D-SAT MISSION: an In-Orbit **Demonstration** of Satellite Controlled Re-entry

Alessio Fanfani

Clean Space Industrial Days
October 26th 2017 – ESA-ESTEC

D-ORBIT
NEW SPACE SOLUTIONS

D-SAT

Mission Description

THE MISSION

D-SAT HAS BEEN DESIGNED TO BE THE FIRST SATELLITE TO BE REMOVED IN A QUICK, SAFE AND CONTROLLED WAY BY AN INDEPENDENT DECOMMISSIONING DEVICE

D-SAT is a miniaturized satellite featuring a zero-single-point-of-failure and full redundant architecture. It hosts two experiments that are tested during the first two months of operations in orbit.

D-ORBIT DECOMMISSIONING DEVICE (D3)

AUTONOMOUS

Power and telemetry-independent from the host satellite during the decommissioning maneuver

FLEXIBLE

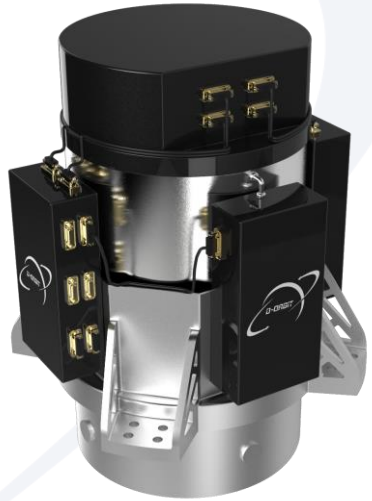
Compact design, easier to be integrated in satellite system and customizable to customer's need

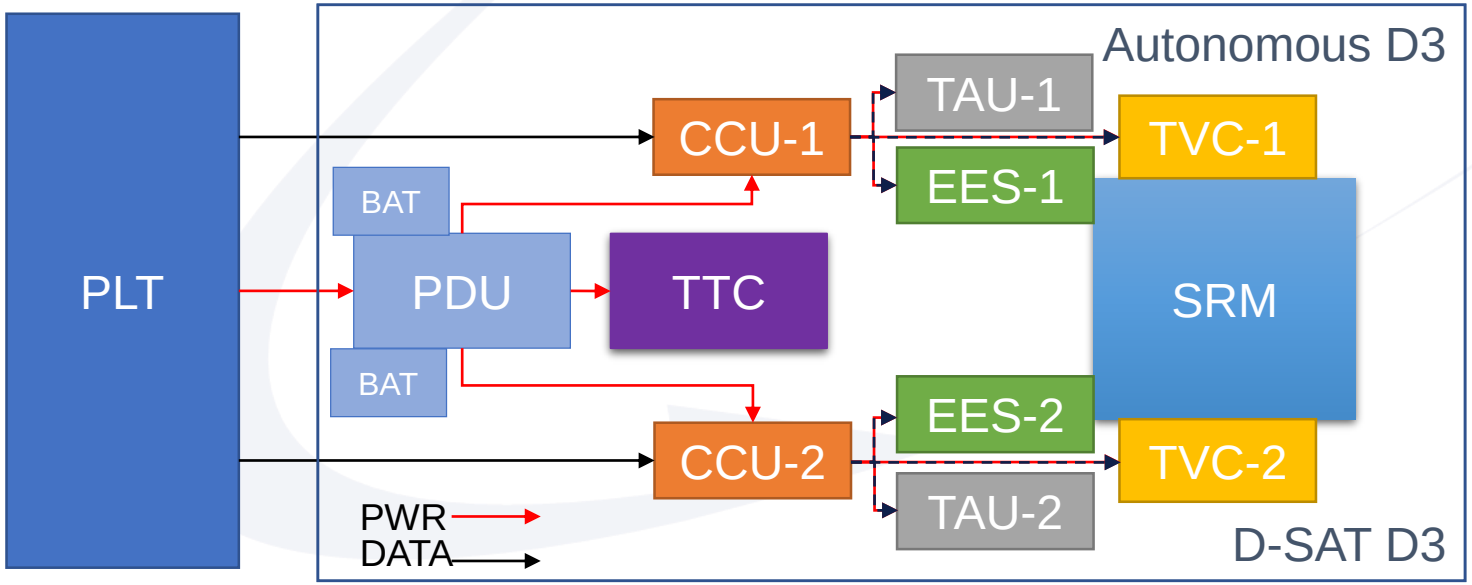
RELIABLE

All the most sensible subsystems have already reached space qualification

SAFE

Complaint with the major safety standard and requirement NASA, ESA and MIL-STD





CDF ESA CleanSat Technology Assessment:

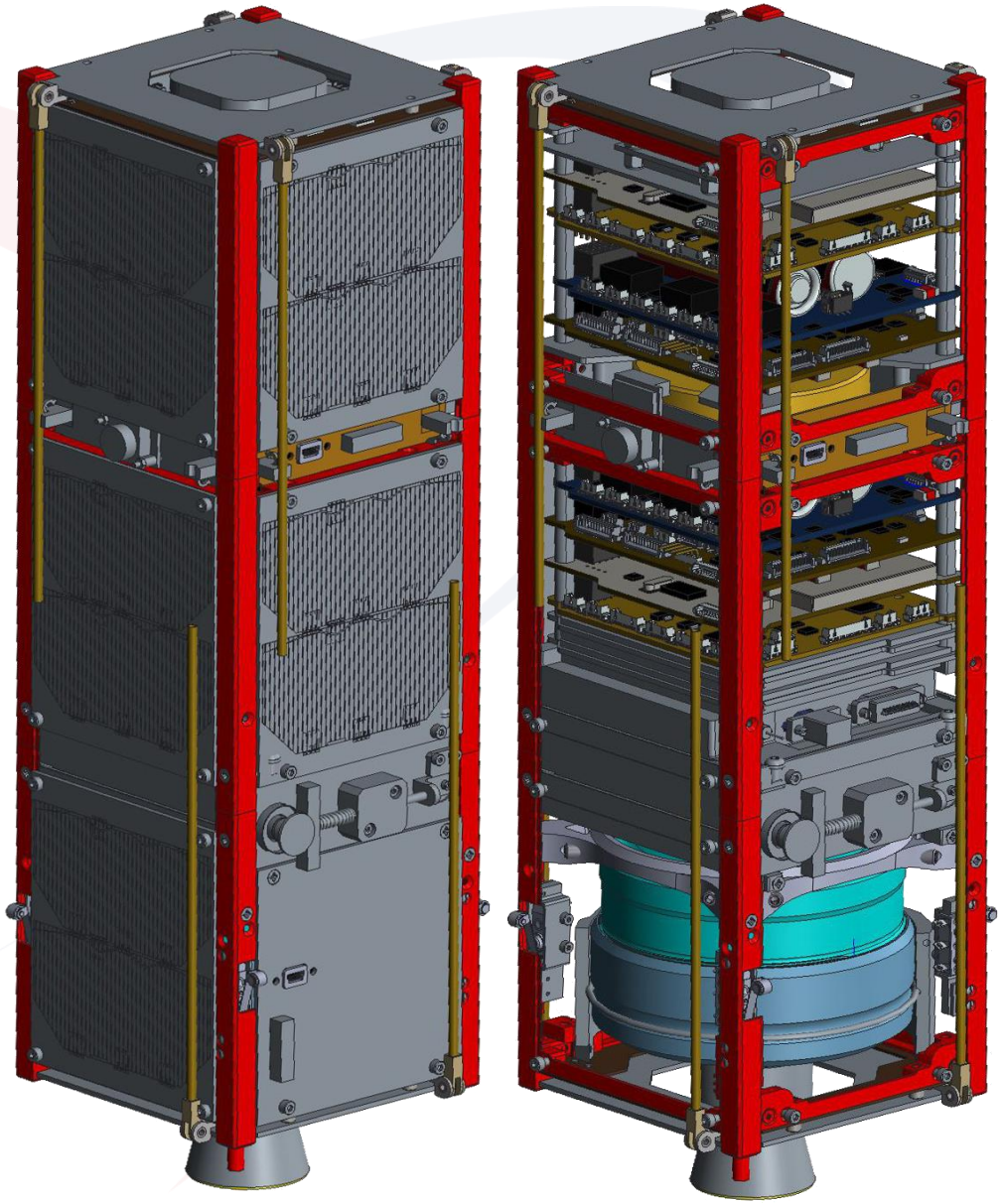
Building Block 14 - Autonomous De-Orbit System

THE SPACECRAFT

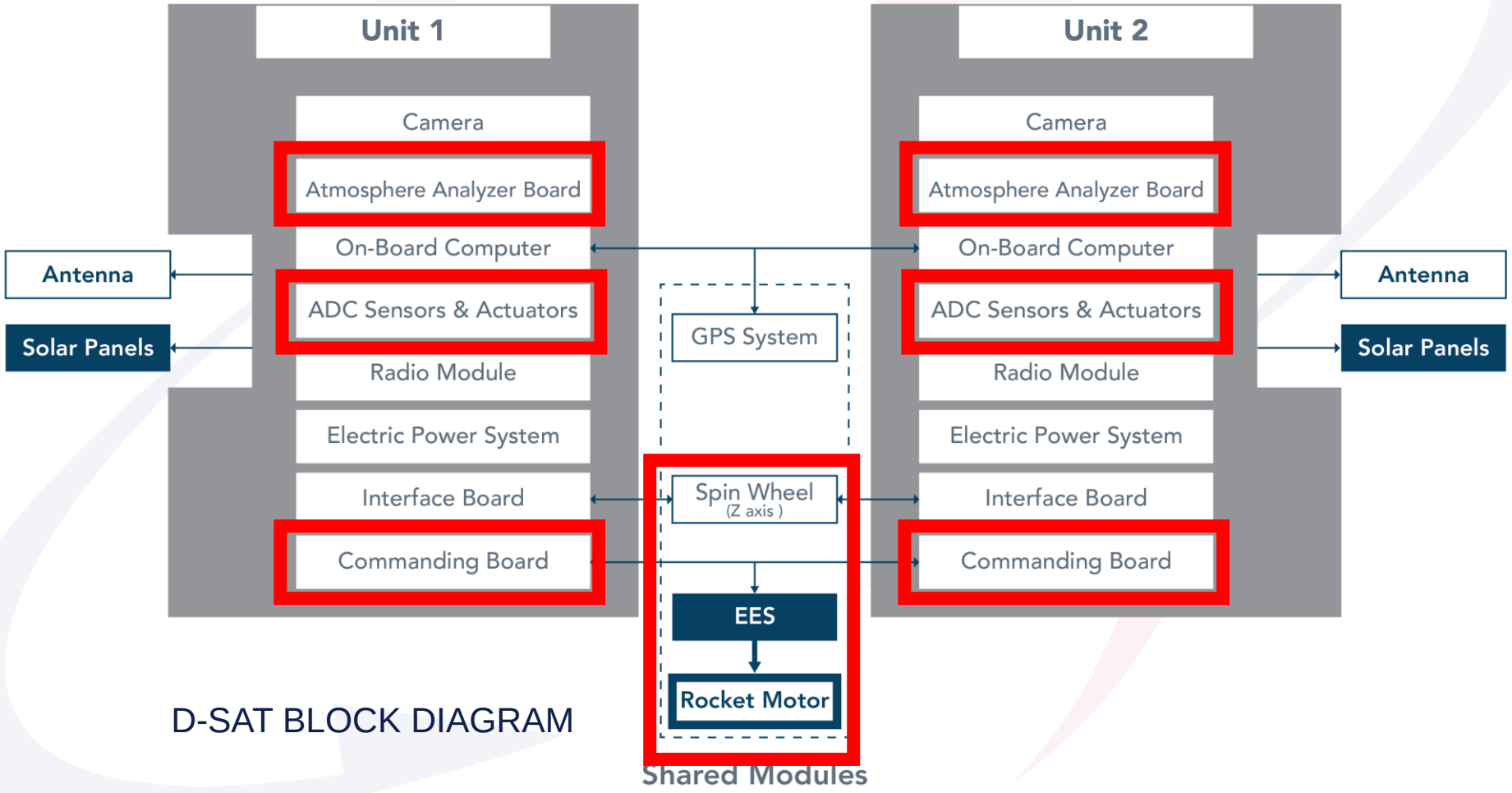
- D-SAT is a 4,3 kg nano-satellite (100x100x340 mm) composed by two main elements:

- the **Platform**, a complete, standard CubeSat system;

- the **Decommissioning Device**, with an independent electric power system, on-board computer and attitude determination and control system. The decommissioning device features a Decommissioning Motor, to provide the propulsive thrust for the deorbiting maneuver.



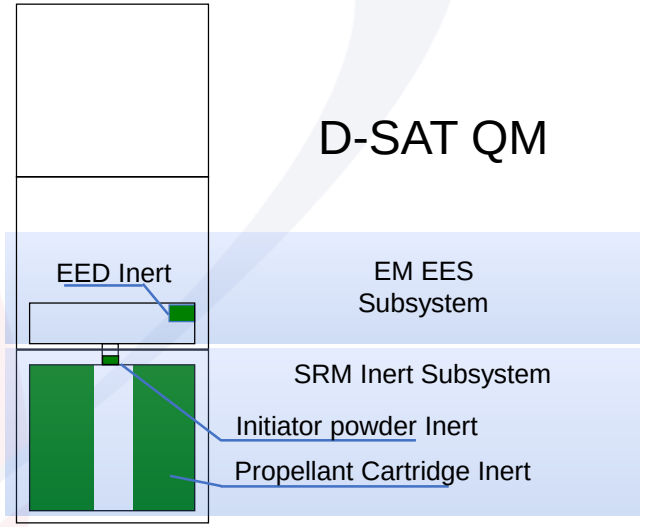
THE SPACECRAFT



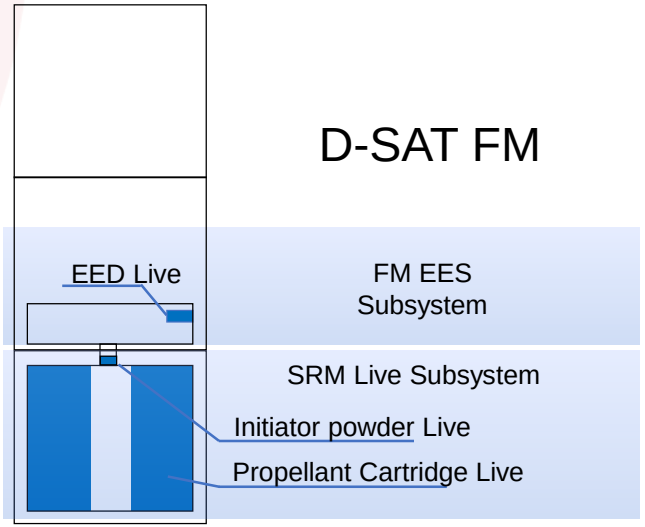
D-SAT BLOCK DIAGRAM

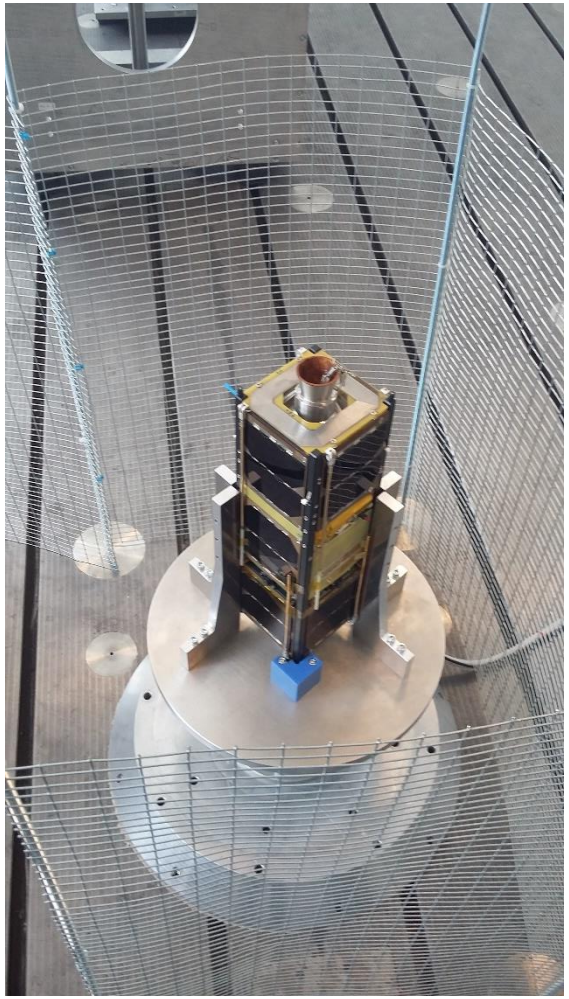
D-SAT VERIFICATION PLAN

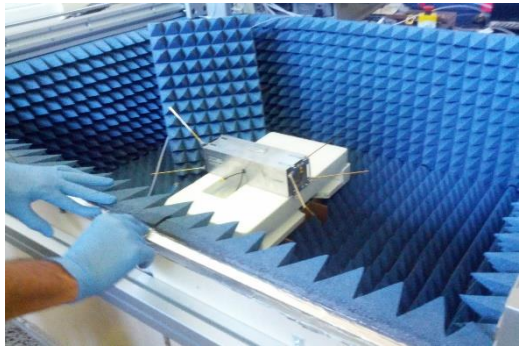
Who perfomed Qualification tests?

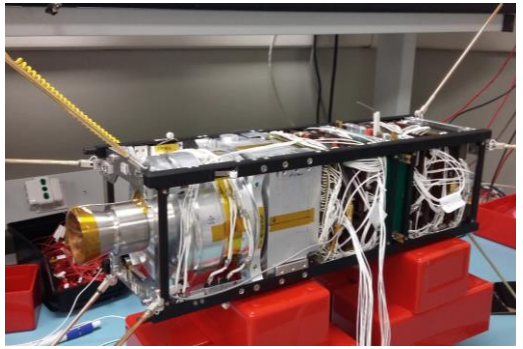


Who perfomed Acceptance tests?









Acceptance

Q4 2016

Launch

PSLV C-38

23rd June, 2017

D-SAT

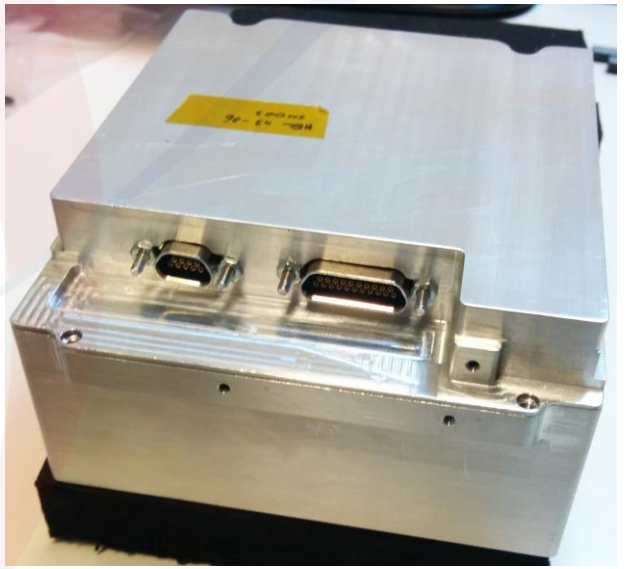
Innovative Sub-system

D-SAT - ELECTRO EXPLOSIVE SYSTEM (EES)

EES function is to ignite the rocket motor through an Electro Explosive Device (EED) in a safe and controlled way.

MAIN FEATURES:

- Designed according to MIL-STD-1576 standard
- Mechanical barrier with a double lock architecture
- Four electronic barriers to avoid inadvertent EED ignition
- Hermetically sealed metallic box against EMI, humidity, explosive atmosphere and external fire
- Safing plug connector and additional mechanical provision for a safe ground handling
- Operate temperature range -34 / 71°C
- Cubesat Form Factor

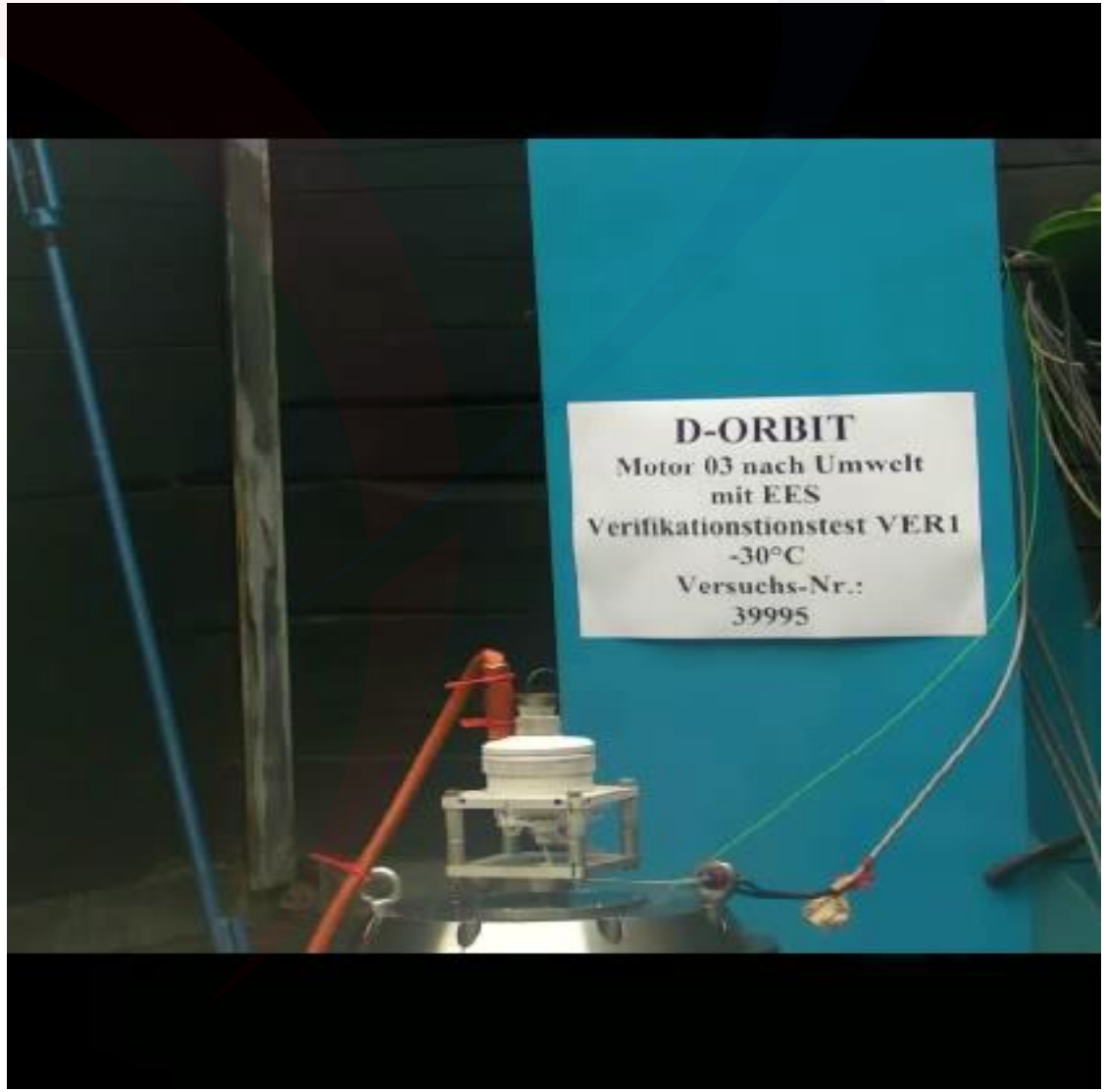


D-SAT - SOLID ROCKET MOTOR (SRM)

D-SAT propulsion system consists of a small Solid Rocket Motor delivering about 750 Ns total impulse to the satellite. It uses about 300 grams of **non-metalized** composite propellant based on ammonium perchlorate (AP) and binder (HTPB).

CONSTRAINT:

- Fixed nozzle: Thrust-vector control systems didn’t satisfy programmatic and technical requirements. It imposed D-SAT to be spin-stabilized during firing and strict mounting tolerance.



D-SAT – SRM ALIGNMENT TEST

REQ: The alignment error between SRM Nozzle axis and D-SAT’s CoG shall be lower than 1.5 mm

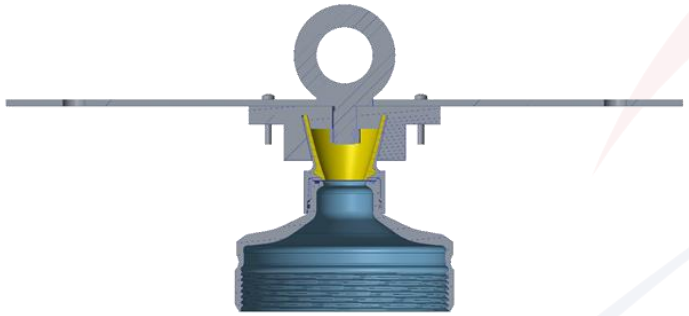


Fig. 1: Testing Tool

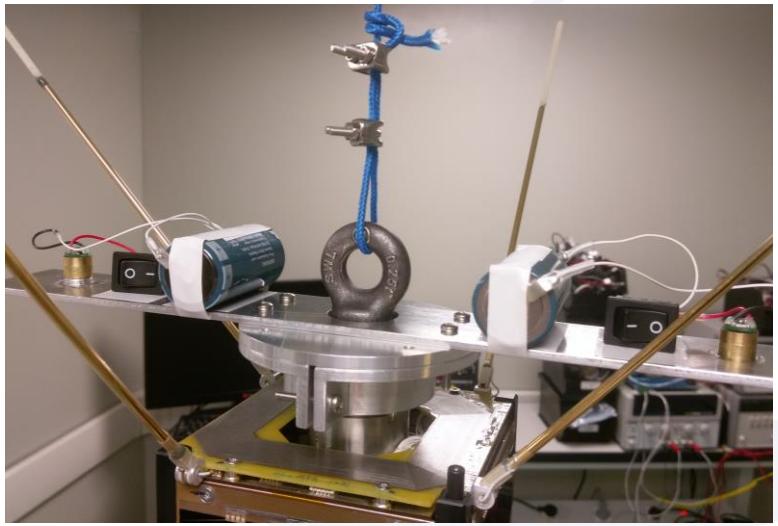


Fig. 2: Final Assembly alignment

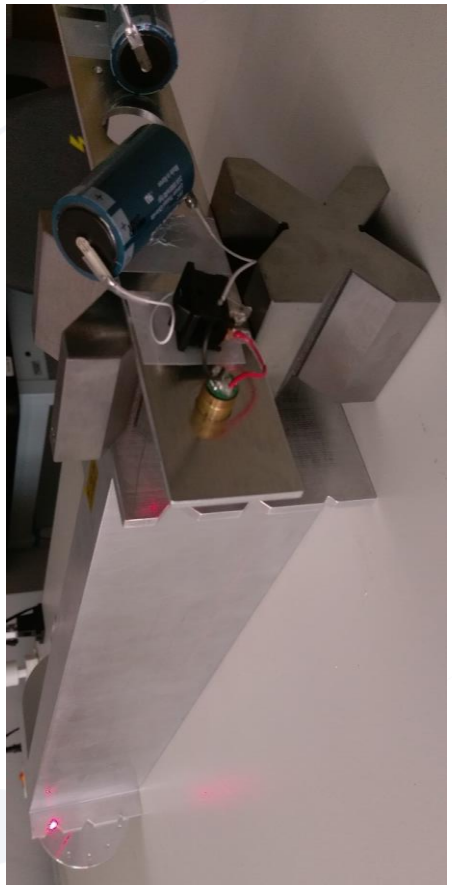
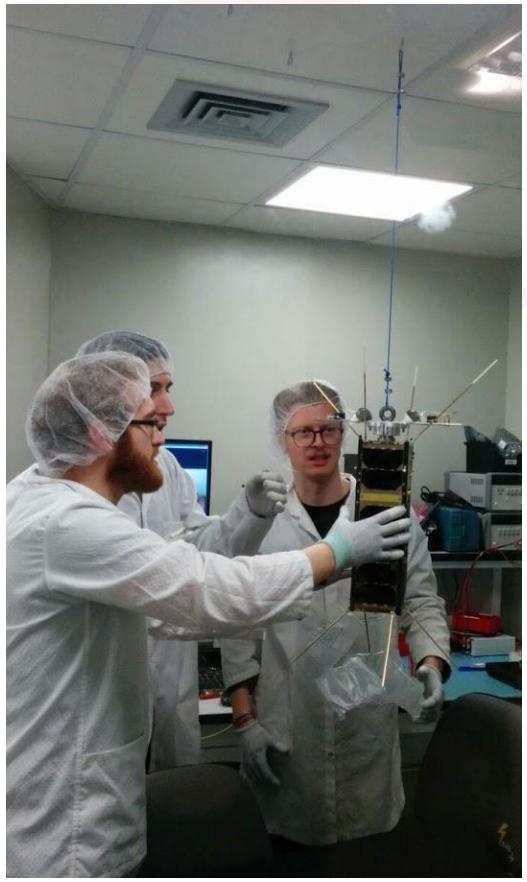


Fig. 3: Lasers alignment Check



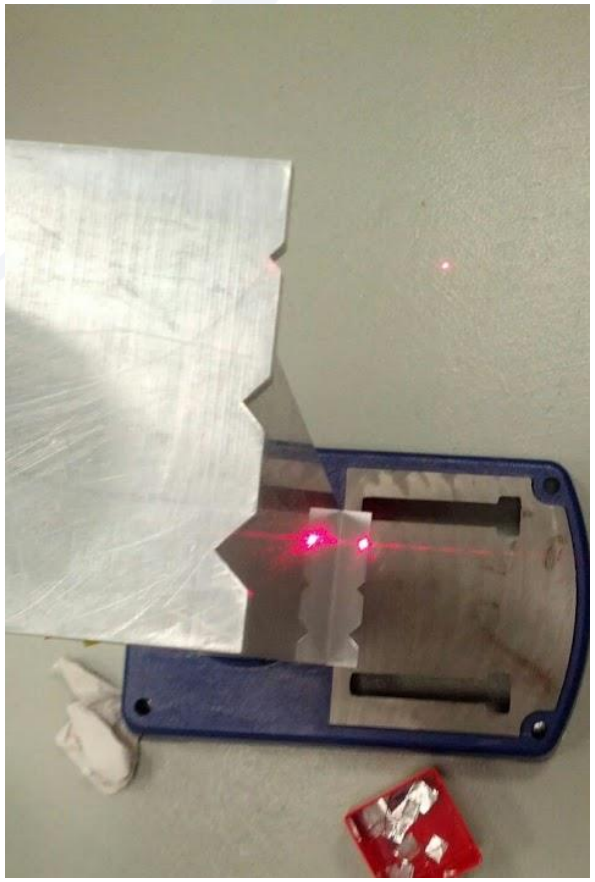
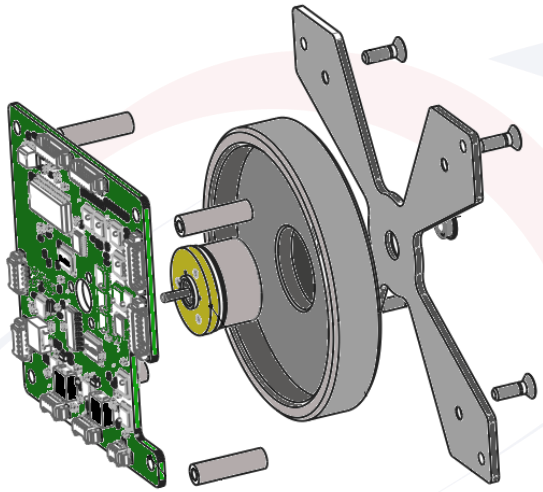


Fig. 4 & 5: D-SAT Alignment Test

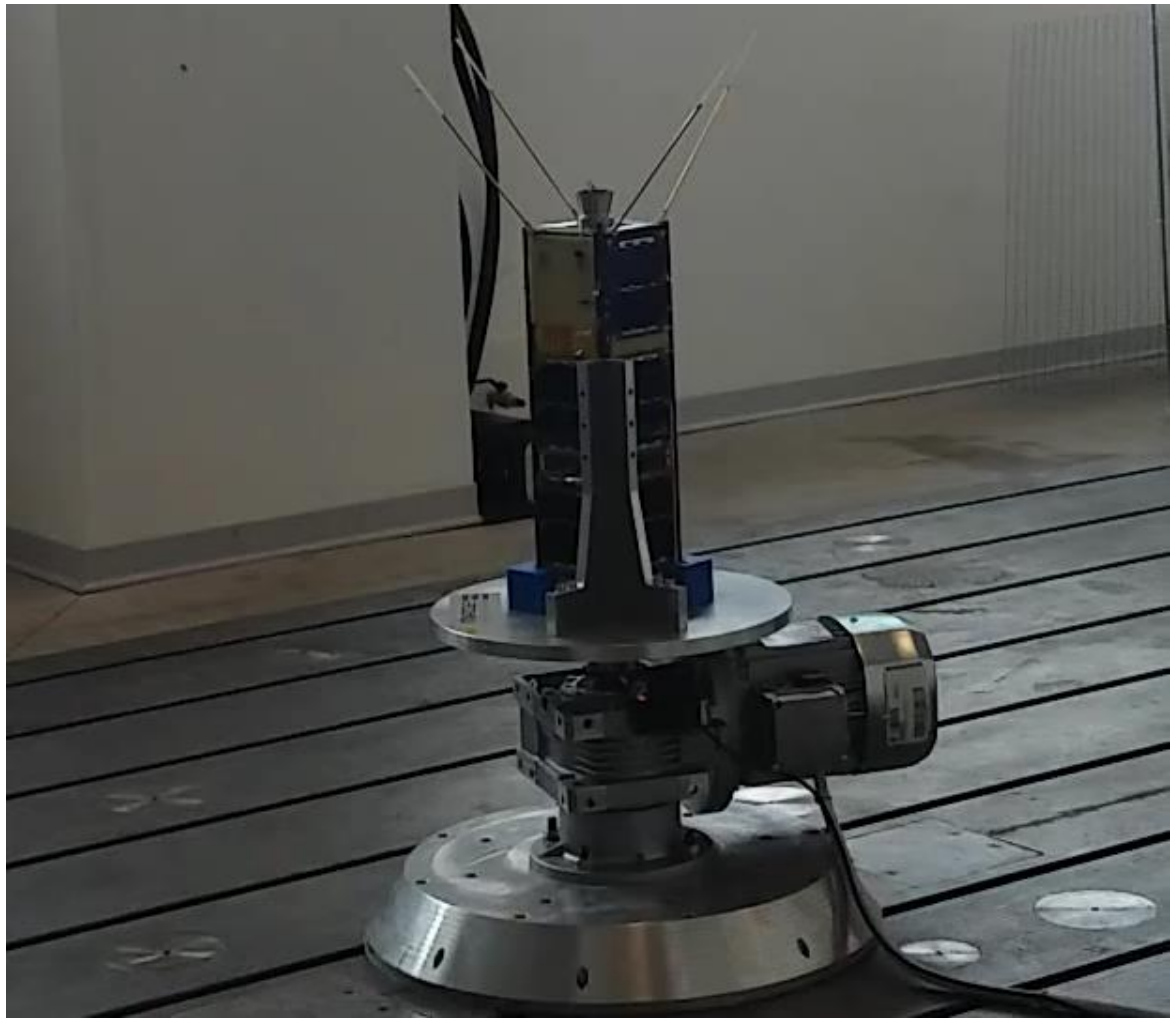
D-SAT - SPIN WHEEL

The D-SAT spin wheel system provides an angular momentum for spinning the satellite up to 400 rpm (6.6 Hz).



MAIN FEATURES:

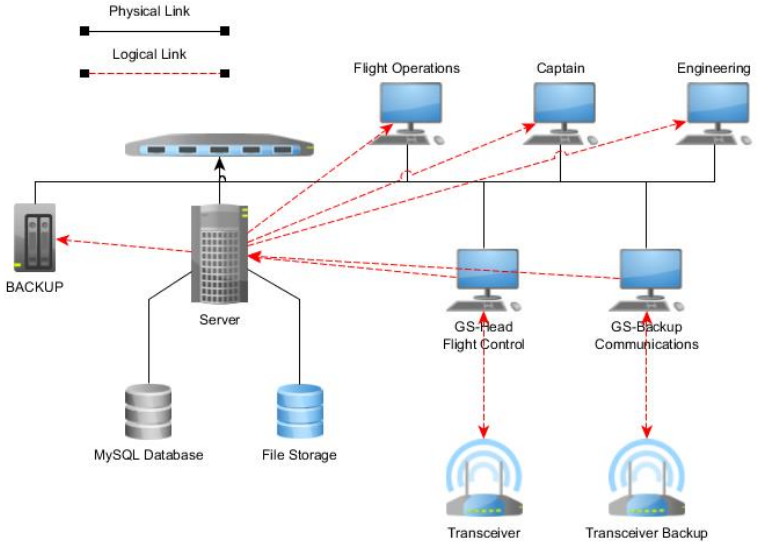
- Mass = 200 g
- Momentum of inertia, Ir = 1.8 [kg cm^2]
- Angular Velocity, ω = 16000 rpm

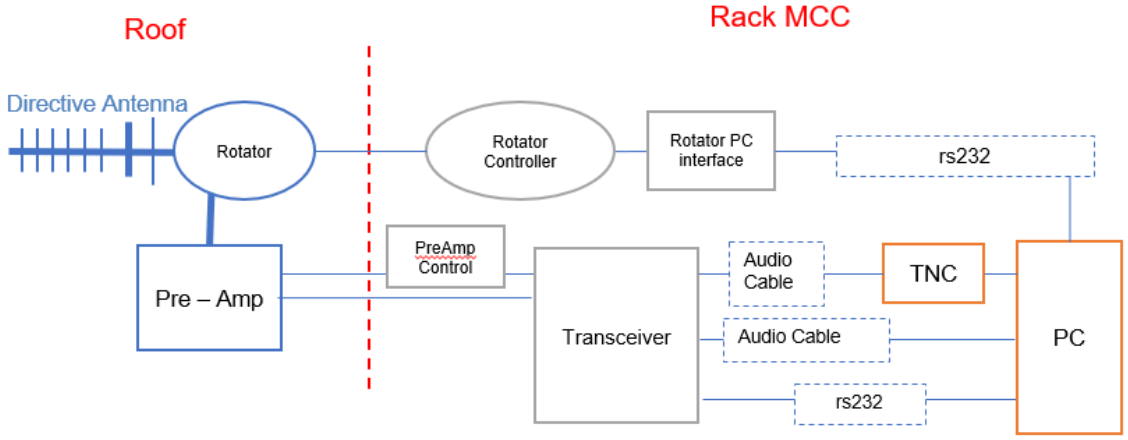


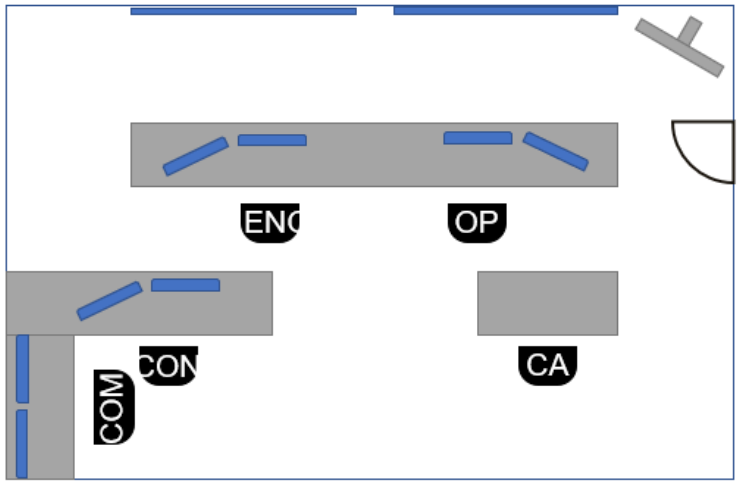
D-SAT

GROUND SEGMENT

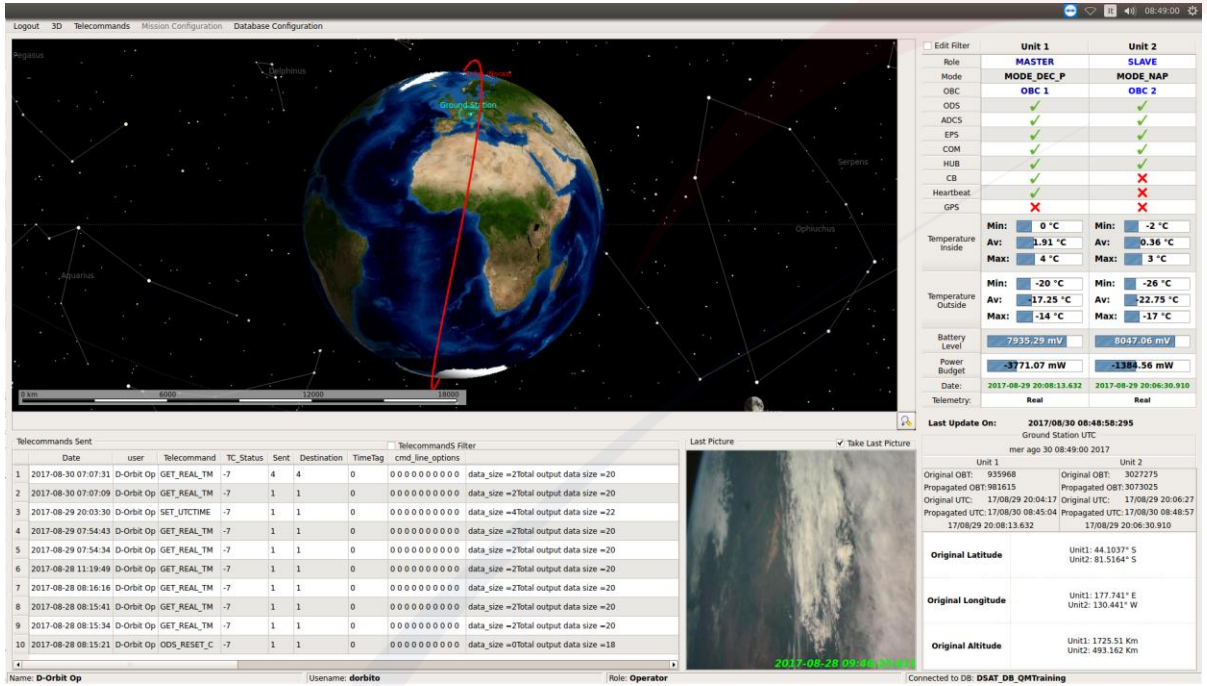
D-SAT GROUND SEGMENT

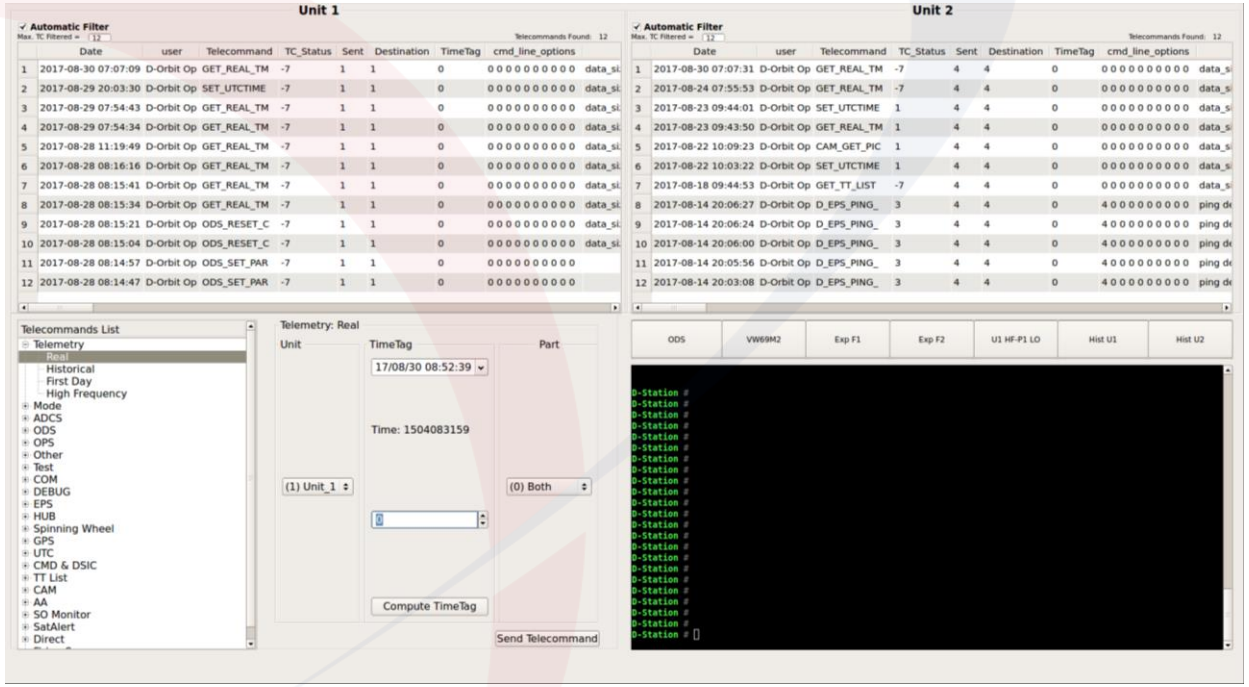






D-SAT GROUND SEGMENT





- Completely developed in-house
- With point-and-click user interface
- Interfaces directly with TNC, ground station hardware and remote database
- Real-time update of telemetry and plotting utility

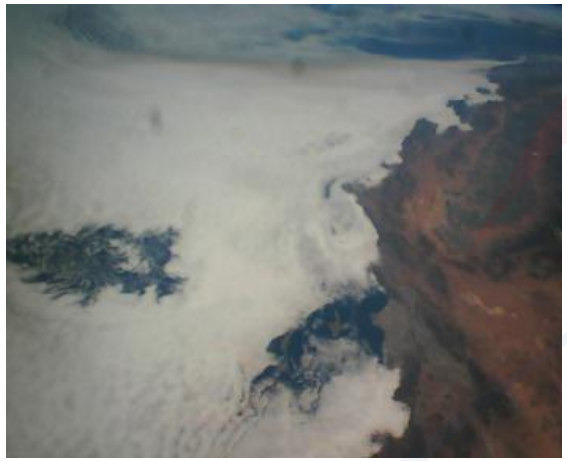
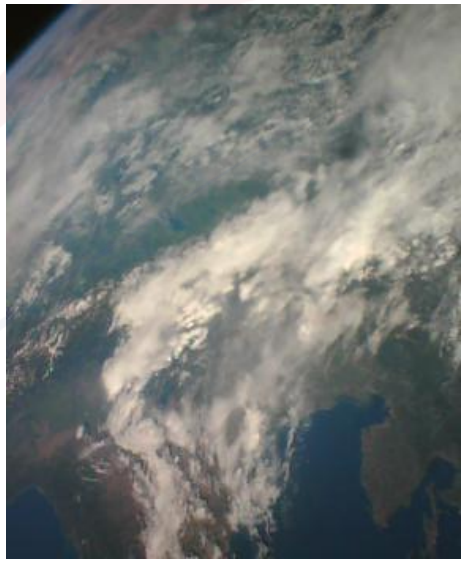
- Implementing reconfigurable color-code and format for all windows
- Allows multiple telemetry frames and units (i.e. satellites) information merge and filtering
- Database suitable for MATLAB export and post-processing

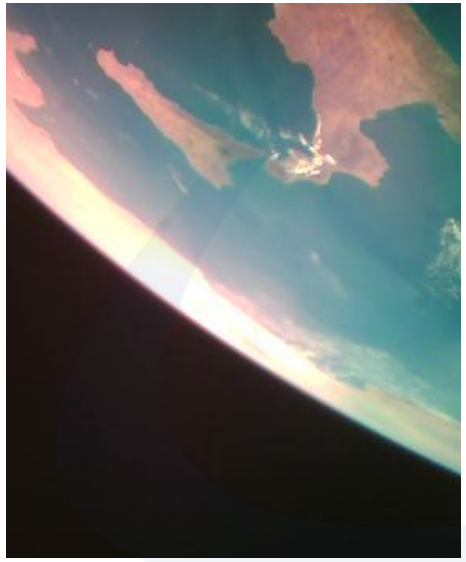
D-SAT OPERATIONS

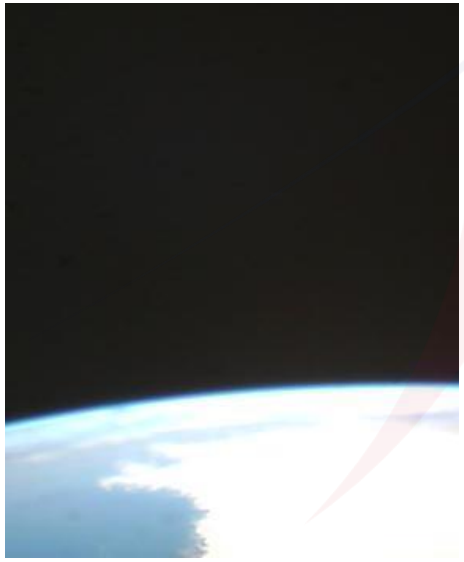
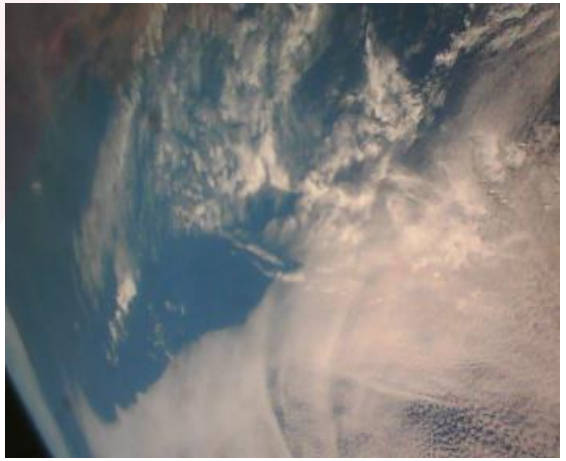
Mission Schedule

Phase	Start	End	Description
LEOP and Commissioning	23 Jun	01 Jul	During LEOP, the telecommunication link has been acquired, frequency characterized and health status confirmed. Systems testing and characterization has been carried out.
ADCS Calibration	01 Jul	15 Jul	In this phase, sensors and actuators was deeply tested, calibrated and characterized, and ADCS performance have been verified by means of testing pointing manoeuvres.
Experiments Campaign	15 Jul	08 Aug	During these weeks, the partner's experiments have been conducted
Earth-Imaging Campaign	08 Aug	25 Aug	In these weeks of Earth-imaging campaign, a number of Earth pictures have been taken and downloaded, mainly for outreach purposes.
Testing for Decom. Manoeuvre	25 Aug	Sep. 2017	In this phase, multiple testing to prepare the system for the decommissioning manoeuvre and to allow precise mission analysis for the deorbiting have been conducted.
Decommissioning Maneuver	2nd of Oct 2017		In this final (and very short) phase, the spacecraft will be removed (see Section 4.2.8) by activating the D-Orbit Decommissioning Device

EARTH IMAGING CAMPAIGN

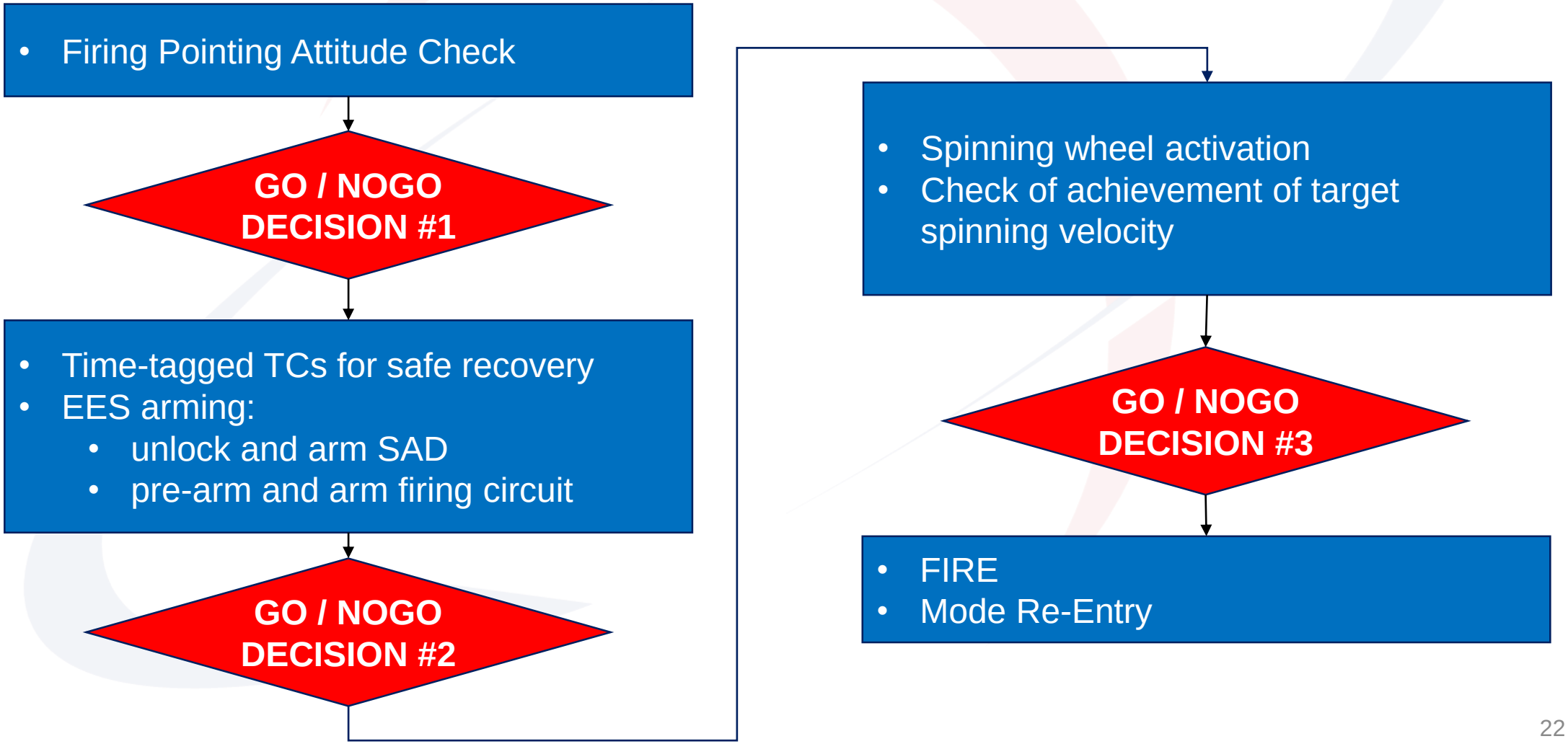



D-SAT

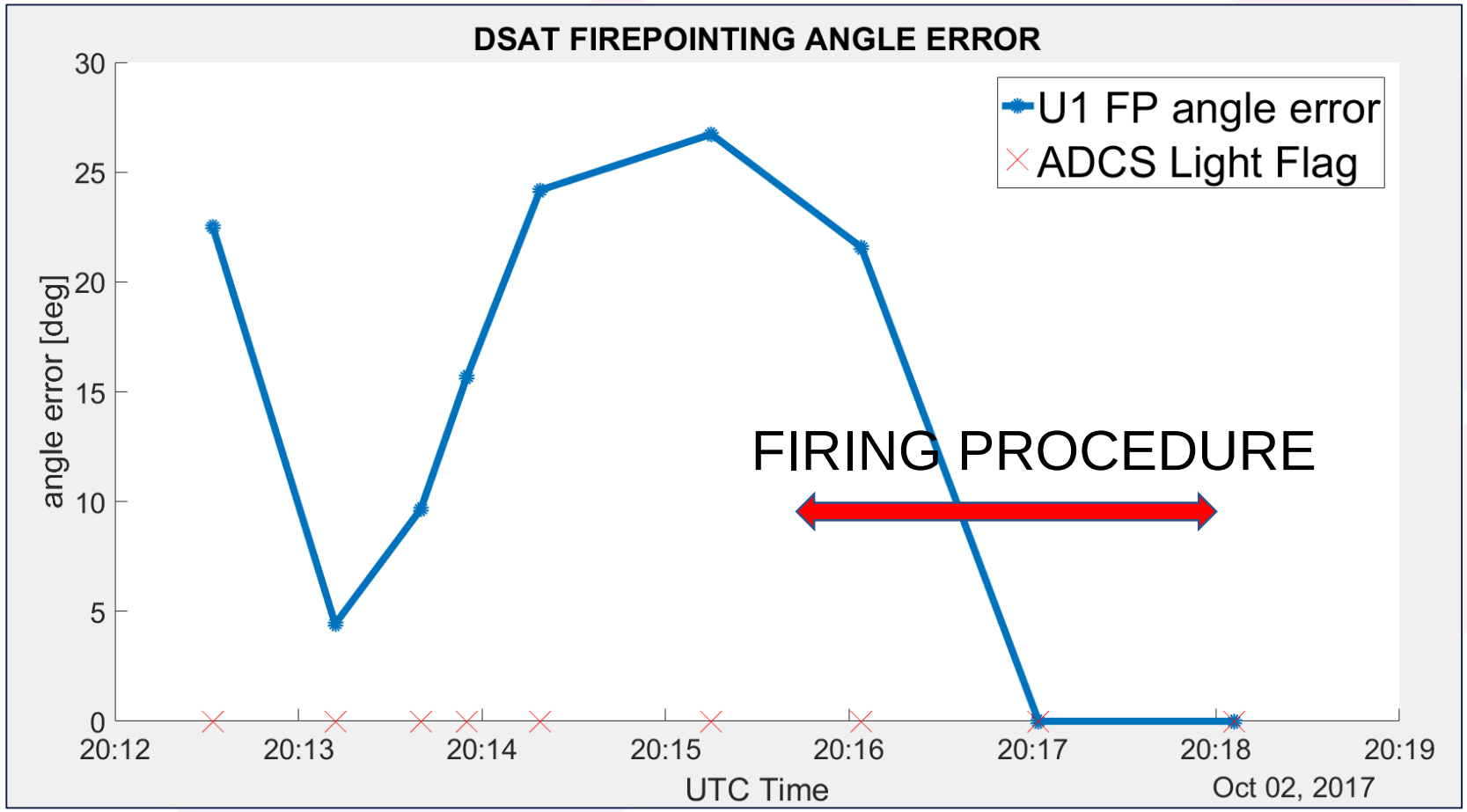
Disposal Manoeuvre Analysis

D-SAT DISPOSAL MANOEUVRE

Steps of the Firing Procedure in chronological order:

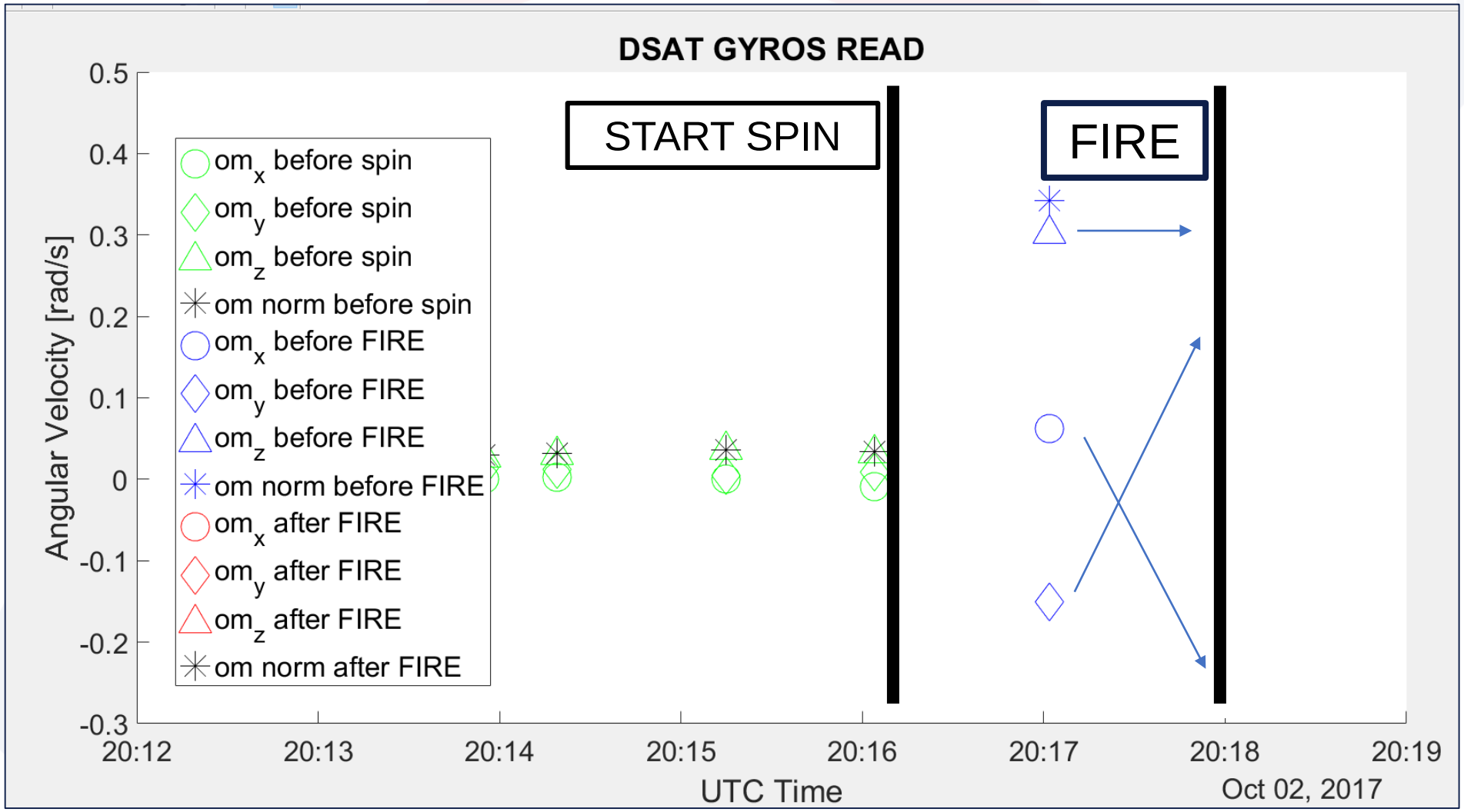


D-SAT DISPOSAL MANOEUVRE



Pointing Error: Nominal
within tolerances
(i.e. **< 25 deg**)

D-SAT DISPOSAL MANOEUVRE



D-SAT DISPOSAL MANOEUVRE

Red = original orbit

Perigee = 503 km

Apogee = 514 km

Inclination = 97.4388 deg

Yellow = post-fire orbit

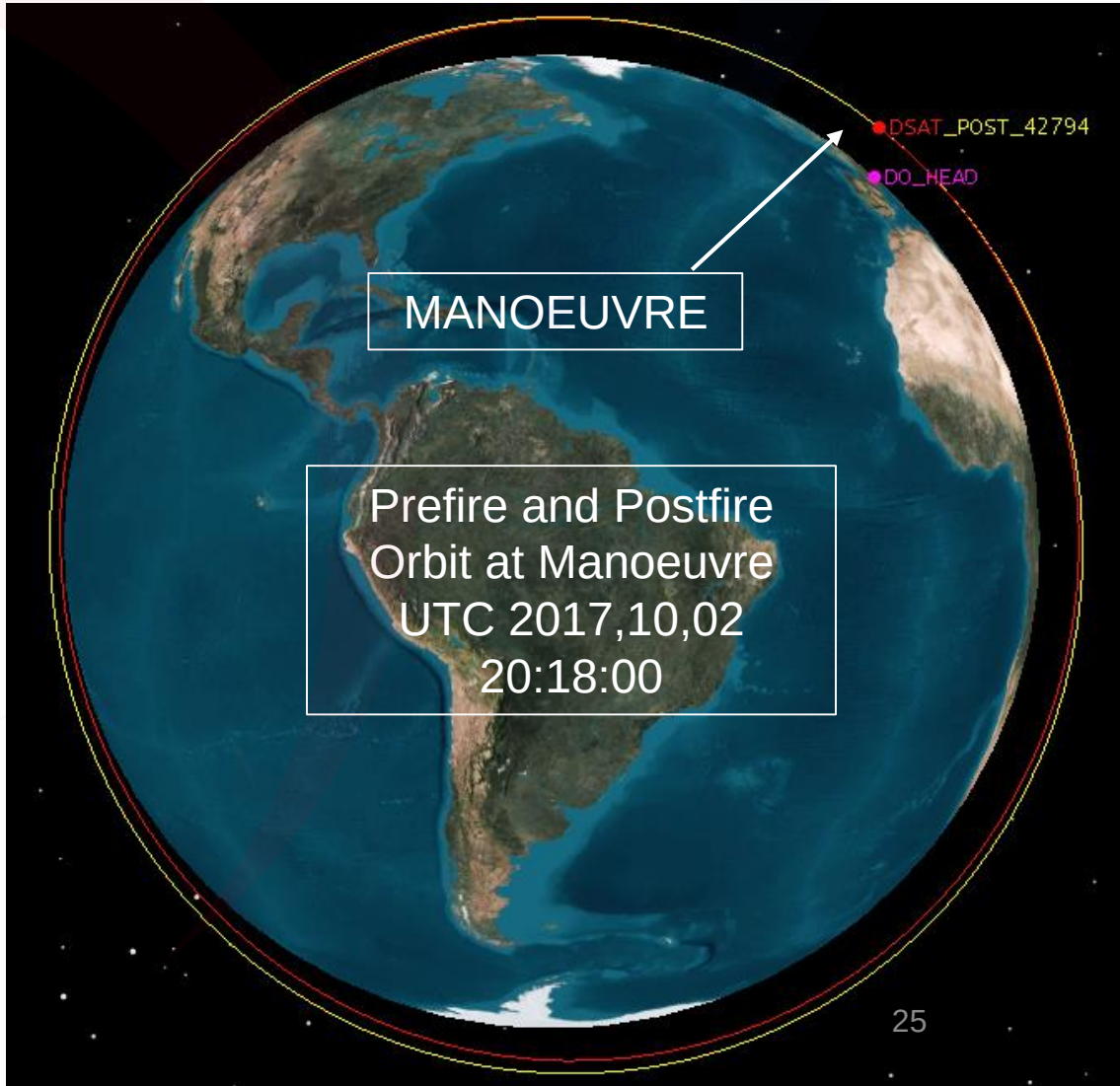
Perigee = 513 km

Apogee = 692 km

Inclination = 97.6306 deg

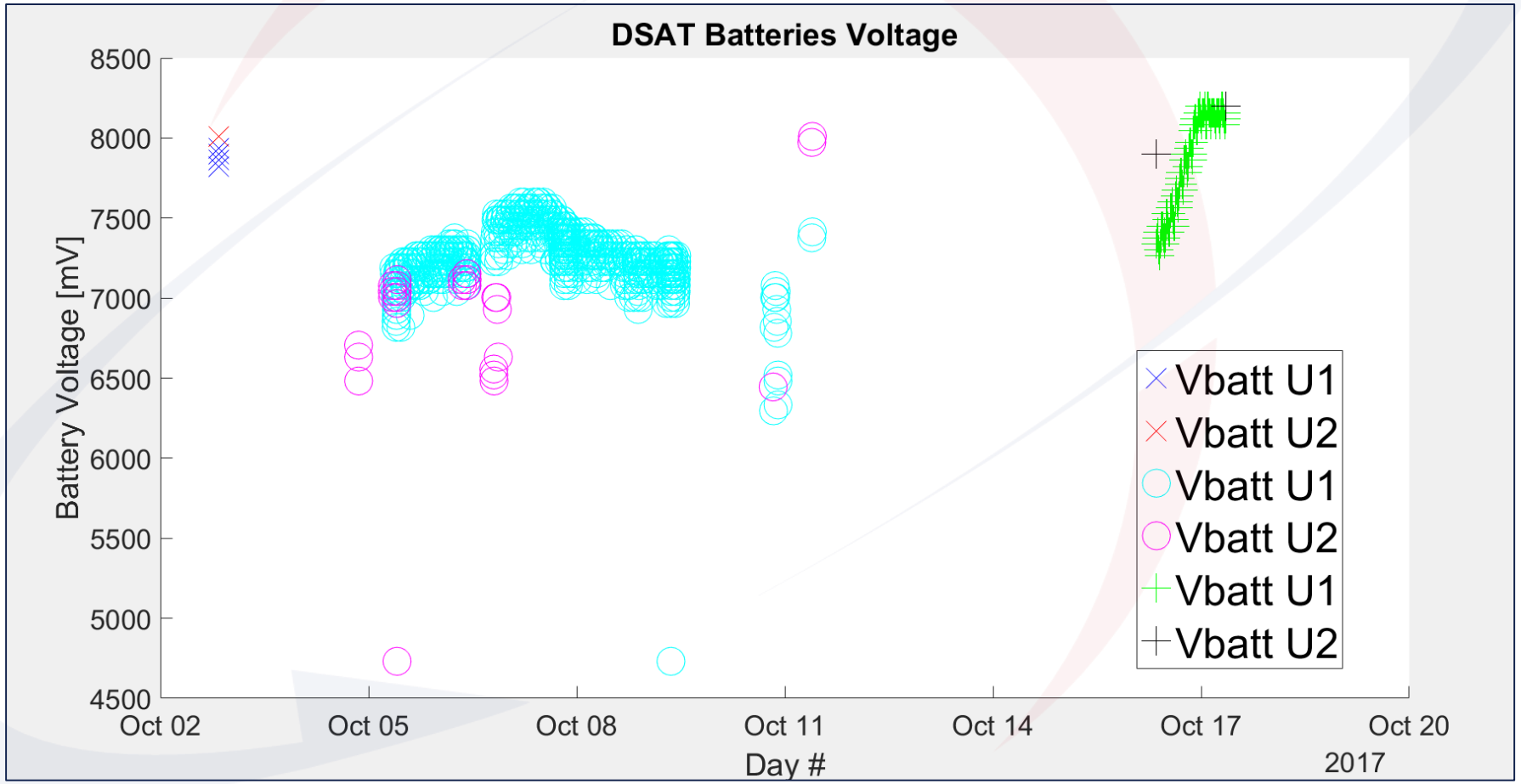
Tot DV provided ≈ 70 m/s

Against ideal 180 m/s



D-SAT DISPOSAL MANOEUVRE

D-SAT Survived: EPS and Batteries Status



D-SAT

RESULTS & LESSON LEARNT

D-SAT DISPOSAL MANOEUVRE

Conclusions

1. The D-SAT disposal manoeuvre was not nominal because:
   - Mounting misalignments of SRM within satellite structure (tolerances in this regards were critically < 1.5 mm);
   - Possibly combustion instabilities, which may deviate the thrust vector during the fire.
2. Possible mitigations:
   - Thrust misalignments could be assessed both during SRM verification and during D-SAT qualification campaign via dedicated firing test on thrust vectoring bench.
3. The D-SAT post-fire orbit is about 100km higher than the original one and with 0.2deg delta-inclination (still compliant with the 25-year rule)
4. All Decommissioning Device's sub-systems was verified in space.

D-SAT: RESULTS AND LESSON LEARNT

D-SAT has been the first CubeSat:

1. With a completely redundant avionic's architecture;
2. With a pyrotechnic device compliant with the MIL-STD-1576 standard;
3. To maintain a stable communication link during the spin-stabilizing pre-firing phase when it was rotating on its axis at 400 rpm;
4. To survive after firing of a solid rocket motor with a total impulse of 750 Ns (a very high trust for such a small satellite);
5. To perform an orbital maneuver with a delta-velocity of 70 m/s.

D-SAT: RESULTS AND LESSON LEARNT

Thanks to D-SAT Mission, D-Orbit has:

1. Demonstrated in space its Decommissining Device's features: **Autonomy**, **Safety** and **Reliability** and reached the TRL 9;

2. acquired capabilities in nanosatellite manufacturing, validation and testing, both software and hardware;

3. acquired experience in nanosatellite operations;

4. acquired capabilities in dealing with explosive materials and safety laws and regulations for storage, handling and transportation;

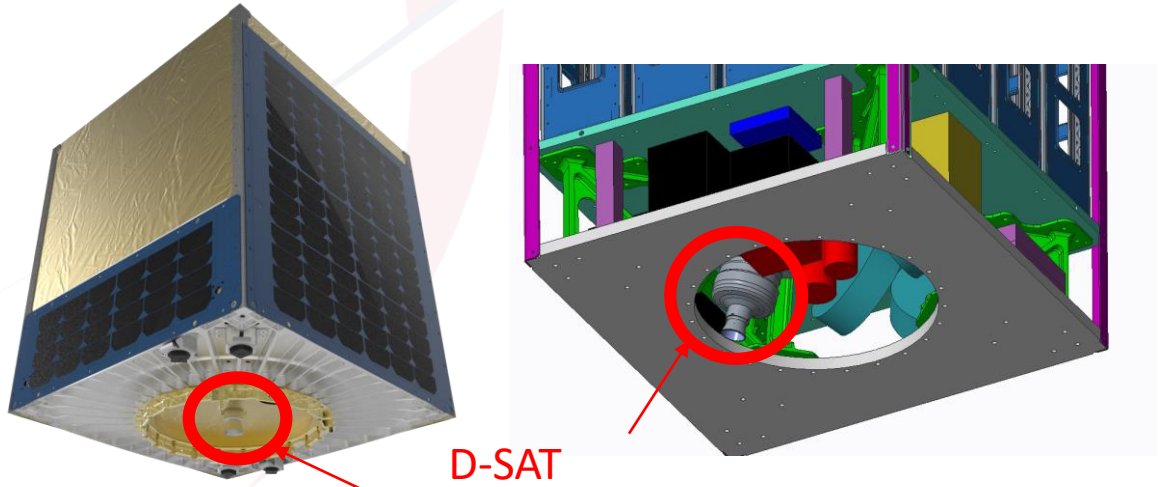
D-SAT: RESULTS AND LESSON LEARNT

Next D-Orbit's Activities:

1. D-SAT mission highlighted the importance of TVC features for D3 designed for a direct reentry. D-Orbit is working with Almatech e Sitael, on a Thrust Vector Control system for Solid Rocket Motor under an ESA contract;

2. Focus on **Autonomy**;

3. D-Orbit will integrate the same D-SAT's Decommissioning Device on its new satellite platform: the **ION CubeSat Carrier** – a CubeSat free-flying dispenser (first flight Q1 2019).




D-ORBIT
NEW SPACE SOLUTIONS