
**Luca Rossettini, CEO**

**Technical Day on “Deorbiting Strategies”**

# Our Mission – Clean and Safe Access to Space

***Preserve the orbital space while promoting a clean and safe access to space***

- D-Orbit is focused on stopping the systematic increase of concentration of uncontrolled objects in space, promoting a sustainable access to Space and adding a fourth dimension to the common notion of sustainability: Earth, Air, Sea and Space.

***Provide our customers with suitable decommissioning solutions***

- Based on technology qualified for space applications
- Selected from a broad technology portfolio
- Developed using advanced and genuine methods
- Produced in modern state-of-the-art facilities and in partnership with well established players in the market
- Done by a skilled and careful workforce

***Fields of activity***

- Space debris mitigation and prevention
- Solid rocket motors and gas generators
- Special rocket motors
- Space grade electronic design and manufacturing
- Critical software (B class)
- Safe design and pyrotechnical devices for safety
- Special products and services

# D-ORBIT

- Established in 2011. Now 21 people
- Financial support by Italian Venture Capital funds
- Raised about €2.5m by:





**AWARDS**

2014: MassChallenge finalist (100 selected among 51 nations)
2014: European Space Agency award at ESA Investment Forum
2013: Red Herring global winner (100 most innovative worldwide ventures)
2012: MIT Tech Review: among the 12 most Italian innovative companies
2012: MIT Portugal IEI finalist (award won: 100k€)
2012: Talento delle Idee Area Centro-Nord First Place
2011: Working Capital & “Premio Nazionale Innovazione” Finalist
2011: Mind The Bridge Business Plan Competition Finalist
2011: Bassetti Award: most responsible startup
2010: Rice Business Plan Competition Finalist

# D-Orbit production facility

Engineering design area


ISO 5 – 100’000 class
CLEAN ROOM

Brainstorming and innovation area


- Mechanical workshop
- Space grade painting area
- R&D small tests area
- Electronic and electromechanical production area

AEROSPACE EN 9100

Partnerhsip with ELEMASTER® TECNOLOGIE ELETTRONICHE

# CURRENTLY WORKING ON

**ESA AO 7943 “Thrust Vector Control System for solid propellant de-orbit motors”**

In cooperation with:Almatech (prime) Alta Space (now Sitael)

*Granted on Nov. 2014*

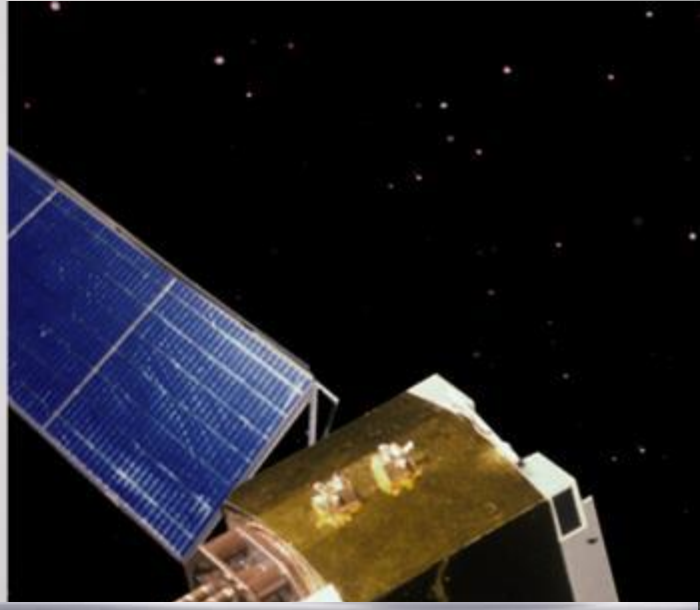
**SME INSTRUMENT Phase 1 “Smart propulsive device for controlled satellite reentry and reorbit.”**

*Granted in Dec. 2014*

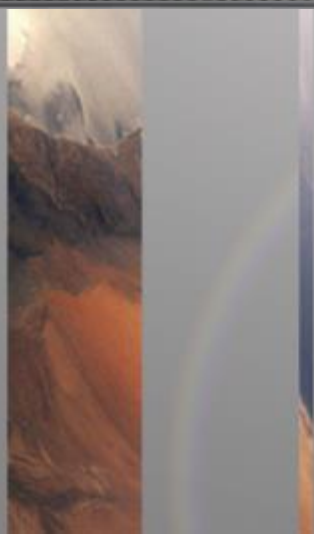
**NASA-CASIS User Agreement UA-2015-201 for launch and delivery from ISS of 3 unit cubesat under the project “D-SAT Active Decommissioning Demonstration Project”**

*Granted in Nov. 2014*





# SPACE DEBRIS MITIGATION
# REGULATIONS


# WORLDWIDE REGULATIONS

| | | | | |
|---|---|---|---|---|
| **INTERNATIONAL** | **UN COPUOS, IADC, ISO 24113**<br>**Limit the long-term presence of spacecraft and launch vehicle in orbit after the end of their mission; Mandatory post-mission disposal manoeuvre.** | | | |
| | **LEO** | **GEO** | **MEO** | **LAUNCHERS** |
| **EUROPE** | **French Law, ESA**<br>Baseline: controlled atmoshperic reentry (causualty risk <2 $10^{-5}$). If compliance is impossible (duly justified) reentry within 25 years with casualty risk < $10^{-4}$.<br>'Best effort' principle. | **French Law, ESA, ITU**<br>Mandatory disposal manoeuvre in graveyard orbit.<br>Required success rate 90%. | **French Law, IADC, ITU, ESA**<br>Mandatory disposal manoeuvre in graveyard orbit.<br>Generation of debris not allowed. | **French Law, ESA**<br>Baseline: controlled atmoshperic reentry.<br>Limit the presence in operational orbit to 1 year.<br>Mandatory disposal manoeuvre.<br><br>'Best effort' principle. |
| **UNITED STATES** | **NASA, NOAA, FAA, DOD**<br>Compliance with ISO 24113. Reentry in 25 years AND casualty probability < $10^{-4}$. | **NASA, FCC, FAA, ITU**<br>Mandatory disposal plan and maneuvre for optaning licensing. | **NASA, FCC, FAA, DOD**<br>Mandatory disposal plan and maneuvre for optaning licensing. | **NASA, NOAA, FAA, DOD**<br>Mandatory disposal by: atmosperic re-entry, storage orbit, direct retrieval. |
| **JAPAN** | **JAXA**<br>Reducing to minimum post mission time of interference with LEO region. | **JAXA**<br>Mandatory transfer to higher orbit. | **JAXA**<br>Mandatory disposal plan and maneuvre for optaning licensing. | **JAXA**<br>Reducing to minimum post mission time of interference with useful orbits. |


# FOR HOW LONG THE 25 RULE WILL BE APPLICABLE?

# DECOMMISSIONING SOLUTIONS

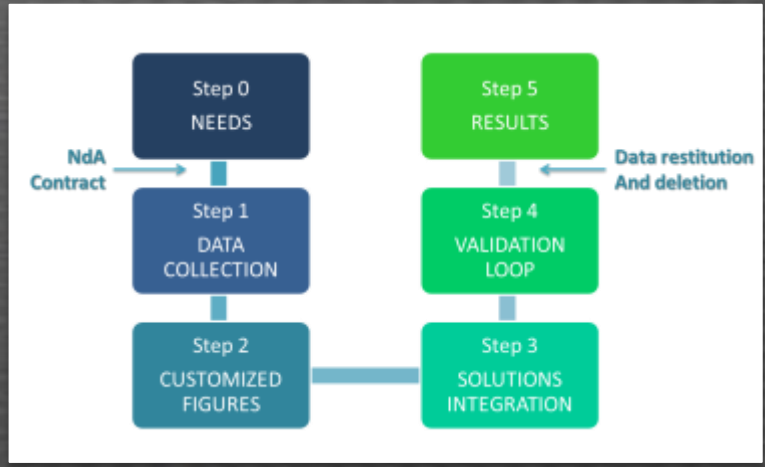
## D-TEAM

### Expertise in decommissioning solutions

**D-TEAM's** main objective is to support Mission Analysis specialists and System Engineers to evaluate the best technologies and strategies to adopt to be compliant with current and upcoming regulations on space debris mitigation.

## DISRUPT

***DISRuPT is a detailed and customized analysis and debris prevention strategies' investigation for satellite platforms***



# DECOMMISSIONING SOLUTIONS

## TETHERS

Interact with the ionosphere and the geomagnetic field to produce currents running along the tether, and these currents in turn cause forces on the tether that lower the orbit of the tethered spacecraft.

Low mass, low volume, negligible power, compact.

TRL: 6-7

## INFLATABLE BALLOON

Very large balloon to increase the aerodynamic drag by a factor of several hundred. This will reduce the natural orbit decay of some objects from centuries to years or months.

Low mass, low volume, negligible power, compact.

TRL: 5


## SOLAR SAILS

Large light sail to generate enough aerodynamic drag to slow down and deorbit the satellite more rapidly. This will reduce the natural orbit decay of some objects from centuries to years or months.

Low mass, low volume, low power, compact.

TRL: 5

## ELECTRIC PROPULSION

Ion thrusters use electrical power to accelerate ions produced in a gaseous electrical discharge to extremely high velocities, typically 30 to 60 km/s generating thrust in the order of the mN.

Medium mass, low volume, high power, compact.

TRL: 9

## SOLID PROPULSION

Solid propellant is a well known and reliable technology used to deliver high thrust from a compact and high performing propellant in solid state. Currently the best candidate for deorbiting solutions.

Medium mass, medium volume, negligible power compact.
TRL: 6-9

## ON-BOARD PROPULSION

Currently, decommissioning maneuvers are delegated to the on-board propulsion system, using station keeping thrusters or additional thrusters fed by liquid propellant.

Low mass, low volume, high power, compact.

TRL: 9

# DECOMMISSIONING SOLUTIONS
# SOLID PROPULSION TECHNOLOGY

## SOLID PROPULSION

Solid propellant is a well known and reliable technology used to deliver high thrust from a compact and high performing propellant in solid state. Currently the best candidate for deorbiting solutions.

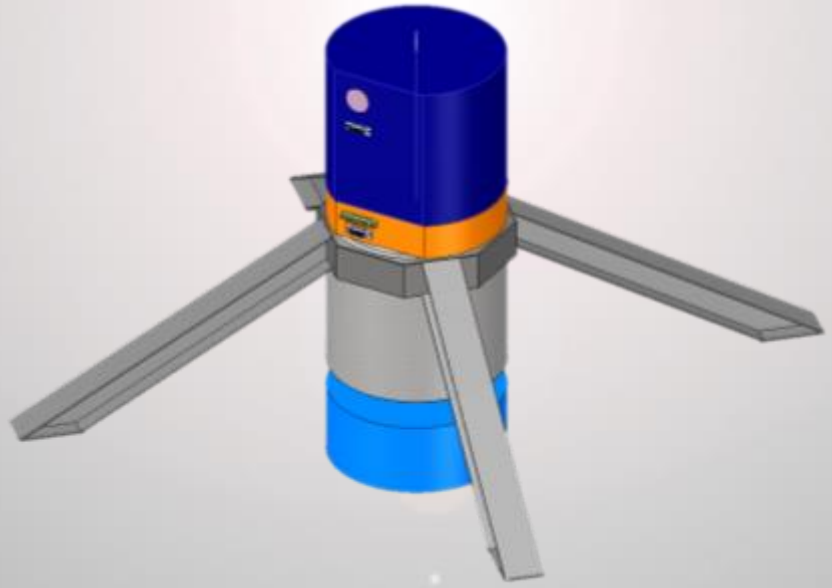
TRL: 6-9

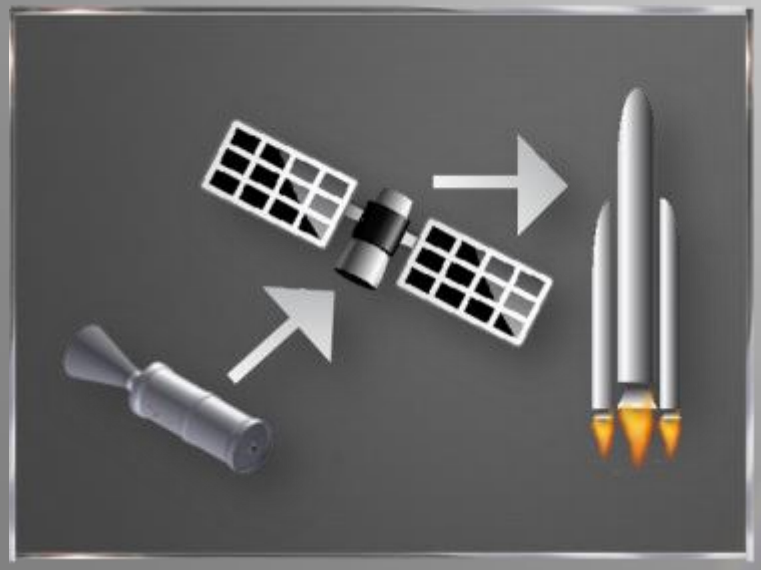
D-Orbit developed one of the most promising decommisioning solutions, in different versions suitable for different in-space applications.

- Short maneuver time
- Low maneuver complexity
- Low risk for constellations of satellites
- Low mass and volume
- Low integration effort

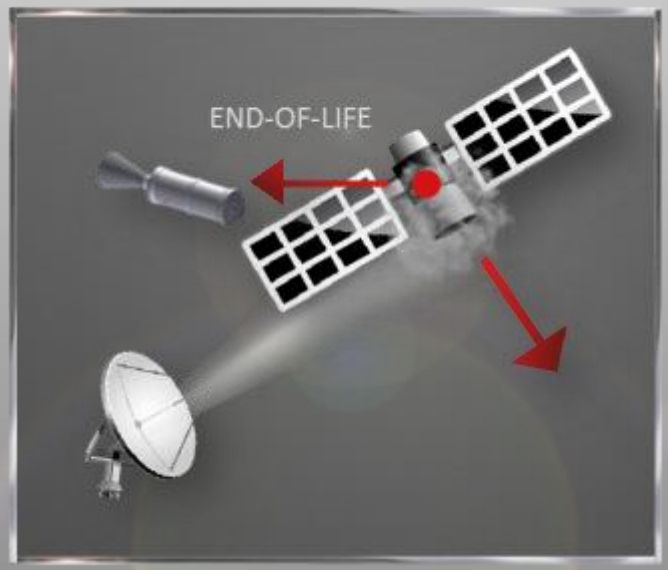
*Selected by ESA as best suited solution for Space Debris Mitigation (ref. SPADES Study in the ESA Concurrent Design Facility)*

# D-ORBIT DECOMMISSIONING DEVICE

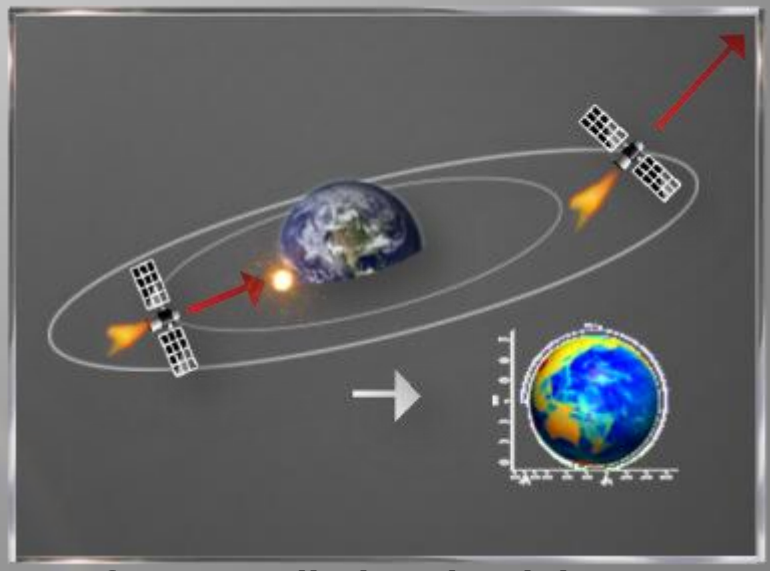




Unique and patent pending (11 countries) smart propulsive device, easy to install before launch




Independent from the satellite, it may works even if the satellite does not



Safe, controlled and quick decommissioning (few hours) both for LEO and GEO satellites

# D-ORBIT DECOMMISSIONING DEVICES: D3

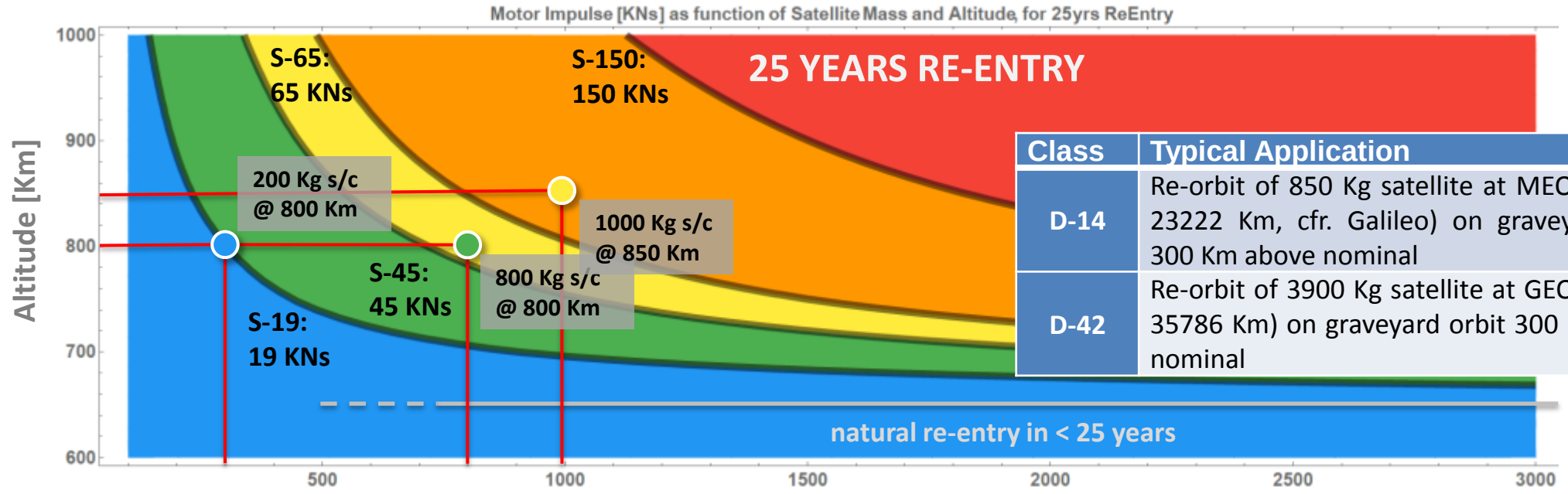
## COMPETITIVE ADVANTAGE

- INDEPENDENT
- LIFE EXTENSION
- SIMPLER OPERATIONS
- AUTONOMY*
- LOWER COSTS
- COMPACT, MODULAR AND SCALABLE

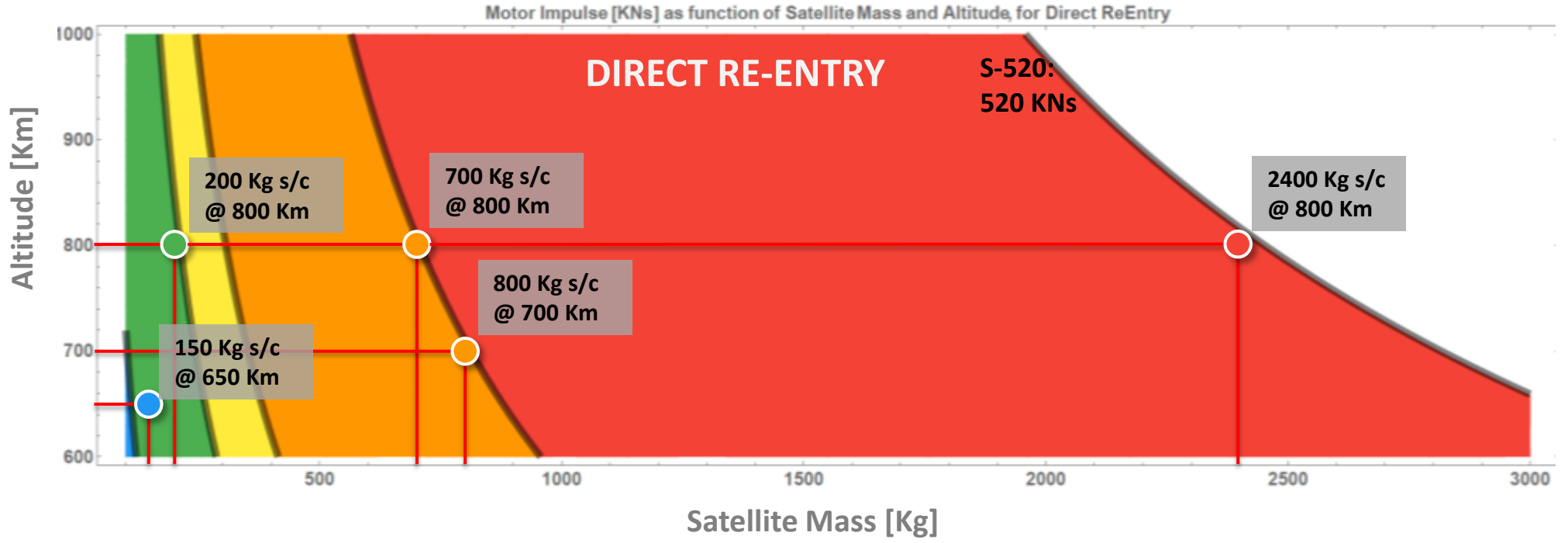

## COMPULSORY FEATURES

- CONTROLLED REENTRY
- QUICK RE/DEORBIT
- NON-INTERFERENCE
- HIGHER SUCCESS RATE
- BEST EFFORT

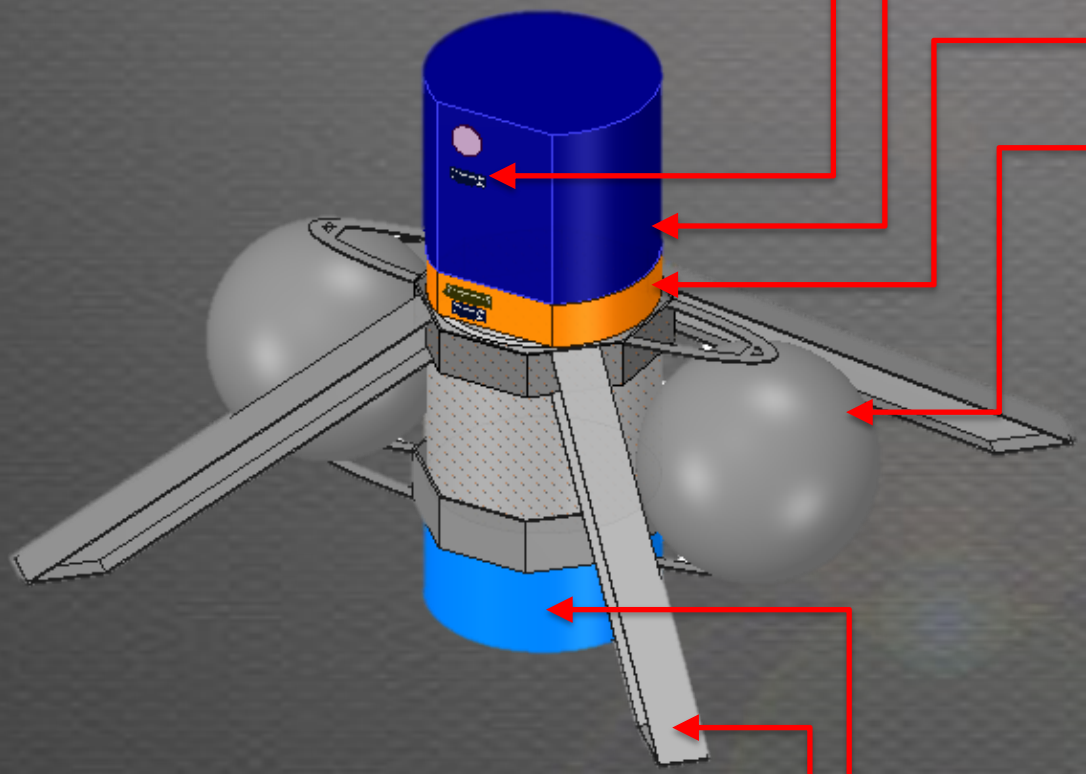
# D3 CLASSES




| Class | Typical Application |
|---|---|
| D-14 | Re-orbit of 850 Kg satellite at MEO (altitude 23222 Km, cfr. Galileo) on graveyard orbit 300 Km above nominal |
| D-42 | Re-orbit of 3900 Kg satellite at GEO (altitude 35786 Km) on graveyard orbit 300 Km above nominal |



# D3 VIEW



Power / Data Interface

D3 Brain

EES (included in D3 Brain)

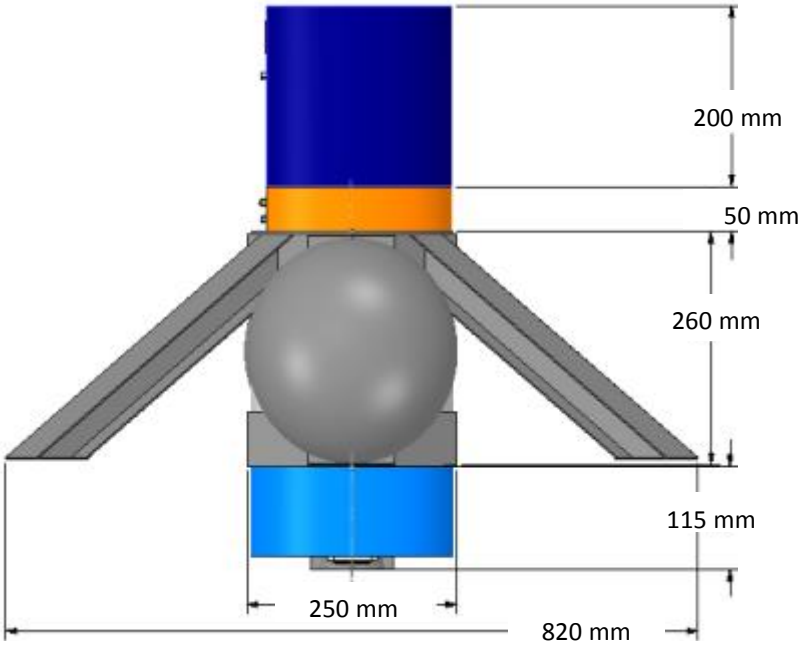
TAU Tanks

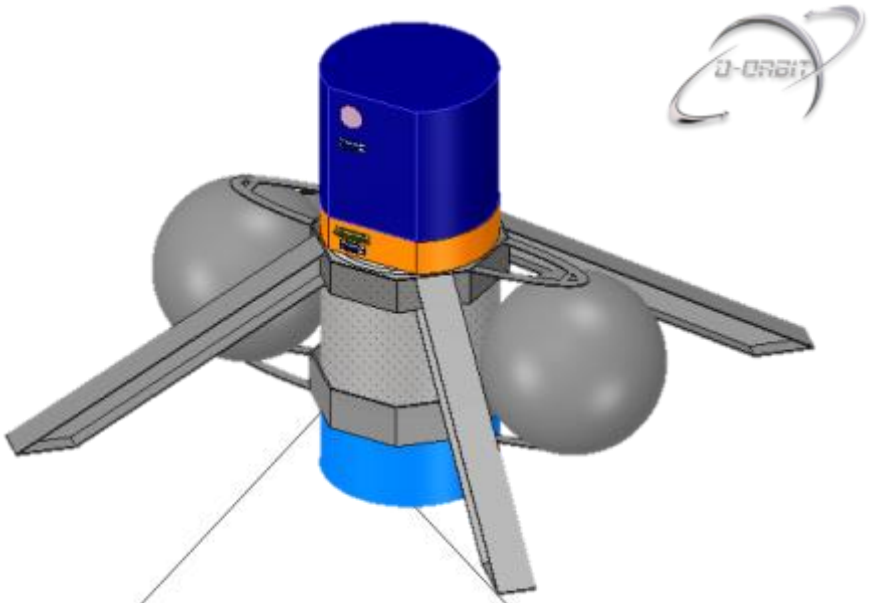
Motor Nozzle and TAU Actuators

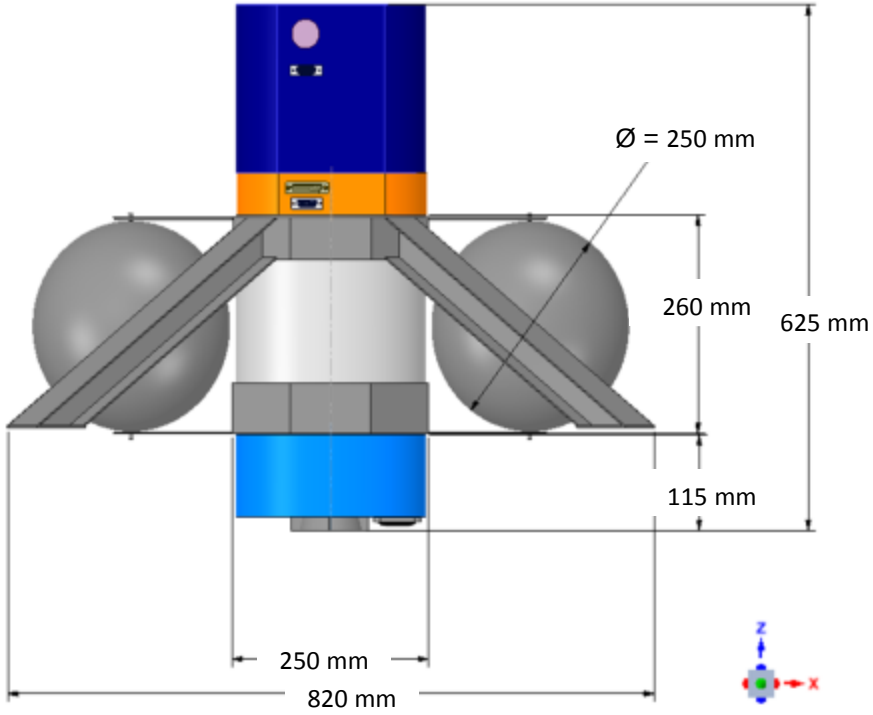
Mechanical Interface

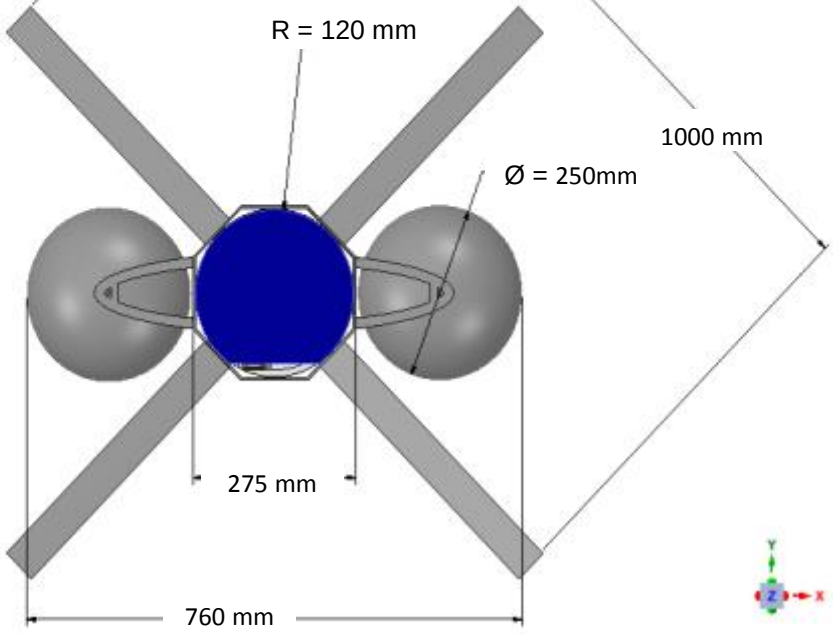
NB: Proportions may change according to the class of the device

# D3 VIEW - D-42 (GEO) CLASS

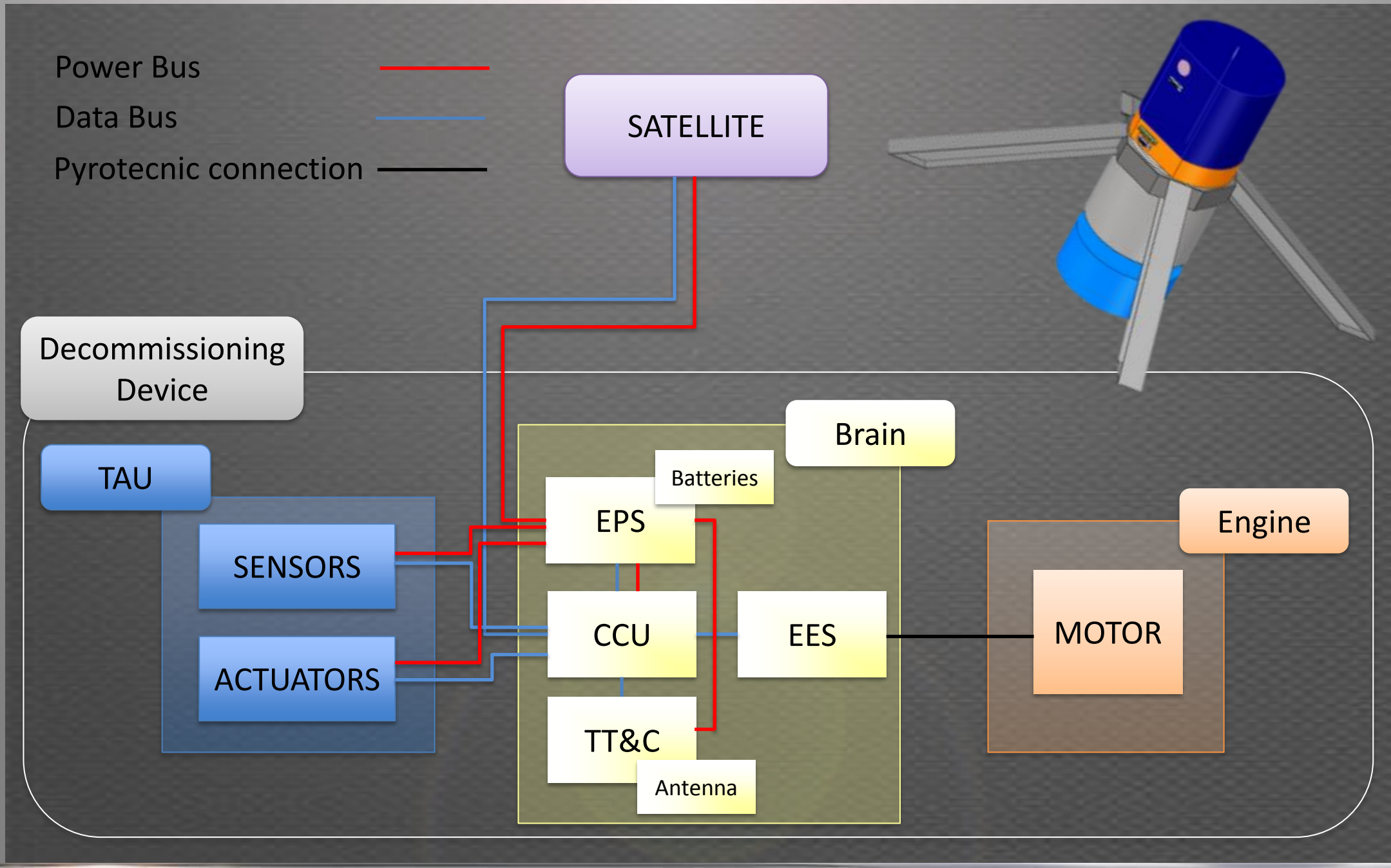




# D3 BLOCK DIAGRAM



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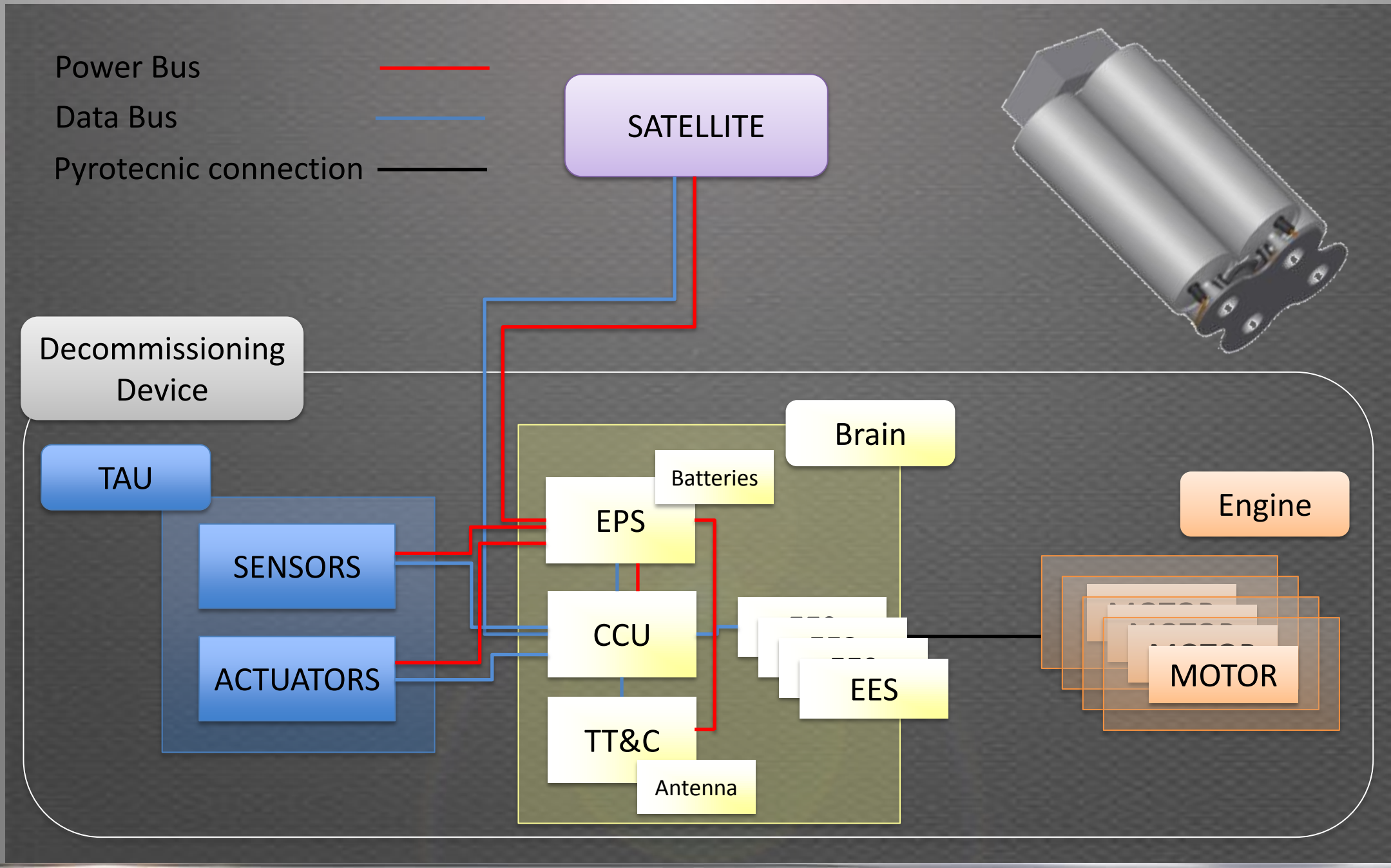
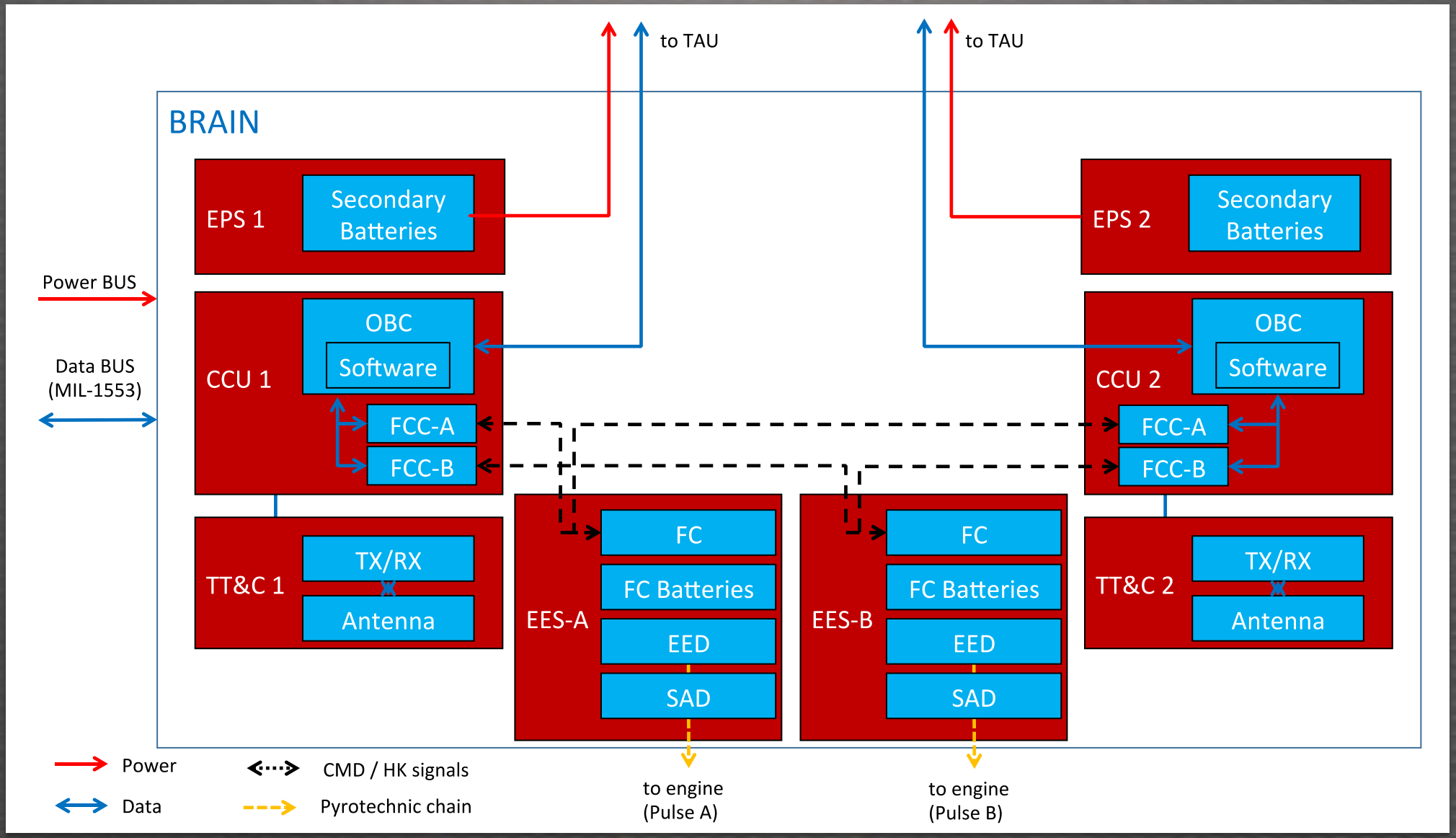


# D3 DUAL PULSE BRAIN BLOCK DIAGRAM



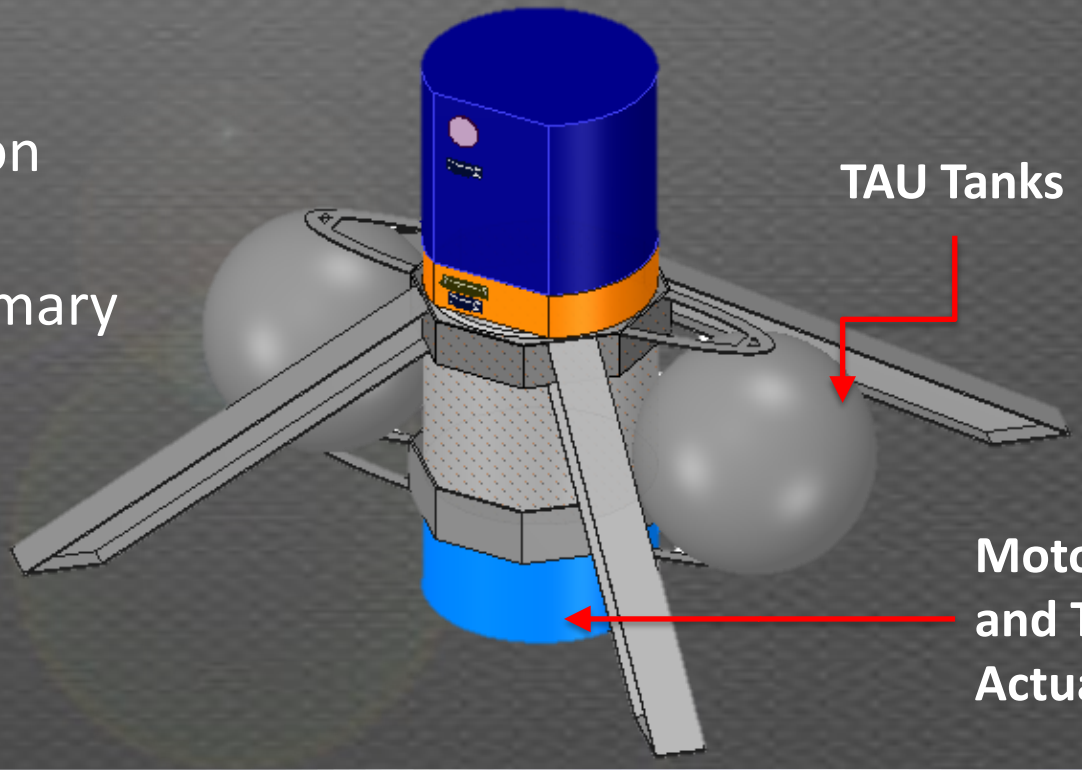
# TAU - TERMINAL ATTITUDE UNIT

**Functions**

- Recovers compromised attitude if the satellite is dead
- Points propulsion system to re-orbit in GYO
- Corrects thrust misalignement

**Constriants**

- Least impact on configuration
- Safety
- Least impact on satellite primary mission

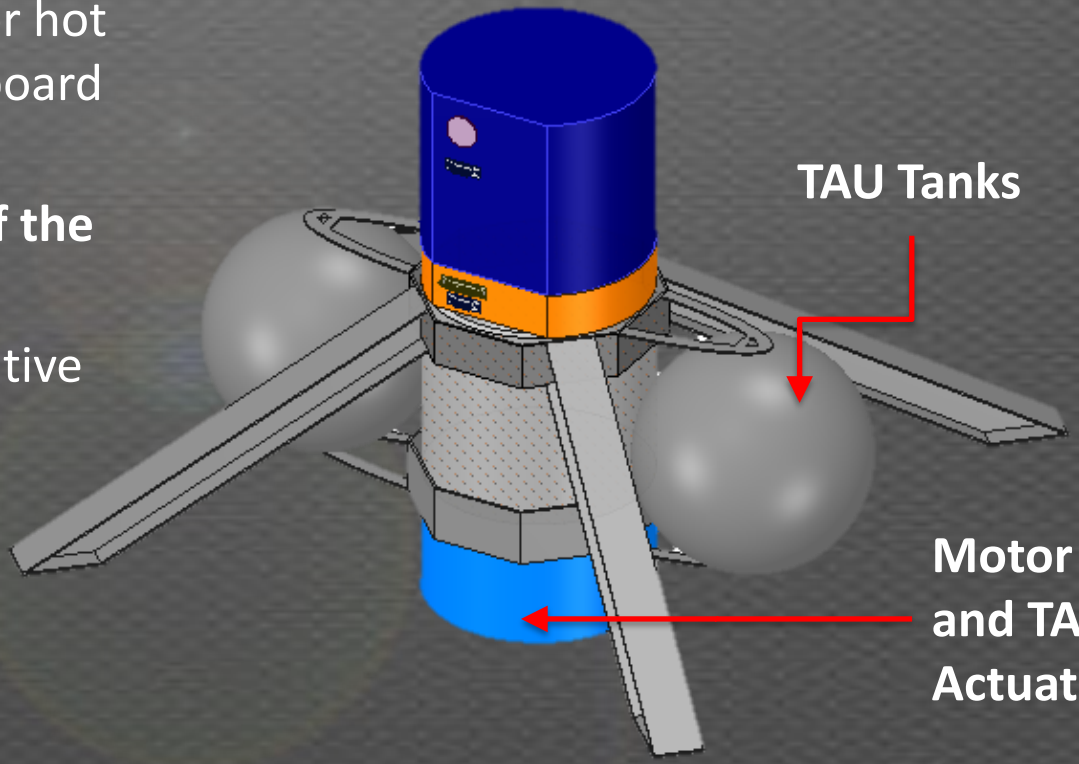


# TAU - TERMINAL ATTITUDE UNIT

## Functions

- Recovers compromised attitude if the satellite is dead
- Points propulsion system to re-orbit in GYO
- Corrects thrust misalignement

- **Attitude recovery from 2.9 deg /s** simulated with cold-gas low thrust or hot gas thrusters typical of satellite on-board RCS systems
- **Design with solid propellant (one of the options):**
  - Empty tank, insulated with ablative
  - Gas generated by propellant cartridges
  - Hot gas thrusters and valves

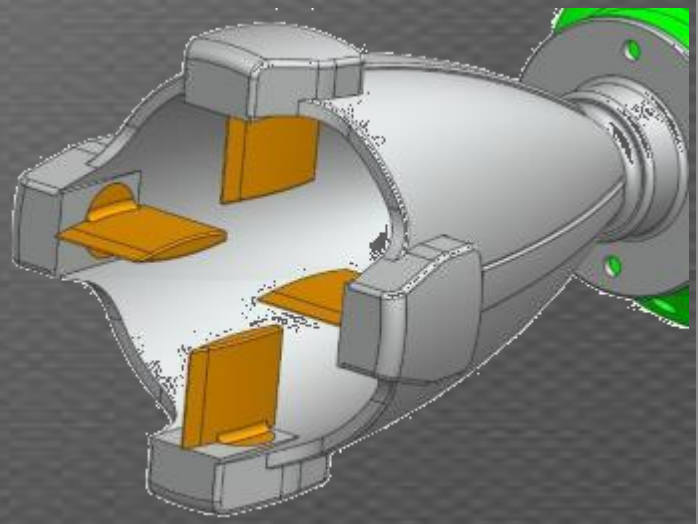


# TAU - TERMINAL ATTITUDE UNIT

**Functions**

- Recovers compromised attitude if the satellite is dead
- Points propulsion system to re-orbit in GYO
- Corrects thrust misalignement

- Thrust Vector Control – TVC:
  - TVC is a technology available in many missiles;
  - D-Orbit is developing a system for ESA within a consortium



# THRUST VECTOR CONTROL SYSTEM FOR SOLID PROPELLANT DE-ORBIT MOTORS (AO 7943)

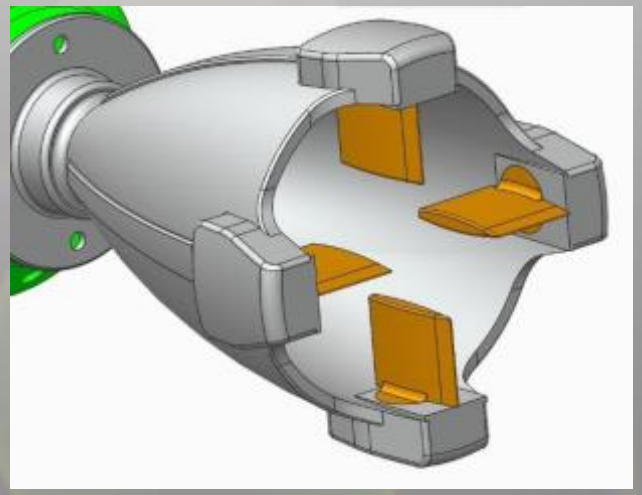
**TEAM:**
- Almatech (Prime)
- D-Orbit
- Alta Space (now Sitael)

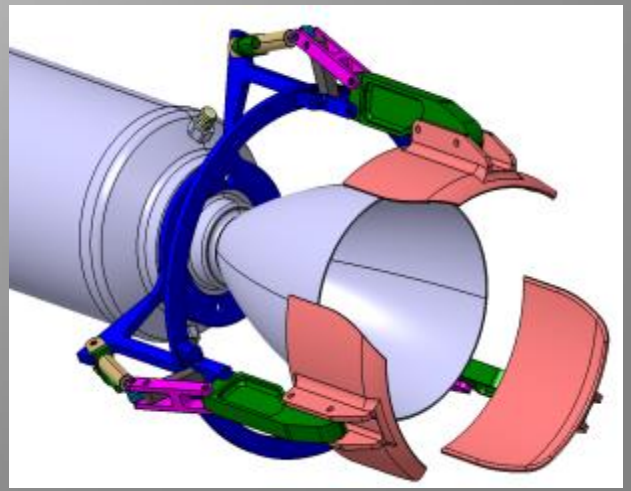
**ACTIVITIES**:
- Identify suitable TVC concepts for solid rocket de-/re-orbit motors and trade them off;
- Design and manufacture a breadboard of the selected TVC concept;
- Design and manufacture test rig for the TVC breadboard;
- Perform TVC breadboard test (cold gas) and evaluate performance.

**Framework → Cleanspace Branch 3 ("Space Debris Mitigation") – Propellant and De-orbit Motor development**

**Status → Ongoing (activities started on Jan. 2015)**

**Duration → 15 months**

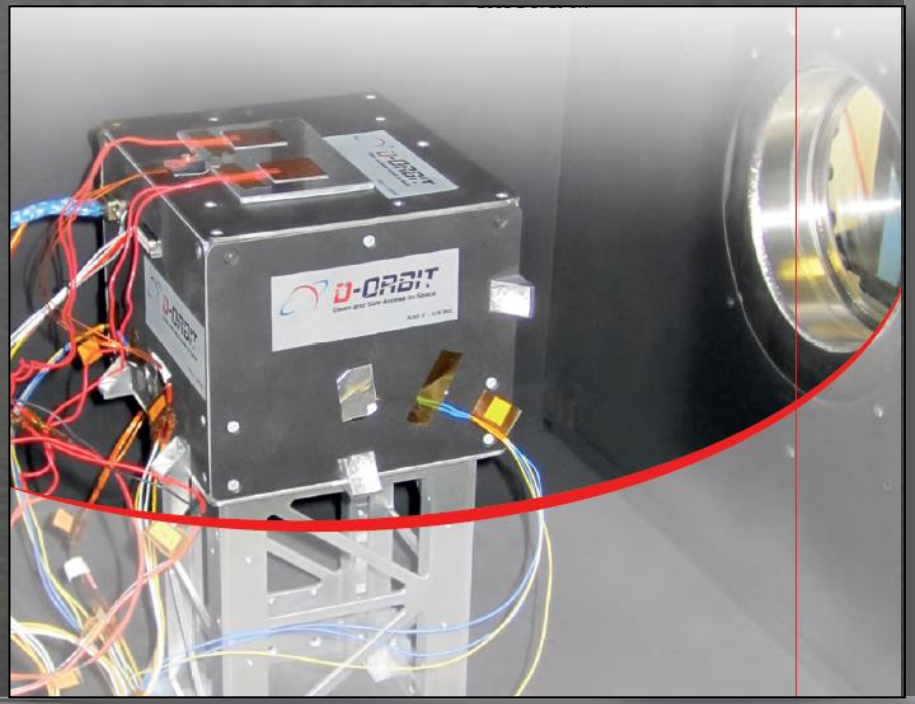




# D-ORBIT HERITAGE

A demonstrator solid propellant motor engineering model was successfully tested on ground in 2012. The 42 cm long and 19.5 cm diameter motor provided 16.2 KN thrust for 1.4 seconds.

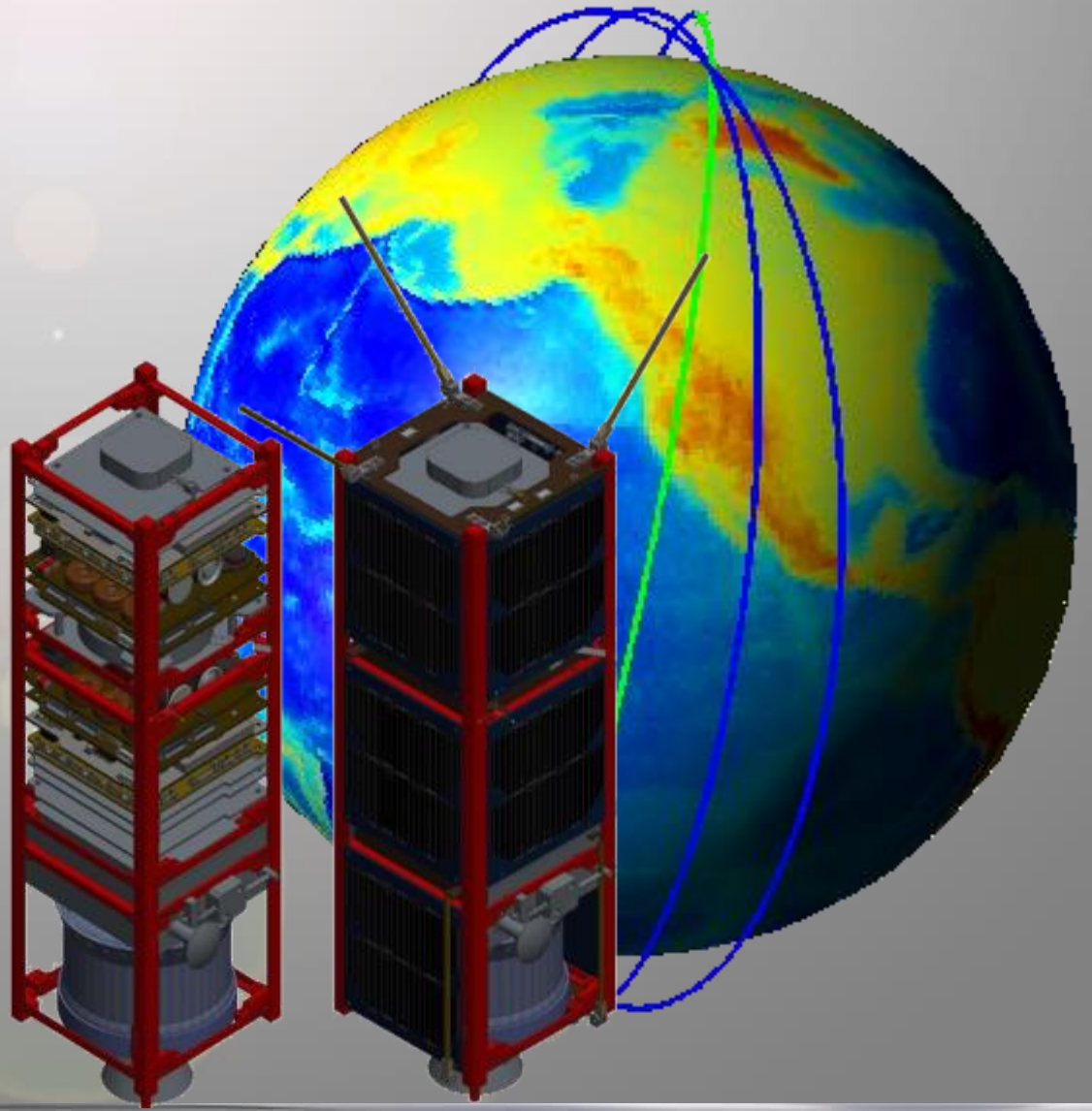
The mission objective was to attain the space qualification standardized procedures and the launch acceptance tests. **ALICE-2** passed electrical and functional tests, thermal-vacuum tests, vibration tests and EMC tests. Final functional and flight accepting testing
were performed in compliance with European Cooperation for Space Standardization's **standard ECSS-E-ST-10-03C, ECSS-E-ST-10-04C and ECSS-E-ST-20-07**.




On November 21st, 2013, D-Orbit's **ALICE2** mission was launched on a Dnepr rocket from Yasni, Russian Federation.
**ALICE2** included a Command & Control Unit and two Safe & Arm Devices mounted on the UniSat-5 unit.

# DECOMMISSIONING DEMONSTRATION
# D-SAT

**FIRST SATELLITE REMOVED IN A QUICK, SAFE AND CONTROLLED MANNER**



D-ORBIT Decommissioning Device
fully qualified for space applications

# D-SAT Mission

- The **D-SAT** satellite is a Three Unit cubesat platform designed, build and integrated by D-Orbit.

- The **D-SAT** satellite carries out two innovative experiments:
  - the **SatAlert** experiment that will be performed during the D-SAT mission;
  - the first and **unique** demonstration of an independent, quick and safe satellite **decommisioning**.

# D-SAT Mission Analysis

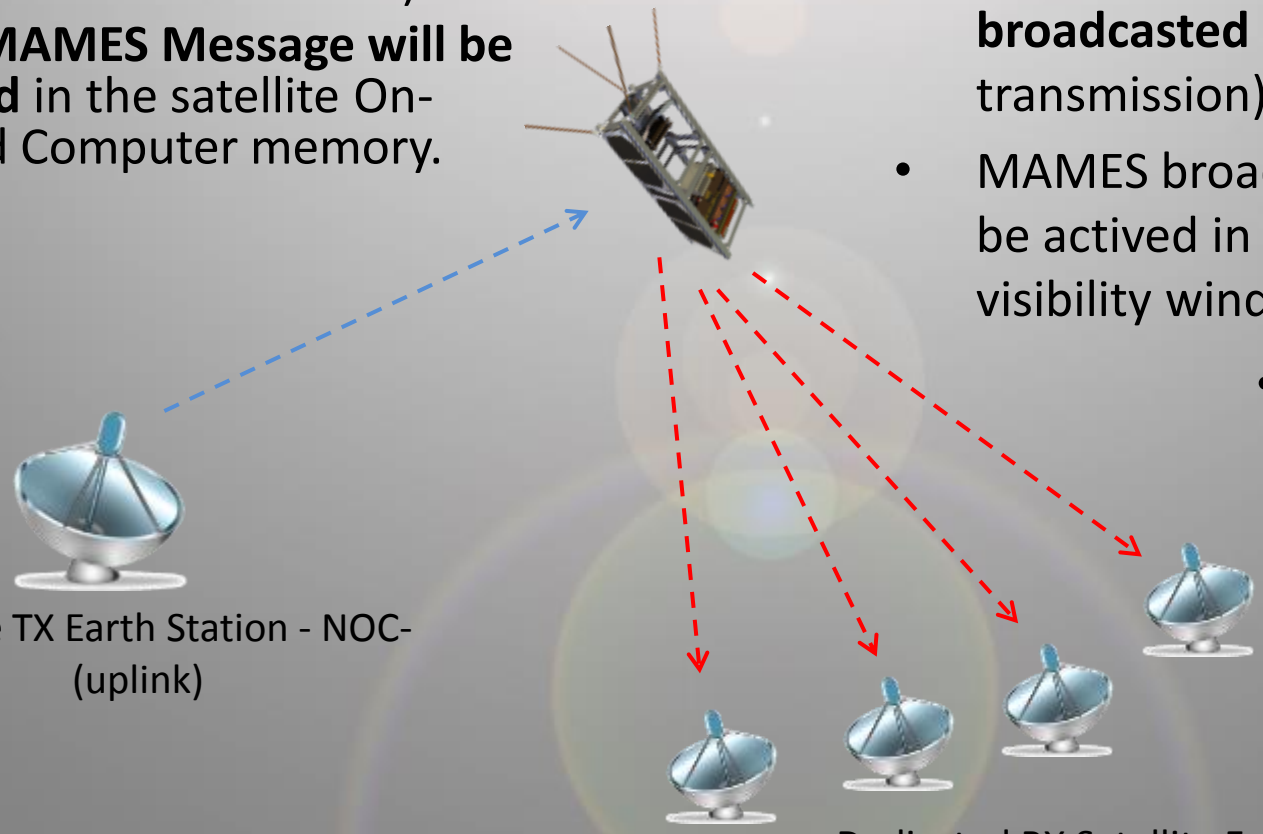
**Decommissioning Maneuver**

- Impact location in uninhabited regions, in open sea (Arabian Sea)
- Reentry Time 20 min

# SatAlert Experiment

## Earth-to-Satellite path

- During the **visibility period** the **Earth station sends** to the satellite a **MAMES message** (maximum width of 4KB).
- The **MAMES Message will be stored** in the satellite On-Board Computer memory.



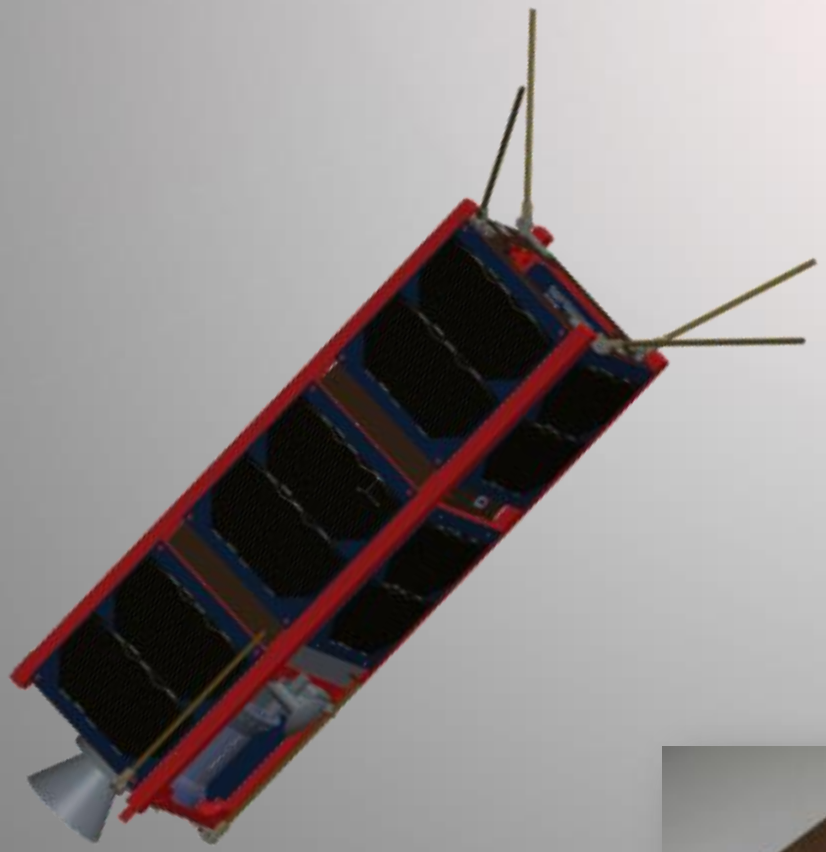
Satellite TX Earth Station - NOC- (uplink)

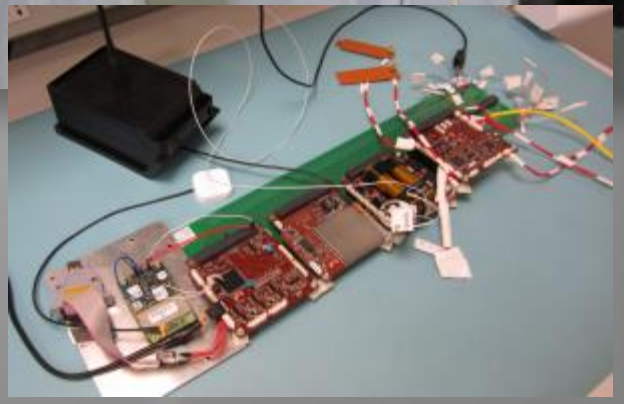
Dedicated RX Satellite Earth Stations

## Satellite-to-Earth path

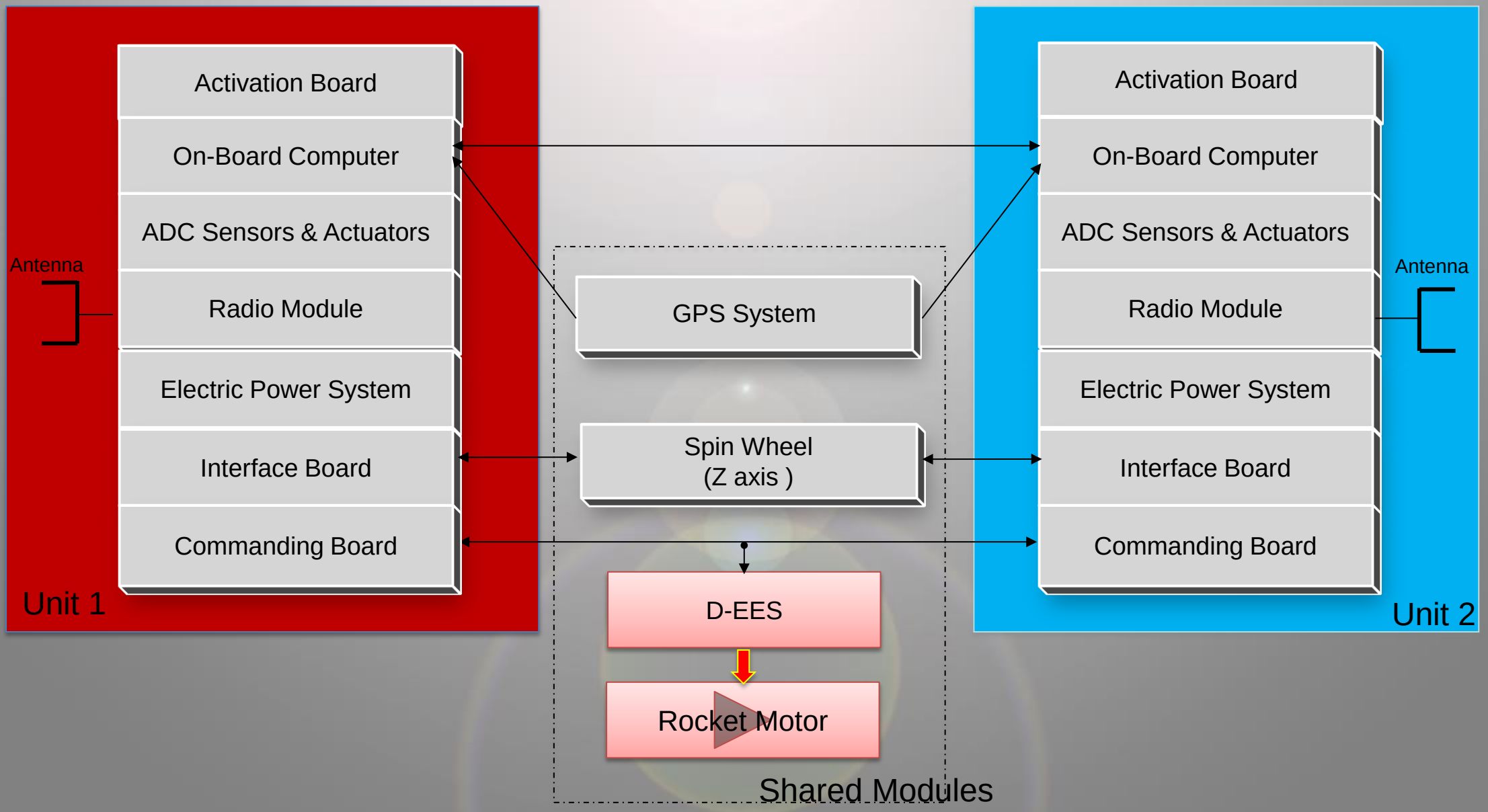
- As a **trigger command** is sent by the Earth Station (NOC), the **MAMES message** stored on satellite **will be broadcasted** (on-demand transmission).
- MAMES broadcast transmission will be actived in all the available visibility windows.
- **A dedicated Earth Station will be implemented for the reception and de-encapsulation of the MAMES messages.**

# D-SAT Integration in progress





# D-SAT Block Diagram



# Ground Station

## Main GS:

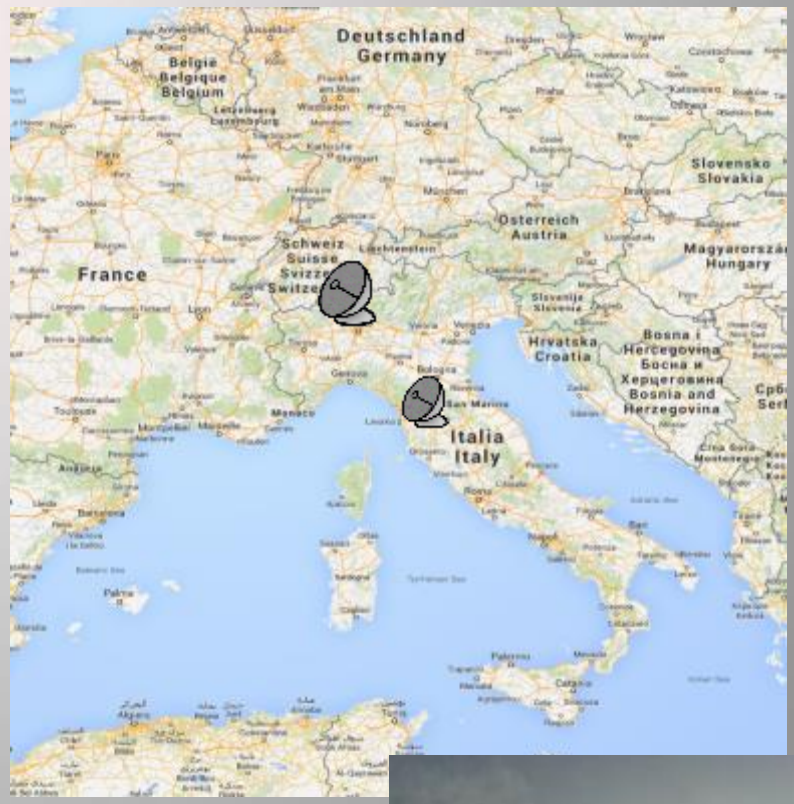
Located at Lomazzo (CO) – Italy

Lat. 45° 41‘ N - Long. 9° 2‘ E

## Secondary GS:

at Florence– Italy c/o CNIT facilities

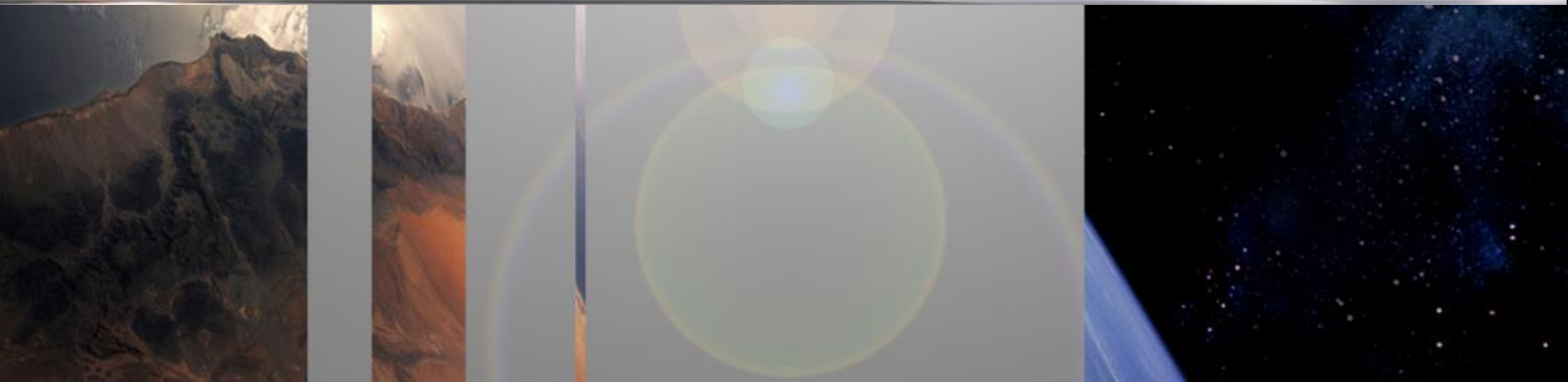
at Malindi – ASI facilities (in definition)




**Configuration:**

- 19 elements Yagi-Uda Antenna (Gain 17 dBi)
- Zenith and Azimuth rotator and controller
- UHF amateur radio transceiver
  - Transmitted Power = 20 W
- Terminal Node Controller with GMSK modem

# D-SAT
# Assembly, Integration and Verification



# D-SAT AIV

## Decommissioning motor and D-EES

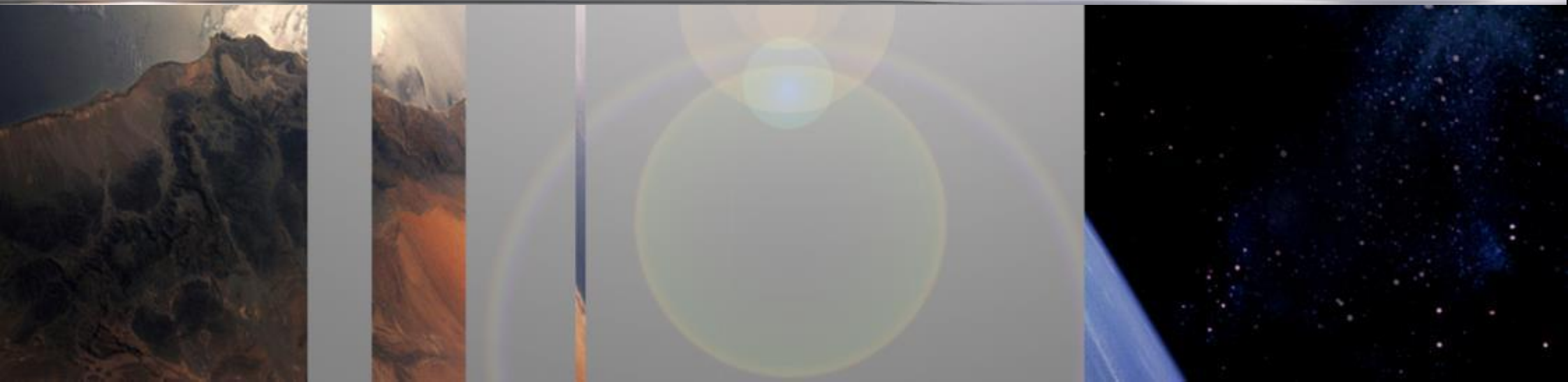
- Internal acceptance testing of all procured equipment prior to integration.
- Materials procurement according to internal procedures (UNI EN 9100: 2009)
- Materials certification according to EN 10204 2.1 or 3.1.
- Decommissioning motor and D-EES developed as a product:
  - Tested according to MIL-STD-1576, AFSPCMAN 91-710 and EWR-127.
  - In particular:
    - Functional tests
    - Thermal Cycling
    - Vibration (Random, Sine, Shock, Acceleration)
    - Leakage
    - Radiography/visual inspection
    - Firing
    - Storage Temperature test
    - Thermal Ageing
    - Mass, Center of Gravity and Moments of Inertia
    - X-Ray (32°F  12 hours)
    - Life tests

# D-SAT AIV

## Acceptance and Qualification testing

- The D-SAT assembly will be accepted and qualified according to GSFC-STD-7000A and ECSS-E-ST-10-03C
- Procurement according to internal procedures (UNI EN 9100: 2009)
- In particular:
  - Functional and performance (ADCS, GPS, Spin Wheel, etc)
  - Physical properties (mass, COG, moments of inertia)
  - Vibration (Random, Sine, Shock)
  - Thermal vacuum cycling
  - EMC (Electromagnetic compatibility according to ECSS-E-ST-20-07C)

# D-SAT
# Safety



# Safety Implications and Objectives

## D-SAT objectives / scope of work related to safety

- Obtain inter-agency safety clearance for International Space Station deployment
- Obtain US launch Range safety clearance

**Payload Safety Policy and Requirements for the International Space Station**

**Baseline**

*This document contains information that falls under the jurisdiction of the U.S. Department of Commerce Export Administration Regulations, 15 CFR 730-774, and is classified as EAR99/NLR.*

**April 2010**

POCKOCMOC

esa european space agency

JAXA

agenzia spaziale italiana

National Aeronautics and Space Administration
International Space Station Program
Johnson Space Center
Houston, Texas Contract No.: NNJ06JE86C

## Clearance for a manned system applies to a non-manned system

# Safety Implications

- **The primary hazard is the inadvertent initiation of the rocket motor**
- **Mishap by definition catastrophic (MIL-STD-1576; NSTS 1700.7B; SSP 51700: loss of vehicle/platform or personnel fatality)**
- **This applies to all phases of the product life cycle: manufacture, storage, transport, integration, launch, use**

# Applicable Standards

- **GENERAL DESIGN, DESIGN VERIFICATION, QUALIFICATION**

MIL-STD-1576 “Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems”;
ECSS-E-ST-33-11C “Explosive Systems and Devices”;
ECSS-E-ST-35-02C ”Solid Propulsion for Spacecraft and Launchers”.

- **GROUND SAFETY**

AFSPCMAN 91-710 “RANGE SAFETY USER REQUIREMENTS MANUAL“ (former EWR-127);
KNPR 8715.3 “KSC Safety Practices Procedural Requirements”;
CSG-RS-22A-CN “CSG Safety Regulations, vol. 2 – part 2 “Specific Rules Spacecraft”;
NASA STD 8719.12 “Safety Standard for Explosives, Propellants, and Pyrotechnics“.

- **THE TOUGHEST**

SSP 51700 “Payload Safety Policy and Requirements for the International Space Station” is the standard valid for payloads deployed from the International Space Station.

Includes NSTS 1700.7B requirements for operating solid rocket motors from the space shuttle (Appendix D).

# Logistics / Installation

**QUALIFICATION LOGIC:**

**Platform qualification concept: similar to liquid propulsion, probably less critical…**

**Satellite manufacturer side:**

- **Inert Device with EES (Nasa standard initiator or equivalent EED)**
- **Identical electrics/electronics, form and fit representative, mass and inertia representative**
- **Safe satellite qualification, no special handling, no special building**

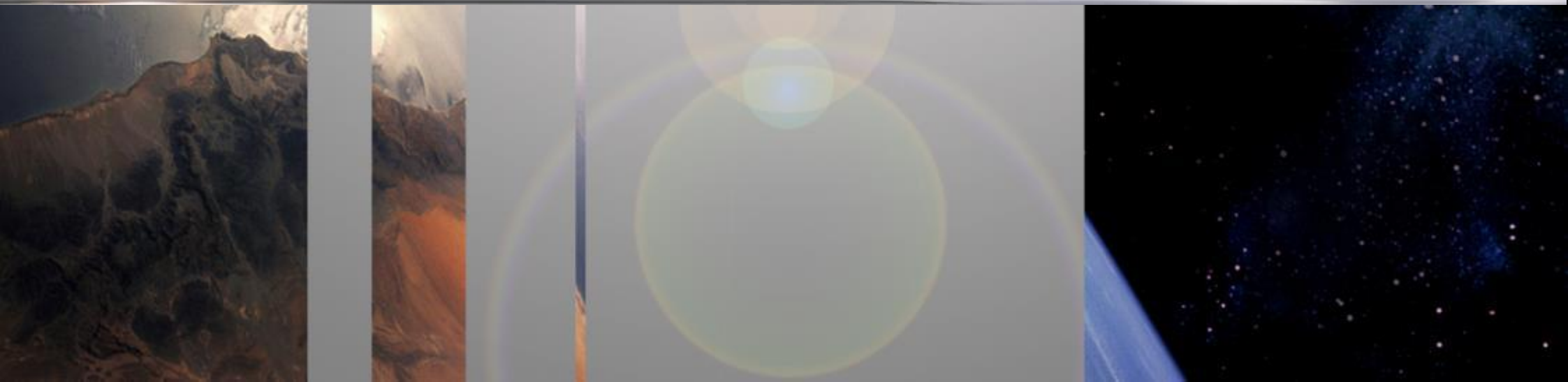
**Tested at solid rocket motor manufacturer:**

- **Live device (with propellant), mounted on a satellite frame replicating satellite environment**
- **Device qualified to expected loads**

**Transportation to the launch site & integration**

- **Integration on the satellite at CSG or other launch site; CoG alignment with mechanical interface (beams with pivot & linear guide); no toxic liquid, no spillage, tanks, valves, etc.**

# D3
# DEVELOPMENT AND QUALIFICATION



# D3 DEVELOPMENT AND QUALIFICATION PLAN

## Device qualification from ATP

- Qualification of a SRM (12-18 months from ATP, ROM available from several manufacturers)
- EES qualification (ongoing, available in 2015, plan is before the summer break)
- D3 Brain qualification (12 months from ATP)
- TAU development and qualification: 18 months
- D3 complete integration and qualification: 24 months

# QUALIFICATION

## ENGINE:

10 engines manufactured from the same propellant batch. Tested according to EWR 127-1 Range Safety Requirements.

Qualification testing on 4 of the 9 motors that has been acceptance tested.

- Thermal ageing
- Transport shock/bench handling
- Transportation vibration
- Sinusoidal vibration
- Shock
- Acceleration
- Thermal cycling
- Random vibration
- Leakage
- Radiography / Visual inspection / Inertial
- Storage temperature test
- Firing

## EES:

17 manufactured for test and qualification. Designed and tested according MIL-STD-1576.

Live EES are used to:

- Safety test
- Barrier test
- Qualification tests
- Firing tests
- Flight hardware

Inert EES are used to

- Pressure leakage test
- Functional test
- Satellite QM and FM qualification and acceptance test

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