POLITECNICO DI TORINO

esa

CubeSat
polito team

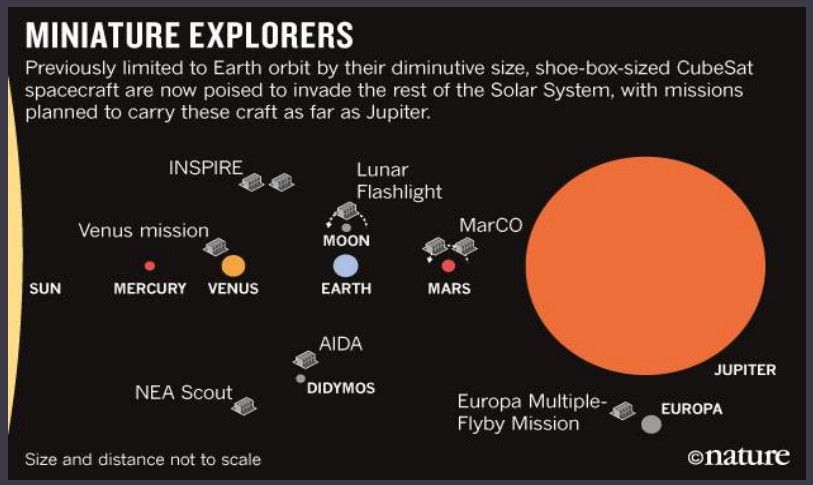
New technology requires new testing tools

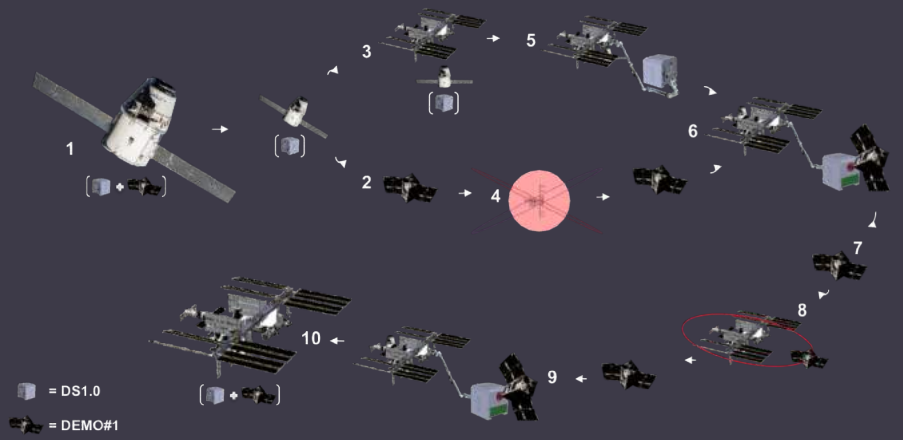
Electric Propulsion Technologies for Small Satellites and New Markets

EPIC Workshop 2018 - London - 16th October 2018

What's going on

- New generation of Cubesats for challenging applications and unprecedented mission such as:
  - Remote sensing
  - Communication
  - Inspection of debris and outposts
  - Interplanetary exploration





New needs and technology

- New missions require to increase CubeSat capabilities such as:
  - High data-rate communications
  - Active thermal control
  - Enhanced attitude and orbit control
- Electric propulsion is a key technology towards innovative CubeSat applications

Low technological maturity of miniaturized propulsion systems

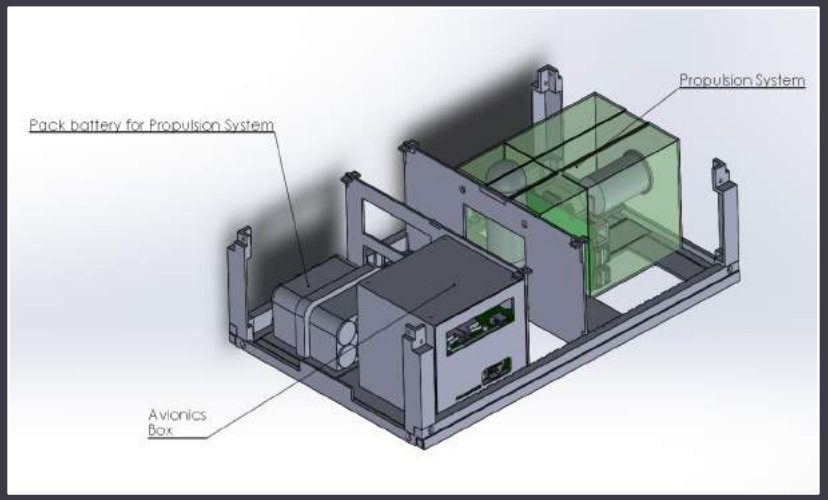
Poor knowledge of the propulsion system impact on CubeSat systems

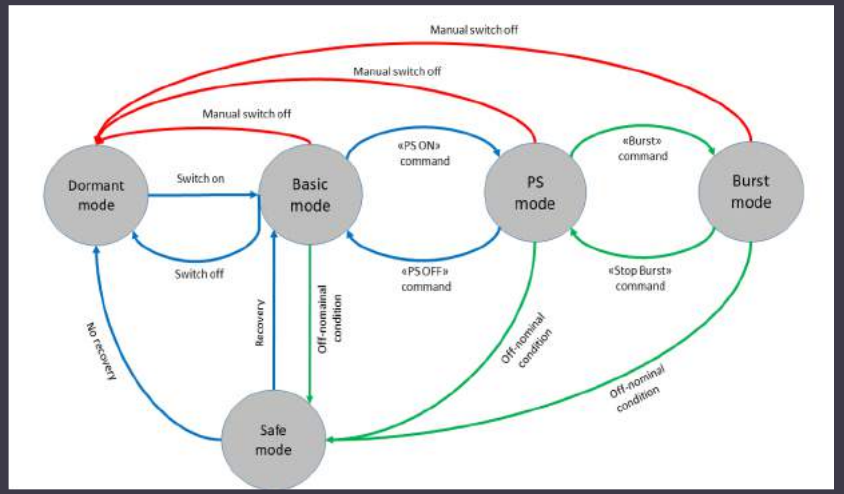
Difficulty of the verification of integrated Cubesat systems

- Need to increase the Technology Readiness Level (TRL) both of the Propulsion systems and the Cubesat Platform
- Need to assess the effects of the operations and the interactions between miniaturized propulsion systems and a Cubesat platform:
  - Electro-magnetic interferences
  - Heat transfer
  - Electrical power consumption
- Need to maintain the low-cost/fast-delivery paradigm

New solutions

- A CubeSat standard test platform suitable for:
  - hosting a wide range of miniaturized electrical propulsion systems
  - conducting test campaign in relevant environment at system-level
- A dedicated test plan and procedure addressing:
  - reusability and automation
  - compliance with current verification and quality standards





- The new CubeSat Test Platform will be available beginning 2019 @ESTEC Electric Propulsion Lab

IDEAS FROM YOU ARE WELCOME FOR NEXT STEPS OF THE PROJECT

Additional info

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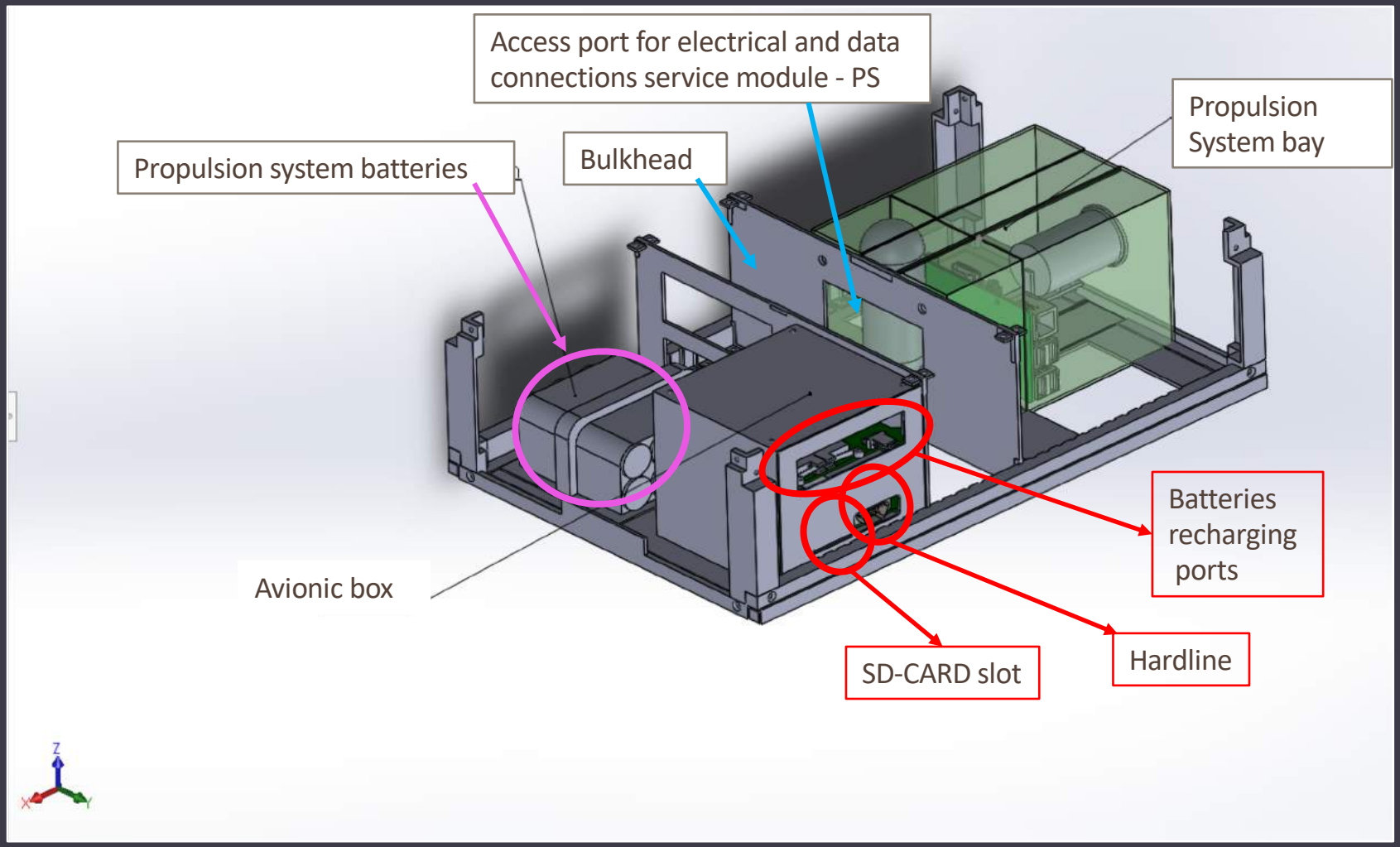
  - https://www.facebook.com/CubeSatTeam
  - http://www.cubesatteam-polito.com
- Paper:
  - S. Corpino, F. Stesina, J. Gonzales del Amo, E. Bosch Borras, and G. Saccoccia, *Design of a Test Platform for miniaturized Electric Propulsion Systems*, 2018, Proceedings of the 69th International Astronautical Congress, Bremen

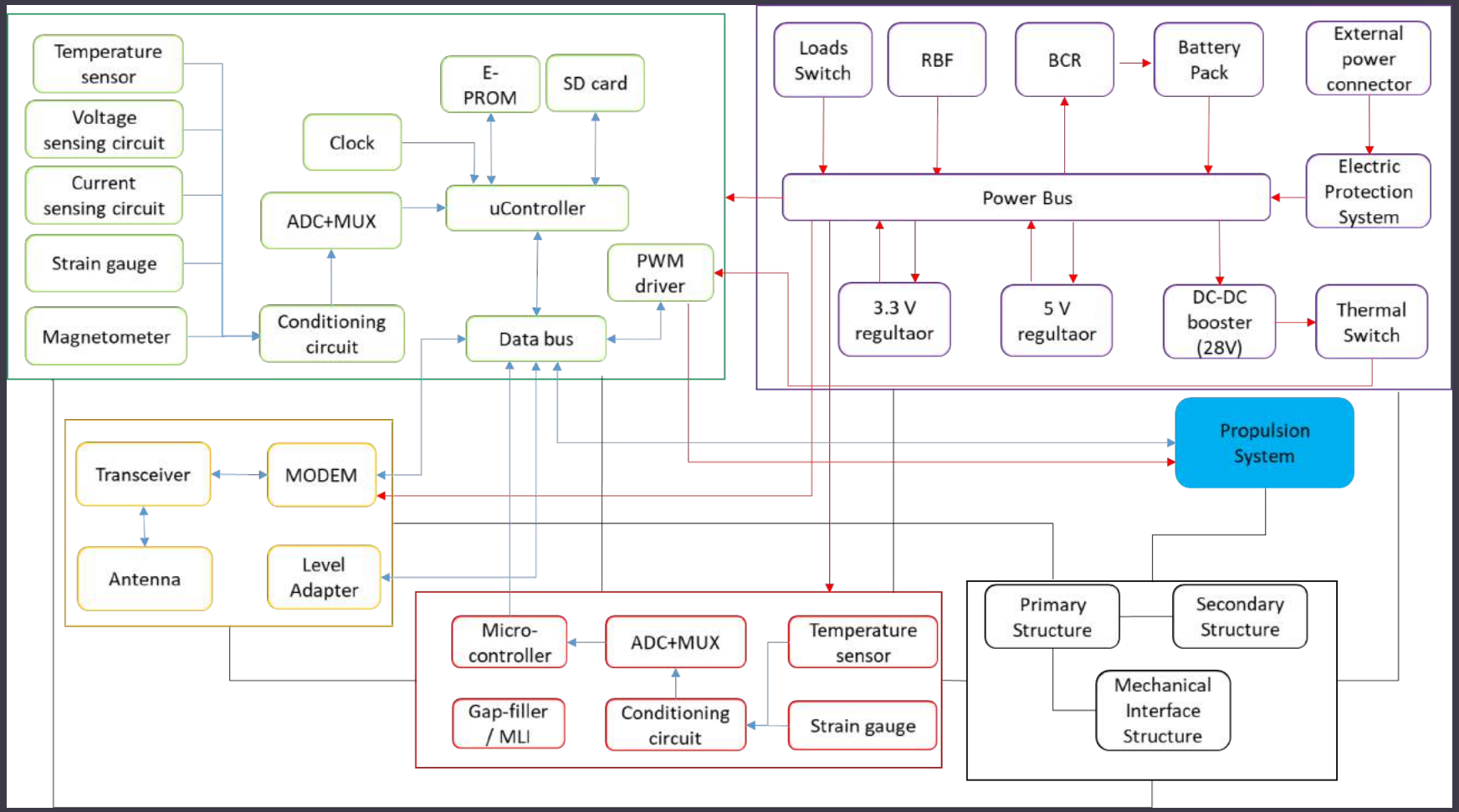
Drivers for the platform design

- Safety:
  - *Leakage and contamination protection*
  - *Over-voltage and over-current protection*
  - *Thermal protection*
  - *Electro-magnetic interferences protection*: protection of CTP and propulsion system from mutual and external electromagnetic interference
- Reliability: no single-point failure, FDIR system
- Level of autonomy
- Flexibility/adaptability of the interfaces with the PS
  - handling (wide) ranges of electrical power and operative voltage,
  - managing different communication protocols,
  - managing different data and commands,
  - providing a mechanical interface (between the platform and the propulsion system) able to adapt to the specific system of interest
- Accessibility
- Manufacturing
- Cost

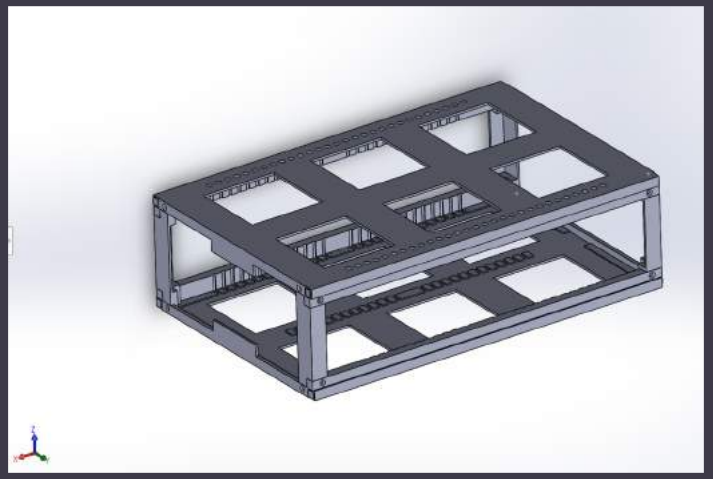
CTP Layout

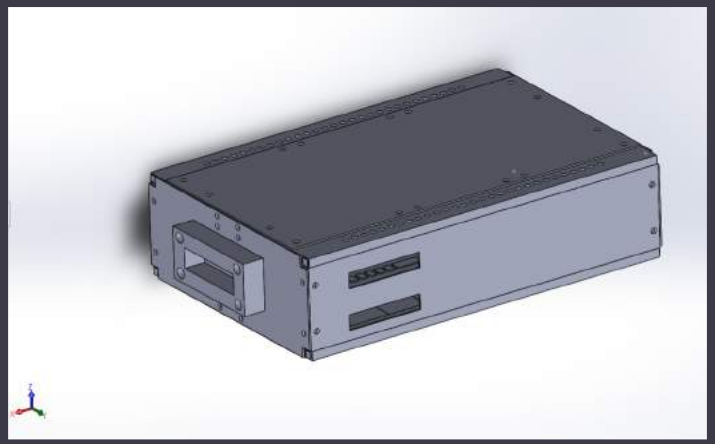

Access port for electrical and data connections service module - PS
Propulsion System bay
Propulsion system batteries
Bulkhead
Batteries recharging ports
Avionic box
SD-CARD slot
Hardline

Functional block diagram



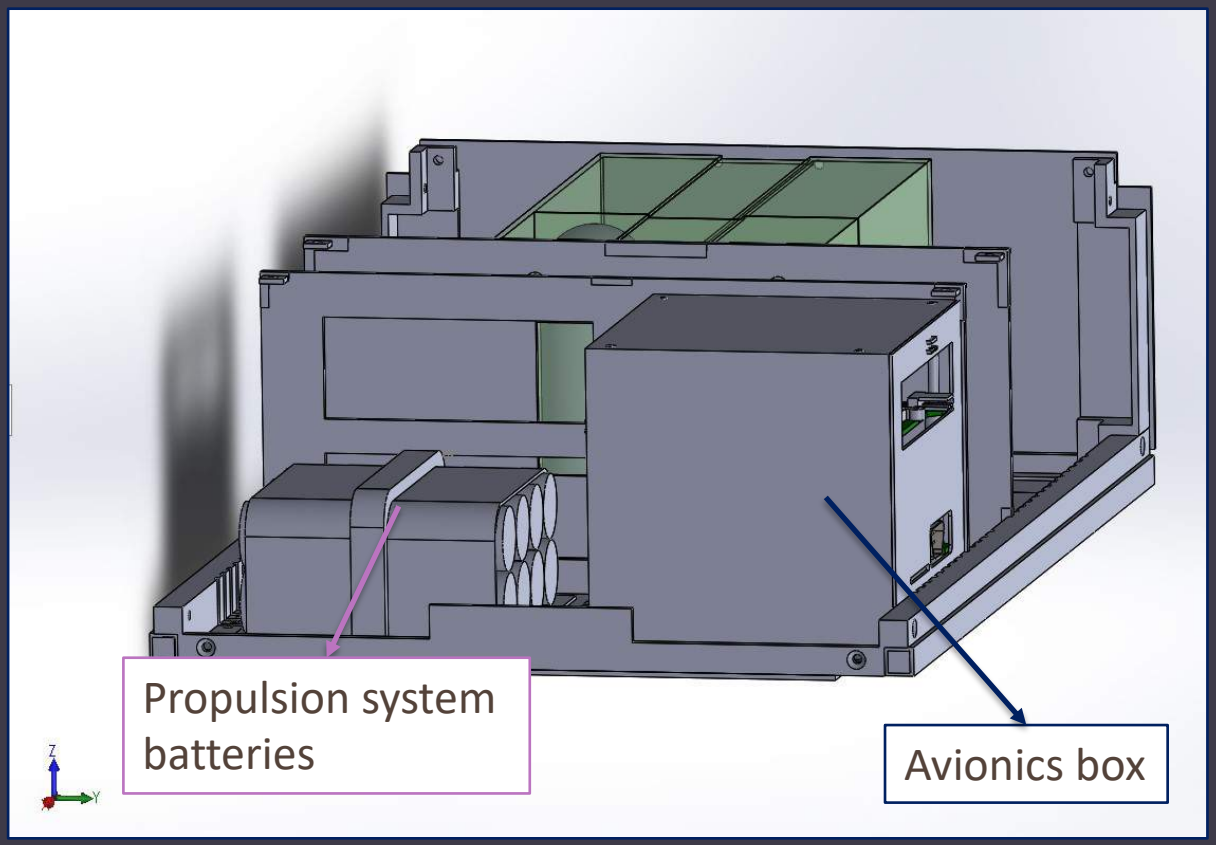
CTP - Structure





- **Primary structure**: two 20 cm x 30 cm Al Alloy elements joined by four brackets of the same material to form a truss-like box.
- **Secondary structure:** internal mounting elements (screwed to the primary structure) for installation of avionics and the propulsion system. The secondary structure also includes external panels for protection of onboard systems from external.
- Adaptable internal layout depending on the specific test.
- Mechanisms and removable structural parts can be mounted on the external panels to change the configuration for specific needs of the test, or to host antennas and sensors

CTP service module

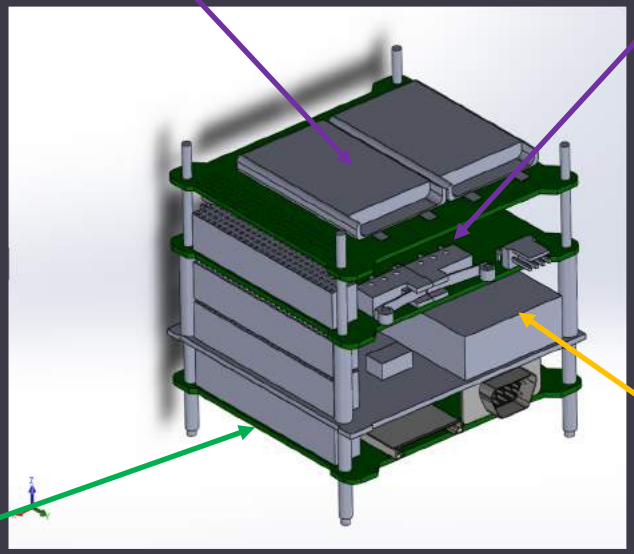


Propulsion system batteries are Li Ion battery packs 14,8 V and max current 5.2 A. They are strictly dedicated to provide electrical power supply to Propulsion System.

CTP – Avionics box

Electrical Power System daughter board

Electrical Power System Mother-board



On board computer

Communication System

CTP – Avionics box

- EPS
  - Mother board
    - **Protection circuits for over-voltage**: Refresh fuses and thermal switches protect PS and avionics electrical supply lines
    - **Loads Switch (LS) and Remove Before Flight (RBF) switch** manages loads and the entire system power supply when satellite is not operative
    - **Voltage regulation for avionics**: two regulated main bus (3.3V - max 500 mA, 5V - max 1 A) for service module
    - **Voltage regulation for PS**, through step-up circuit and PWM circuits, up to 28 V
    - Availability of housekeeping data of voltages, currents and temperatures
    - PS battery packs recharging circuits allow a complete recharging in less then 6 hours
  - Daughter board
    - Avionics battery packs: Li-Ion cells, capacity: 2Ah @ 14.8V
    - Availability of battery packs housekeeping data of voltages, currents and temperatures
    - Avionics battery packs recharging circuits allow a complete recharging in less then 5 hours

CTP – Avionics box

- OBC
  - ARM-9 architecture micro-controller (TRL 9 – already used in CubeSat mission)
  - **Real Time Operating System:** Linux Embedded
  - **Available data:** temperatures, voltages, currents, magnetic field intensity, acceleration
  - **Data storage:** EPROM and external SD CARD for data storing up to every second.
- COM SYS (TRL 9 – already used in CubeSat missions)
  - UHF radio-frequency line
    - **Data rate**: 1200 bps.
    - **Radio:** full duplex COTS UHF radio-module transceiver
    - **Dipole antenna**
    - **Protocols**: AX.25 format on the radio channel.
  - Hardline
    - **Protocol:** Serial RS232
    - **Data rate**: 115.2 Kbps

Interface requirements

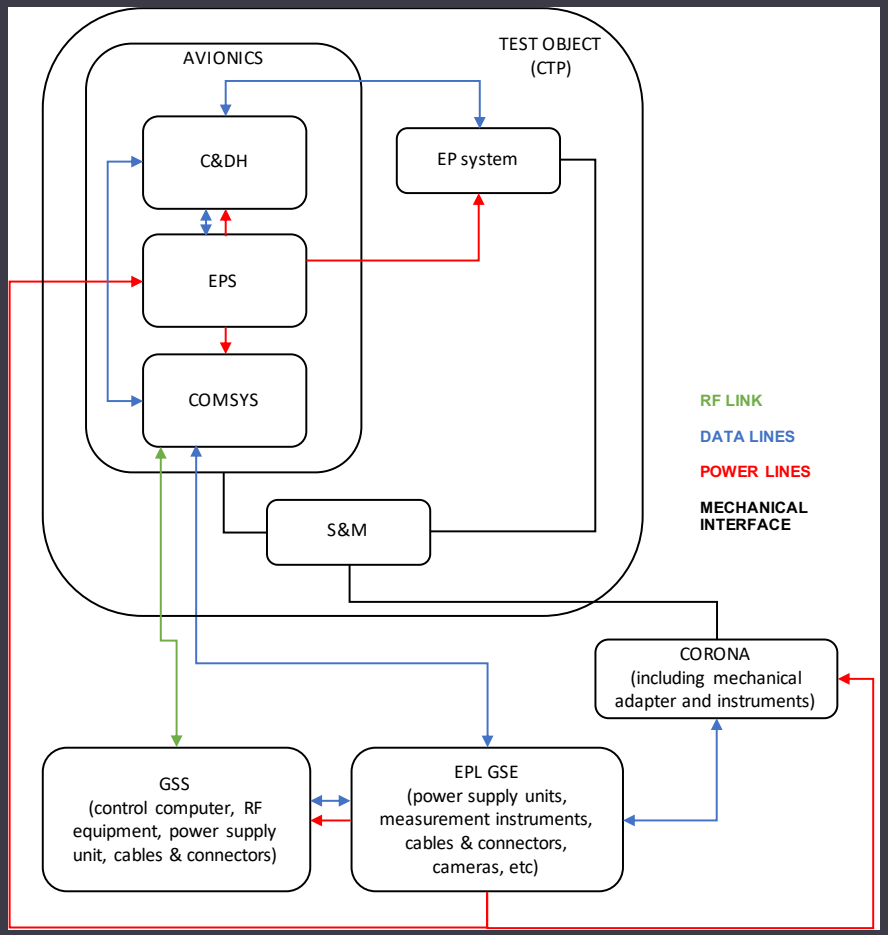
- To/from Propulsion System
  - Electrical interface:
    - CTP shall provide a regulated operating voltage in the range 5 - 28 V with a maximum current of 2 A.
    - Electrical power for PS shall be supplied by battery or directly from an external source (power supply unit)
  - Mechanical interface:
    - CTP shall host PS with a total size up to 4U and a mass up to 6 Kg. An adaptable bulkhead separates service module and Propulsion System bay
  - Data interface:
    - CTP shall send/receive commands and data to/from PS via I2C, SPI, RS232/RS485, USB and CAN bus lines.
    - CTP shall store data from PS in onboard memories every second
    - CTP shall send data to Ground Support System every 10 seconds via RF link and every second via hardline

Interface requirements

- From/To EPL facility (CORONA)
  - Electrical interfaces:
    - CTP shall receive power from the EPL facilities via feedthrough
    - GSE (power supply unit) shall provide a voltage of 15V (max current 1A) to recharge PS battery packs via 4-pins connector with label “PS battery recharge”
    - A GSE (power supply unit) shall provide a voltage of 8V (max current 0,5 A) to recharge avionics battery packs via 4-pins connector with label “AV battery recharge”
  - Mechanical interfaces:
    - CTP shall be arranged in a mechanical interface compliant with the CORONA structure
    - Wires for electrical power connections and data exchange shall pass in the feedthrough of CORONA
  - Data interfaces:
    - CTP hardline shall be connected to GSS RS232 port
    - CTP Ground Support System
    - CTP shall send data to Ground Support System every 10 seconds via RF link and every second via hardline

Test configuration

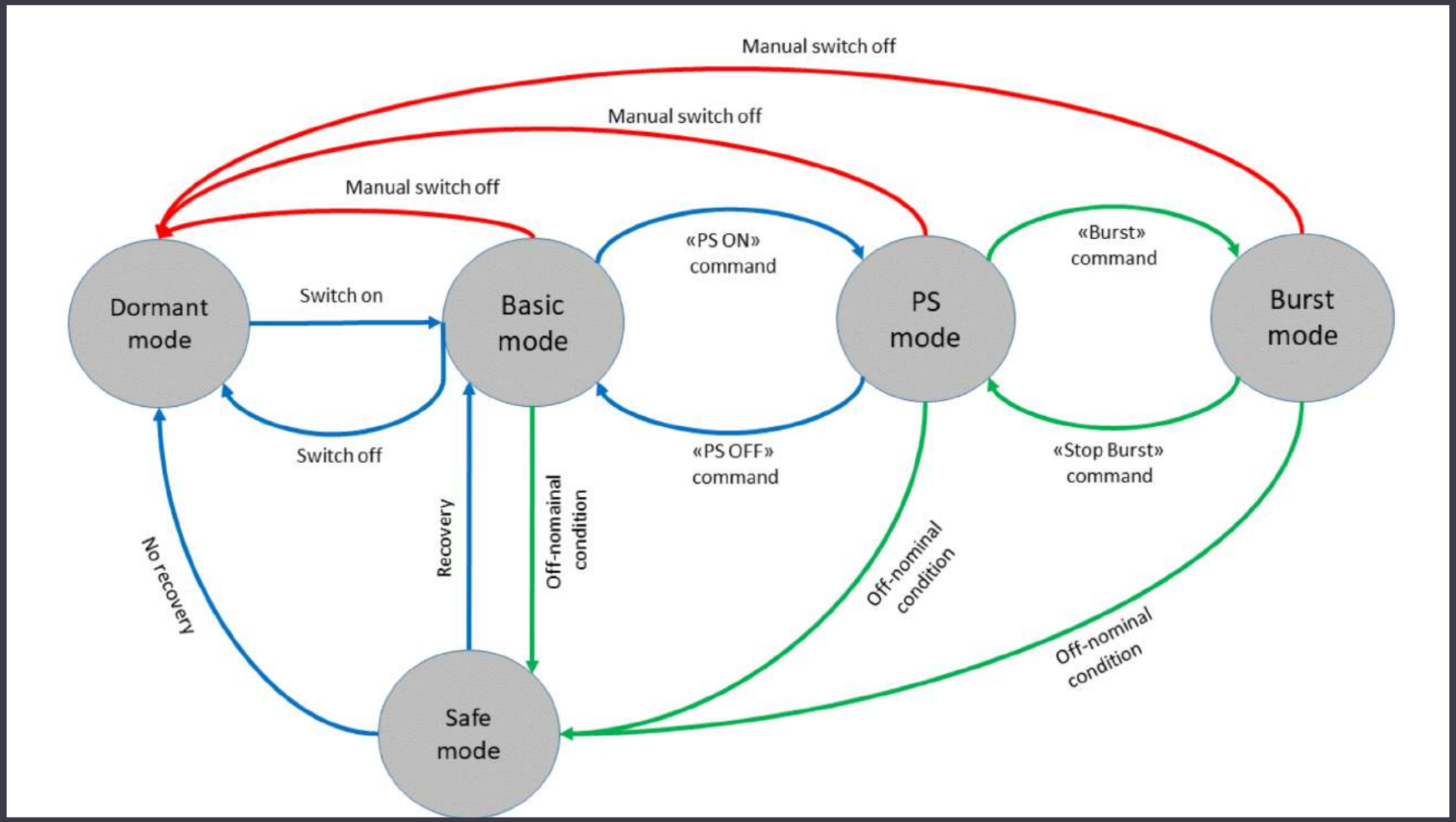
- Functional block diagram of the test architecture @ESTEC



Measurements

- On board the CTP:
  - Electrical and diagnostics parameters
    - Voltage and current
    - Temperature
    - Pressure
    - Magnetic and electrical field
- Via Ground Support Equipment of ESA/ESTEC Electrical Propulsion Lab
  - Thrust performance
    - Thrust
  - Mass flow and mass variation
    - Mass flow rate
    - Propellant mass variation
    - Flux mapping
    - Propellant mass consumption
- Specific parameters can be gathered according to type of Propulsion System under test

Operative modes



Test execution

Phase	Sub-Phase	Starting event	Ending event	Operative mode
Integration	Integration	CTP and PS delivered at EPL and checked separately	CTP and PS integrated and checked	Dormant/CTP/PS
Set up	Installation of CTP in CORONA	CTP, CORONA and GSE checked	CTP installed in CORONA	Dormant
	Pre-experiment checks	Functional check test of CTP, CORONA and GSE	CTP, CORONA and GSE completed checks	CTP/PS
	CORONA activation	CORONA door closed and activated	CORONA reaches the operative conditions	Dormant
Execution	CTP activation	CTP commanded ON	CTP checks completed	CTP
	PS activation	PS commanded ON	PS checks completed	PS
	Test sequence execution	Test started (Thruster ON)	Test stop (Thruster OFF)	Burst
	CTP deactivation	CTP checks started	CTP commanded OFF	PS/CTP
Conclusion	CORONA deactivation	CORONA switched OFF	CORONA checks completed	Dormant
	CTP disassembly	CORONA door open	CTP out of CORONA	Dormant
Analysis	Data collection	Data collected from CTP	Data processing completed	Dormant
	Data analysis	Data available to users	Experiment results available	Dormant
	CTP checks	CTP available for test	CTP checked	CTP
CTP stowage	CTP stowage	End of data processing	Next test session	Dormant

Summary

- The test platform features high degree of flexibility with respect to the ability to host different EP systems
- The test platform can be also adapted for installation of miniaturised propulsion systems based on other technologies
- The platform is fully representative of a 6U CubeSat flight unit, which can be used for qualification of propulsion systems as well as for verification of on-board avionics
- The test platform offers a valuable support to propulsion system providers to assess characteristics and performance of their product, and their impact on the hosting platform
- First prototype of the CubeSat Test Platform will be available beginning 2019 @ESTEC Electric Propulsion Lab
- The project is ongoing and requirements from the relevant community can be considered for implementation in next version of the CTP.