/private actors in Djibouti)
• To convince the public (citizens/decision-makers) that this funding devoted to space is not money thrown around…
• To Attract investors and partners.

2 - Access to knowledge:
Following the choice of technology transfer:
• To find a reliable educational, scientific and technical partner to access all the knowledge and know-how in a few years.
• To Train in space technologies and remote sensing
- know how to define data/image needs,
- know how to treat them and then exploit them.

2. The PARTNERSHIP

Two partnership agreements between MENSUR and the University of Montpellier were signed in 2020 then 2021 for hosting, training and technology transfer.

Figure 2. Signature of a partnership agreement between MENSUR and President Augé
Background: Mr. Gayssot of FVA and Pr. Dusseau of CSUM

While the training of Djiboutian students takes place at the IUT of Nîmes and at Polytech Montpellier, the design and production of the cubesats takes place at the Montpellier University Space Center supported by the Van Allen Foundation.

Figure 3. Visit to CSUM in 2021
(SG MENSUR – MENSUR – FVA president – DG CERD – CSUM director)

The partnership works as follows:

The MENSUR/ASD is the contracting authority, it relies on its HYDROSAT team to whom it provides the means and sets the objectives.
The HYDROSAT team is made up of five technicians and five engineers trained by UM and then supervised/advised by CSUM.
The HYDROSAT mission is based on the data transmission needs expressed by CERD.
The HYDROSAT team is also in contact with CSUM subcontractors such as Expleo and SDRT.

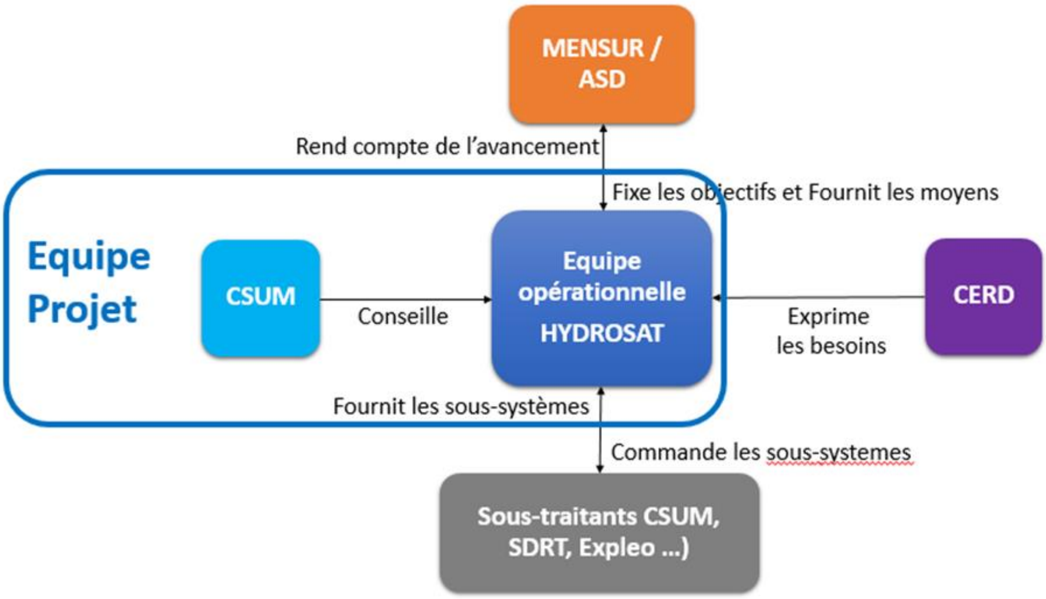


Figure 4. Organization of the partnership for the transfer of technology and the production of satellites

3. DJIBOUTI SPACE PROGRAM

Launched in 2020, the Djibouti space program consists of acquiring knowledge and know-how for the design and production of nanosatellites.
The first phase of this program consists of a training part at the University of Montpellier (from October 2020 to March 2021) followed by the HYDROSAT mission (design and production of the two DJIBOUTI 1A & DJIBOUTI 1B nanosatellites).

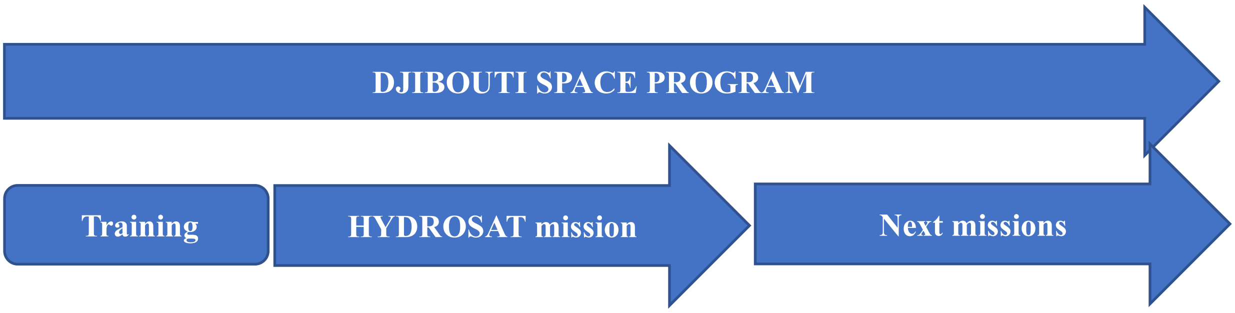


Figure 5. Djibouti space program and its first mission

MENSUR officials keep themselves regularly informed of the progress made.
The EM (Engineering Model) model is ready with its payload on March 17, 2022.

EM assembly and integration

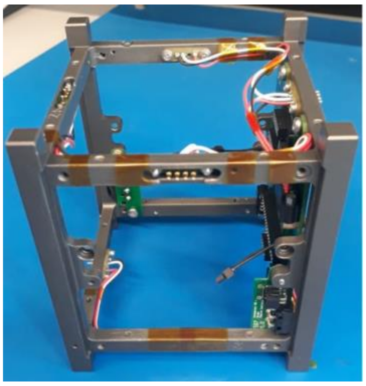


Figure 6. Harness, Motherboard, and Switch PCB Integration

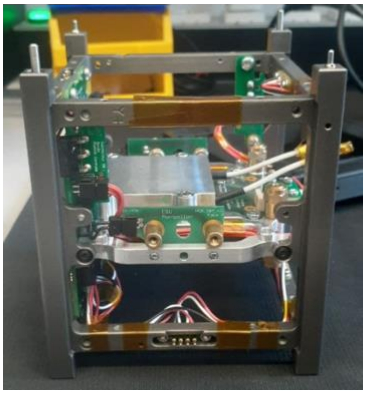
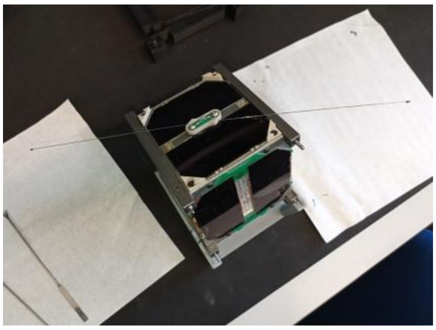
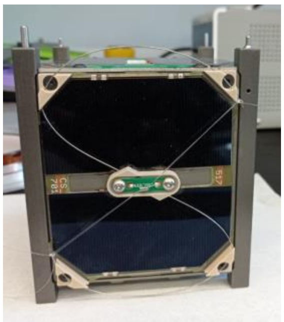


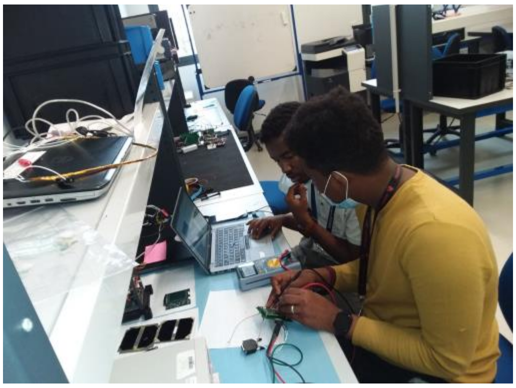
Figure 7. Integration of the side supports and the PCB of the antenna block, integration of the central plate, battery and the covers, integration of the deployment switches and the spacers

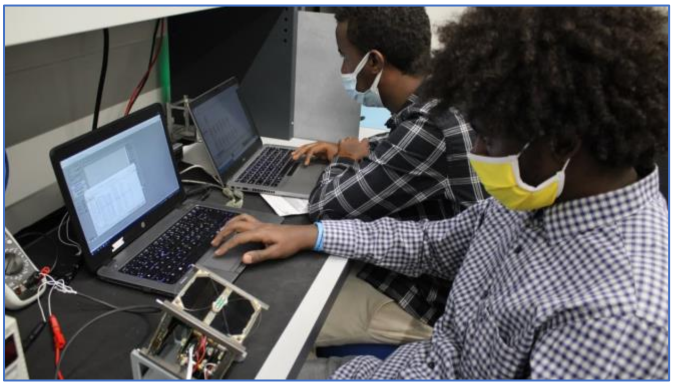
Figure 8. OBDH, EPS and TTC card integration, coaxial cable and interconnect card integration, faceplate integration.





Figures 9 & 10. Integration, fixing the antenna elements on the Y face, gluing the ends of the antenna and folding





Figures 11 & 12. Test in progress on one of the sub-systems of the platform, Functional test of the satellite

Figure 13. Presentation of the EM to the MENSUR

4. HYDROSAT MISSION

As part of the Djibouti space program, the HYDROSAT mission, which will be carried by two 1U type nanosatellites, began in 2021 and should be completed in 2025.
The Center for Studies and Research of Djibouti(CERD) wishes to receive data from isolated climatological stations

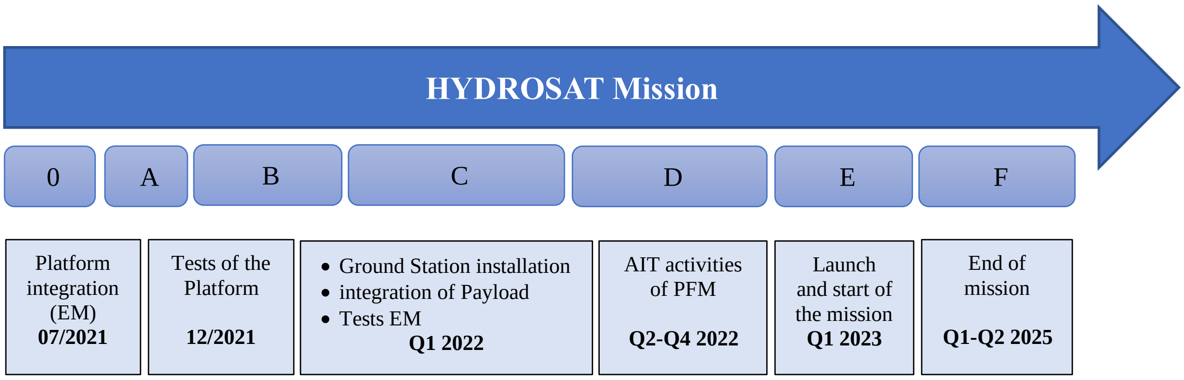


Figure 19. HYDROSAT mission phases

The primary mission objective consists in collecting data in store and forward mode.
The Prime Investigator is the Center for Study and Research of Djibouti, which will receive several times a day, data collected and transmitted by its numerous measurement stations spread over the national territory (climatology, hydrology, etc.).
The first mission that will be carried out by DJIBOUTI-1A and DJIBOUTI-1B (in reinforcement) is named HYDROSAT.

Orbital data

Both satellites will fly in LEO in order to provide the data.
DJIBOUTI-1A is intended to fly on an SSO orbit to allow passes over Montpellier and training of the Djiboutian team at CSUM.
DJIBOUTI 1B may be launched on an orbit with a much lower inclination to allow for a higher number of passes over Djibouti.

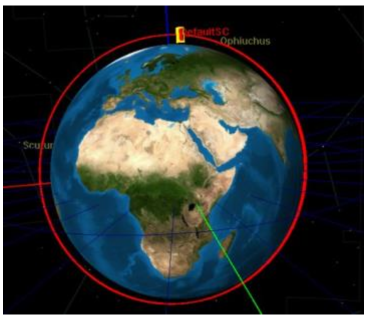


Figure 15. Orbit of DJIBOUTI-1A

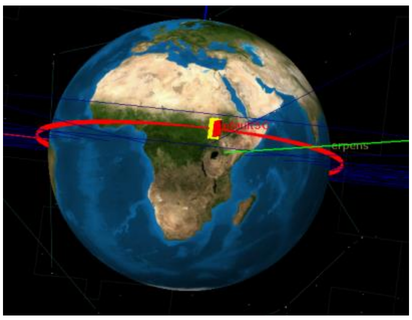


Figure 16. Orbit of DJIBOUTI-1B

Figure 17. Orbital data of DJIBOUTI-1A & DJIBOUTI-1B

SATELLITES	DJIBOUTI-1A		DJIBOUTI-1B
Ground Station	ASD	CSUM	ASD
Design orbit	550km@97.5°		550km@7°
Orbital Period (minutes)	95.31		95.5
Maximum number of pass (per day)	4	4	11
Minimum number of pass (per day)	2	2	4
Average number of pass (per day)	3 (2.6)	4 (3.5)	9 (9.1)
Maximum pass duration (seconds)	468.95	466.42	479.32
Average pass duration (seconds)	362.81	363.56	376.05

Figure 18. Patch of DJIBOUTI-1A

Figure 19. Patch of DJIBOUTI-1B

Mission compliance

The space segment shall comply with the applicable laws of the country operating the space segment. Satellites must not remain in protected area (LEO and GEO) for more than 25 years.
We used STELA to meet this requirement.

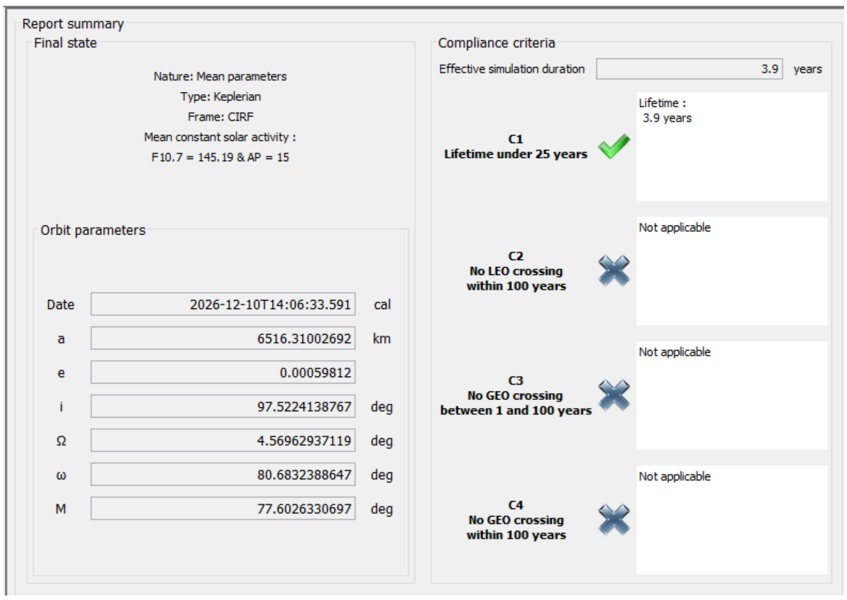


Figure 20. Screenshot of STELA

Mission lifetime

The nominal duration of the mission is 2 years, and the orbit shall allow the satellite to stay on orbit for 5 years. We used DRAMA to meet these 2 requirements and to determine the lifetimes of our 2 satellites.

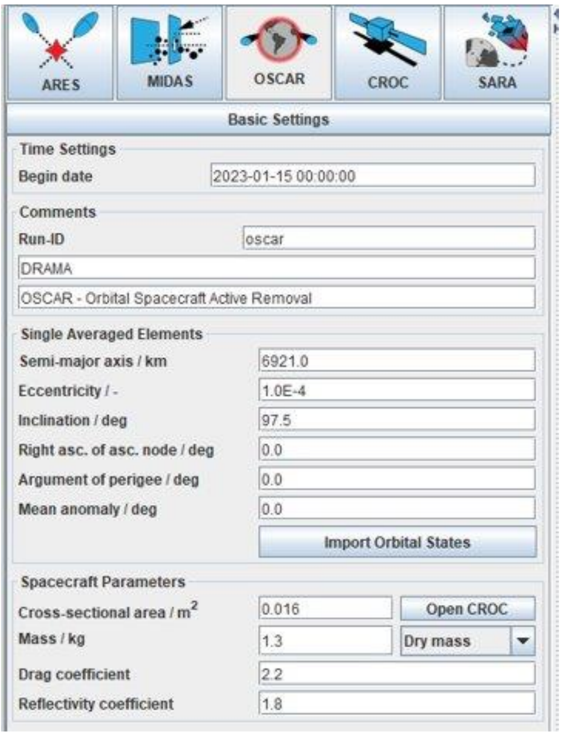


Figure 21. Screenshot of DRAMA

Figure 22. Lifetimes of our satellites

Satellites	DJIBOUTI-1A	DJIBOUTI-1B
Orbit	550km@97.5°	550km@7°
Lifetime (years)	4.87	3.42

Mission analysis

We used GMAT to simulate and analyze the number of satellites passes and their durations over Djibouti.

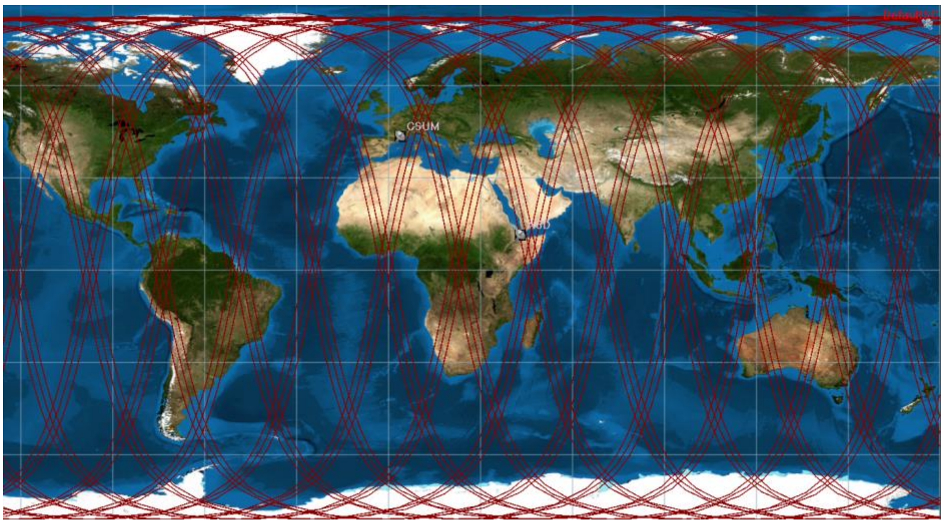
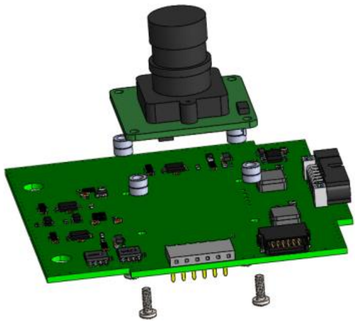
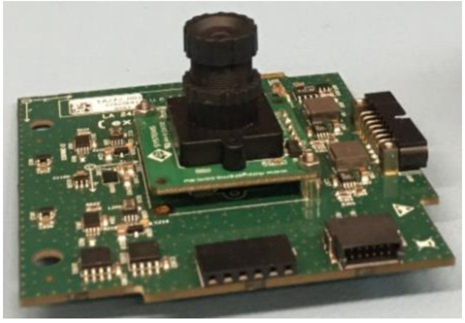


Figure 23. Image from GMAT of the 550km@97.5° orbital analysis for DJIBOUTI-1A

Payload parameters (developed by Expleo)


Figures 24, 25, 26 : CAD view of HYDROSAT payload, Standalone Payload, Payload integrated into CSUM platform

1 – Primary TM/TC:

- Interrogation of the measuring stations according to the order established in the interrogation loop after a command triggered by the OBDH.
- TC which enables and disables the interrogation of a measuring station.
- TC which allows activating and deactivating the interrogation of any given type of measurement station.
- The maximum amount of data to be collected by the payload: 4.2 Mb.

2 - Image capture:

- Resolution: 1 km/pixel
- Burst mode: TC or planned
- Image size ≤ 40 kB

Figure 27. Payload camera

3 - Physical Parameters:

- Dimensions: 80 x 80 x 31 mm^3
- Mass ≤ 325 g
- Average power ≤ 600 mW
- Maximum power ≤ 900 mW
- Gyroscope with accuracy of 5 °/s.
- Accelerometer with accuracy of 60 mg (1 g = 9.81 $m \cdot s^{-2}$)
- Temperature sensors with accuracy of 1.5 °C
- Sensor measuring the current consumption

4 - System architecture: Solution based on the EXPLEO legacy (ENSO payload)

The reuse of technological bricks:

- Interface card / MCU compatible ROBUSTA 1U V.3.5 platform
- Integrated latch-up protection system
- Camera identical to the ENSO payload model (COTS)

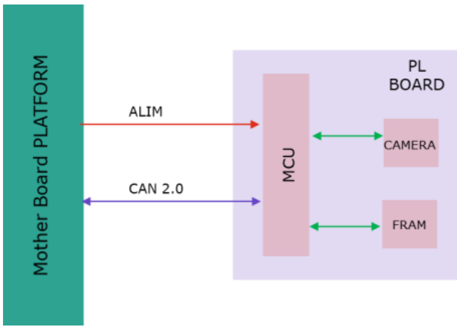


Figure 28. General overview of the HW solution: re-use of the ENSO cubesat architecture

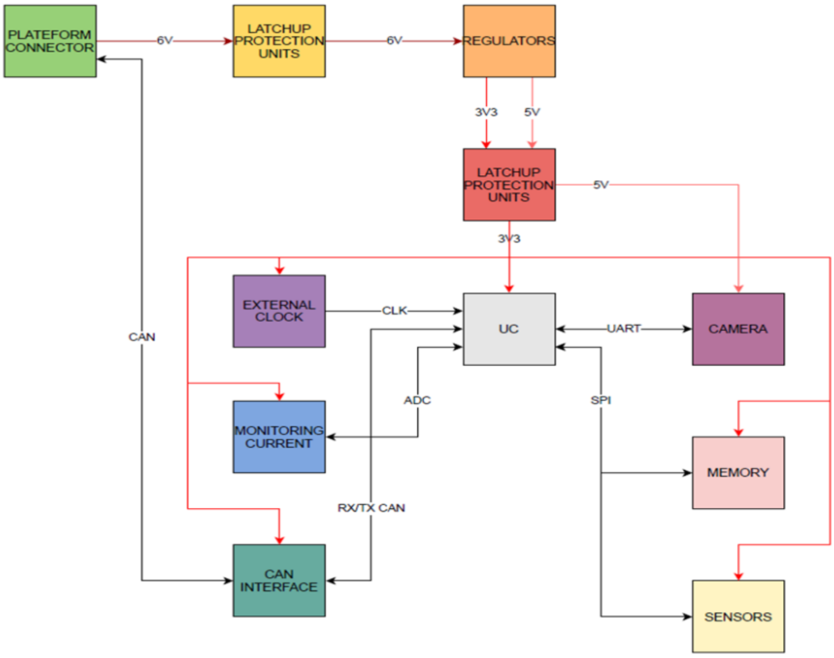


Figure 29. General overview of the HW solution: re-use of the ENSO cubesat architecture

HYDROSAT Team

The training

Djibouti sent ten carefully selected students to training in Montpellier to acquire the knowledge and know-how of designing and building space systems.
Five of them validated a Bachelor (Assembly, Integration, Test), the other five an Advanced Master in Space Systems Engineering.


Figures 30 & 31. The students at CSUM in 2021

Supervision

After the theoretical tests, they all completed their end-of-training internship (3 months) at the CSUM. The five AIT technicians trained there for the various tasks that await them (assembly, wiring, software, telemetry, integration of harnesses, etc.) on the latest nano-satellite of Montpellier University (Robusta 3A) which will soon be launched.
The five engineers, for their part, trained there on satellites already in orbit (Robusta 1A & 1B) and there began the definition of the mission (phases 0 and A) of the DJIBOUTI-1A, the assembly of which began in September 2021.
The training, both theoretical and practical, is rigorous and very professionalizing and the working environment is ideal in contact with recognized experts in the field of nanosatellites.
The tasks entrusted to them are numerous, complex and inspired by reality (eg designing all the software for our satellite) and they also train in the management of a ground station and a mission control center.
They are also in contact with the subcontractors (payloads, etc.) and the end users of the data collected by the satellites (the CERD) in order to finalize the information on the stations (transmitters, speeds) whose data will be transmitted to the satellite.

Figures 32 & 33. HYDROSAT team with MENSUR, CSUM & FVA managers

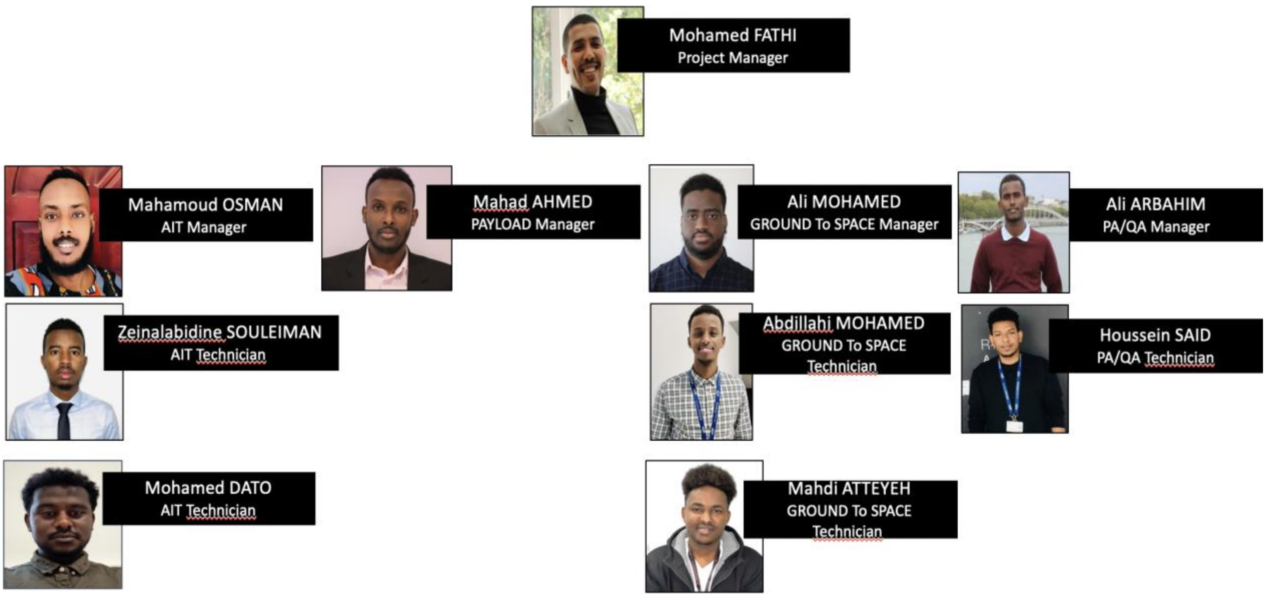


Figure 34. HYDROSAT team

5. SYSTEM DESCRIPTION

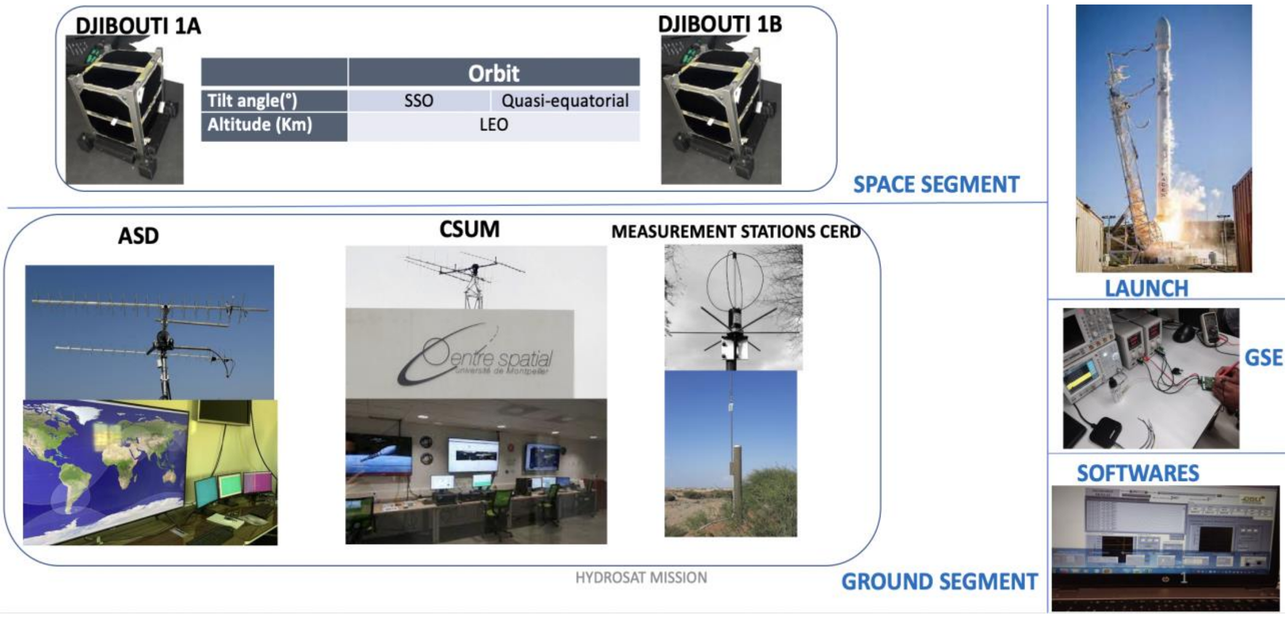


Figure 35. System description

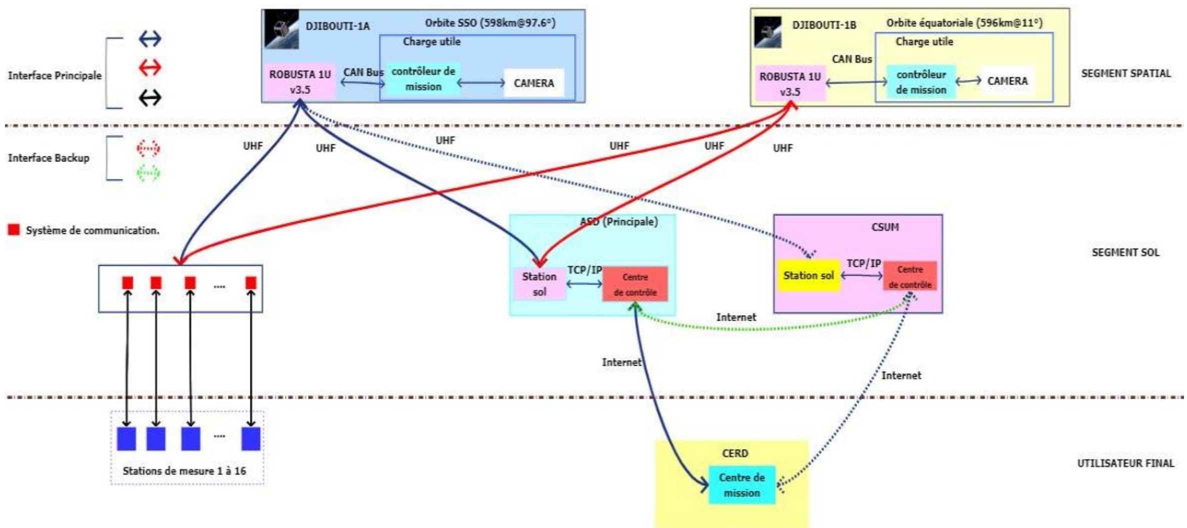


Figure 36. Communication between the project components

Housekeeping, Telecommands and scientific data are transmitted under UHF band.

6. PERSPECTIVES

We are already preparing the future. For this, we are:
- Prospecting for other possible applications for 1U nanosatellites (the technology of which we now master): we are currently studying the possibility of semi-delayed monitoring by geolocalisation of several thousand trucks on the Djibouti-Ethiopian corridor. The 1U cubesats, due to their transmission capacities and their low costs, offer attractive solutions.
- Prospecting for other possible applications for larger nanosatellites (eg 3 up to 12U) that we could develop: multispectral imaging interests us because of the many applications it allows. From urban planning management to mining research, the possibilities are endless.
- Seeking for promising markets: currently, the State of Djibouti, which is the only investor in the program, is also the only beneficiary of the data transmitted, but we hope that when our capacities have been demonstrated, private actors will take an interest and invest in order to benefit from the possibilities offered.

First success recorded: in June 2021, the Djiboutian space program was already noticed by participating in the competition organized by Arianespace to benefit from a free orbiting. The HYDROSAT mission was then distinguished by its place among the six finalists of the competition.

7. APPENDICES

Acronyms & abbreviations

MENSUR	Ministry (or Minister) of Higher Education and Research
ASD	Djiboutian Space Agency (not yet formally created)
HYDROSAT	Name of the mission carried by the 2 cubesats
CERD	Center for Studies and Research of Djibouti
UD	Djibouti University
UM	Montpellier University
CSUM	Montpellier University Space Center
FVA	Van Allen Foundation
SDRT	SDR Technologies (radio link subcontractor)
EXPLEO	Payload subcontractor
EM model	Engineering Model : Functionally compatible with the flight models
PFM model	Protoflight Model

Personnalities

<u>From Djibouti</u>

President of the Republic	HE Mr. Ismail Omar Guelleh
MENSUR	HE Dr Nabil Mohamed Ahmed
SG MENSUR	Mr. Aboubaker Hassan (Space program director)
DG CERD	Dr. Jalludin Mohamed
President UD	Dr. Djama Mohamed

<u>From Montpellier</u>

FVA President	HE Mr. Jean Paul Gayssot
UM President	Pr. Philippe Augé
CSUM Director	Pr. Laurent Dusseau