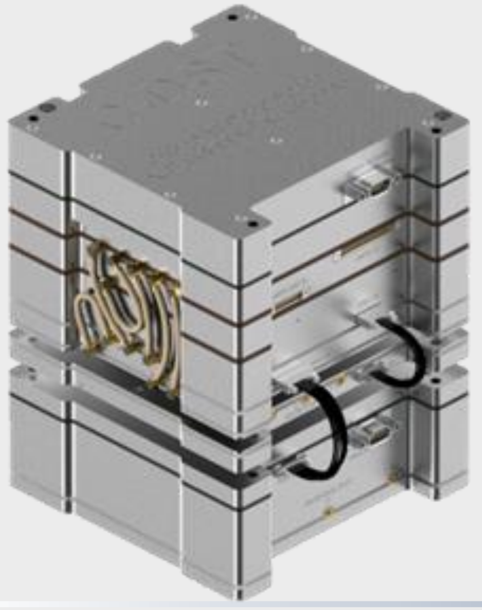
ASI Agenzia Spaziale Italiana

IMT Ingegneria Marketing Tecnologia

L’impegno Italiano nel settore dei CubeSat: tecnologie e missioni future



CubeSAT Deep Space X-Band TT&C Transponder (C-DST)

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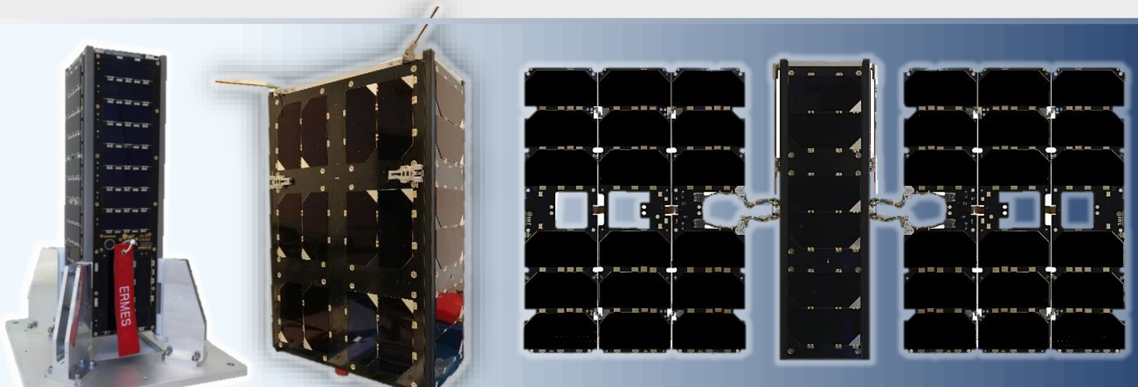
G. Piscopiello, A. Gabriele, C. Attanasio, E. Bruschini (Sitael SpA)

Prof. P. Tortora, Prof. E. Paolini (University of Bologna – (CIRI AERO)

A. Busso, A. Miraglia (ESA-Estec)

Giovanni Cucinella – IMT srl (02-04 Luglio 2024)



IMT at glance -Mission

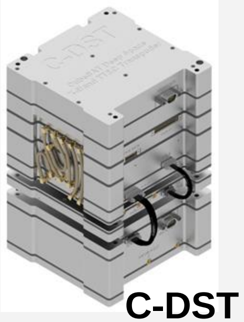
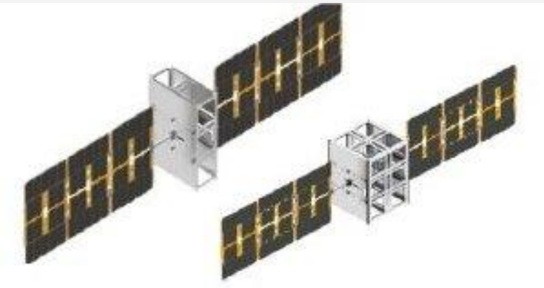
IMT Srl is an Italian private company (SME), founded in 1991 and active on three main activities:

System Engineering: Design and Development of Nano/Microsatellites and relevant On-board units for space commercial, scientific and defence applications *(EOSS, HORTA, µSADA, C-DST)*

Parts Engineering: Characterization and Testing of Electrical, Electronic and Electro-Mechanical components *(Qualification of rad-hard MOS-FET-N-Channel, Advirosing to ASI on EE Space Parts)*

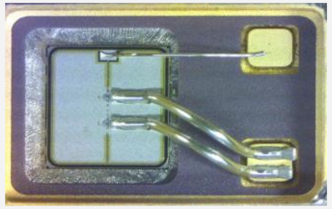
IoT solutions: Development of IoT Solutions for Smart Cities, Environmental Monitoring and Agriculture *(BISS – BiDirectional IoT Satellite Service)*

IMT at glance – Ongoing main Projects

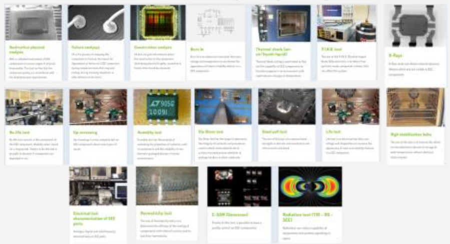



C-DST **μSADA**

μSada and C-DST will be embarked on HENON and LUMIO ESA Missions



Qualification of rad-hard power MOS-FET N-Channel



Advisoring to ASI on EEE Space Parts

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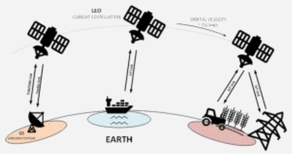
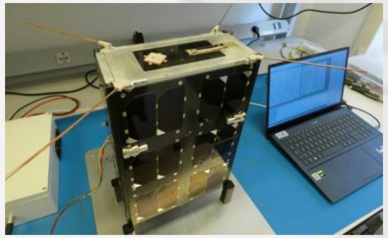


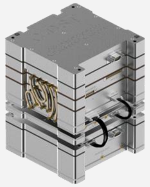
BISS (BI-directional IoT Satellite Service)

Italian Public Funding



EOSS (Earth Observation Small Satellite)

HORTA
(Remote Sensing by GNSS-R Passive Reflectometry)



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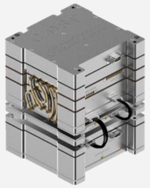
C-DST Overview (1)

ESA Project (GSTP Contract N.: 4000128163/19/NL/FE)

- One of the key elements of Cubesat Deep Space missions is the communication system, which needs to be DSN/ESTRACK compatible, small, light, and not power-hungry.

- Such a unit does not exist in Europe, at the moment.

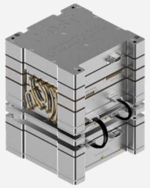
- Bearing in mind JPL's IRIS unit as a benchmark, we preliminarily proposed to ESA our technical solution prepared by a consortium (IMT srl, Thales Alenia Space Italy, Sitael and CIRI Aerospace of University of Bologna) which brings together all necessary know-how and expertise in the field of CubeSat and SmallSat technologies, digital and analog RF TT&C systems, power systems, radio science experiments.



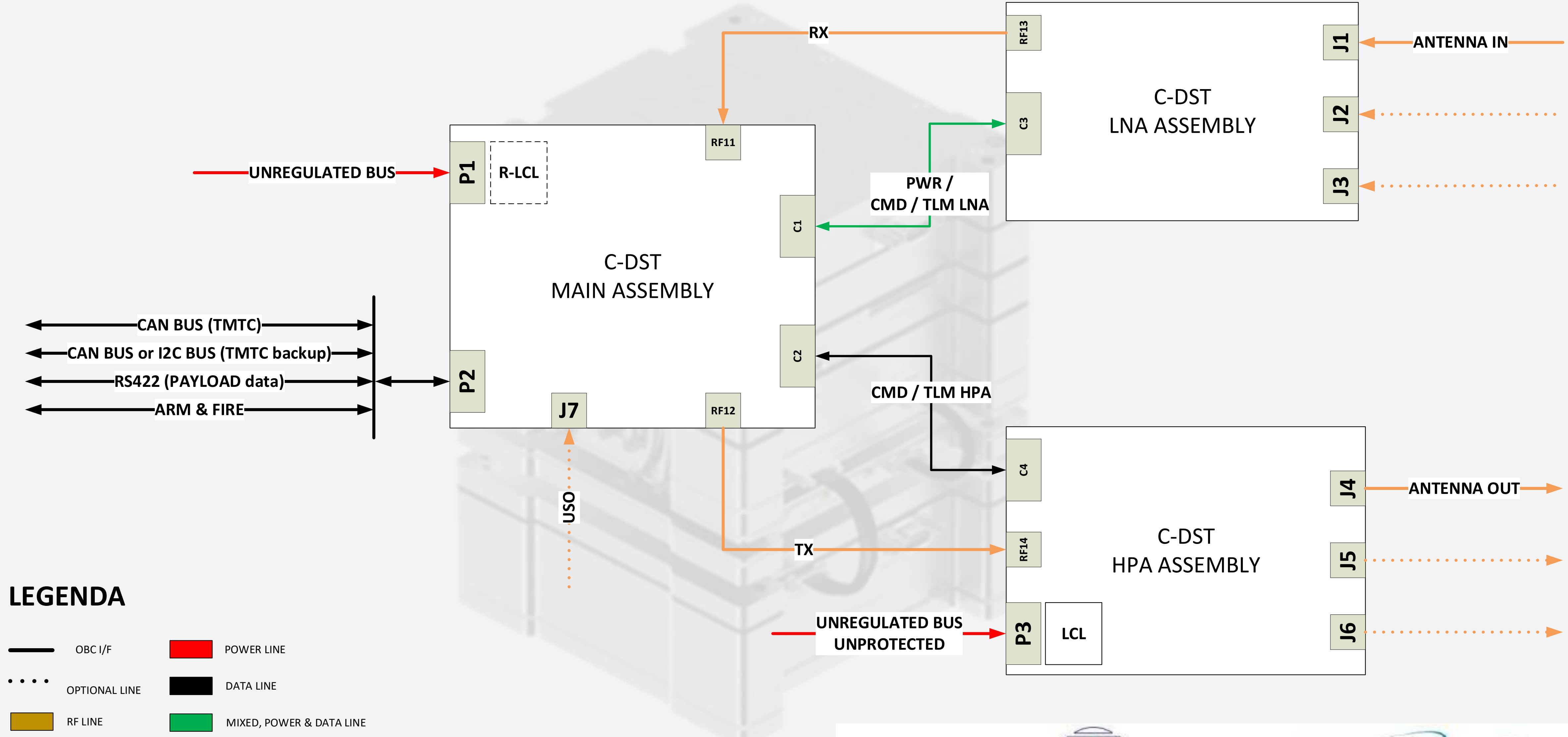
C-DST Overview (2)

ESA Project (GSTP Contract N.: 4000128163/19/NL/FE)

- The Project name, chosen by the consortium, is C-DST: “CubeSAT Deep Space X-Band TT&C Transponder”.
- The Contract with ESA was signed by IMT, as Prime Contractor.
- C-DST is the first European Cubesat Deep Space X-Band TT&C Transponder.
- This subsystem can be used to perform TT&C and Ranging functions.
- C-DST is compliant to the ESTRACK Stations.
- IMT Srl is the Prime Contractor of this project with the ESA (European Space Agency).
- Thales Alenia Space Italia SpA, Sitael SpA and University of Bologna - (CIRI AERO) are Subco’s/Partners



C- DST Block Diagram



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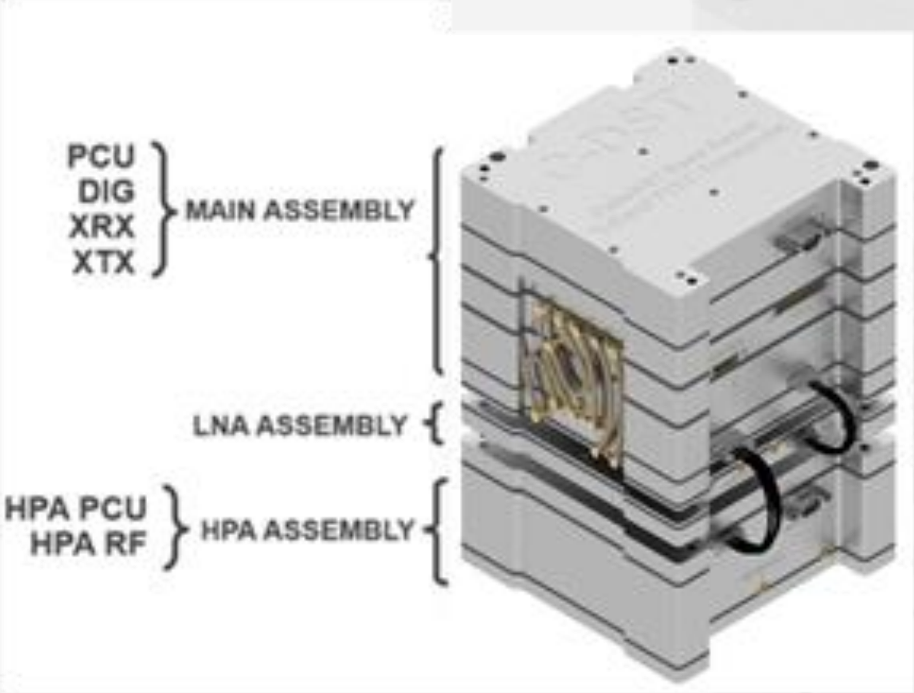
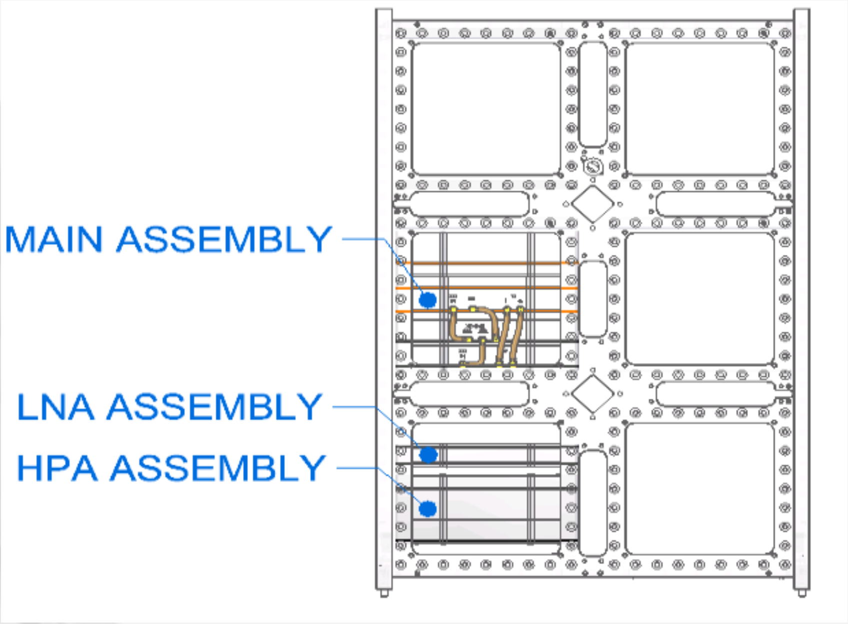
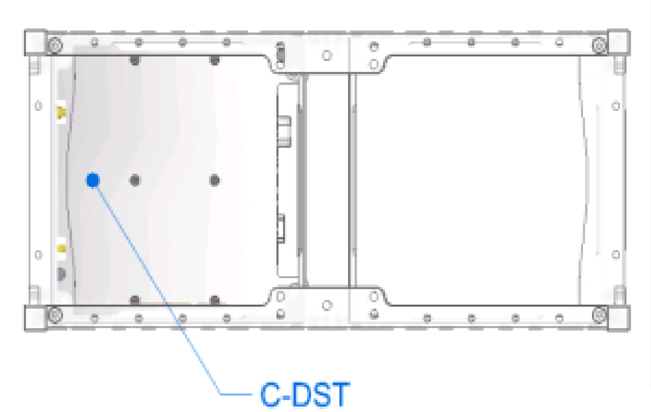
C- DST Layout and I/F

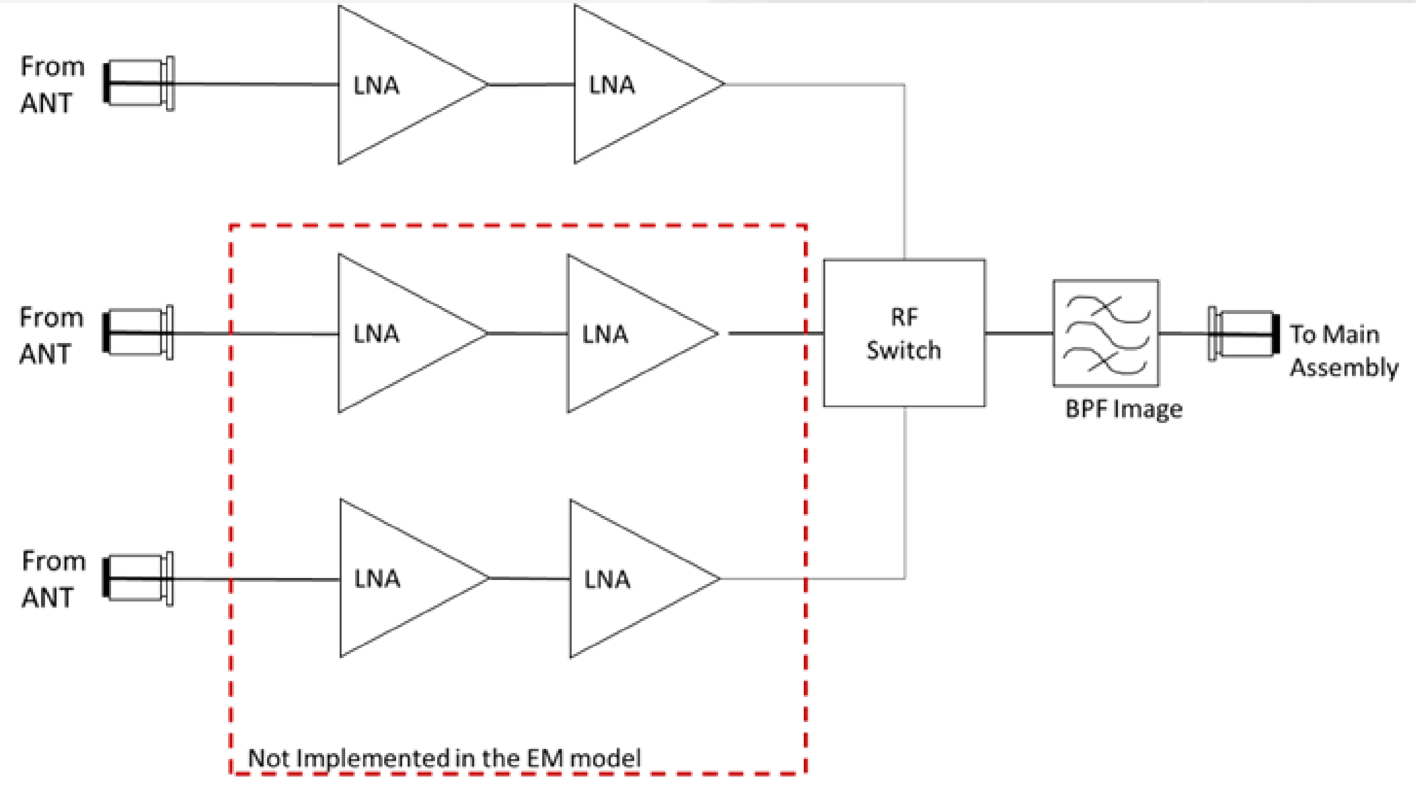


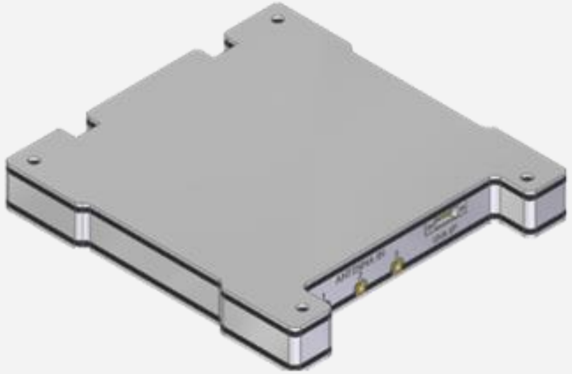




LNA ASSEMBLY

The LNA Assembly (developed by IMT) provides the front-end functions of the transponder. It could be located closed to the antenna (to improve the RF performances) or in-stack mount with the Main Assembly.

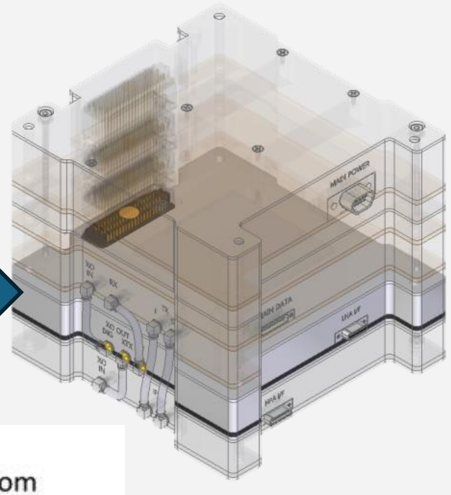


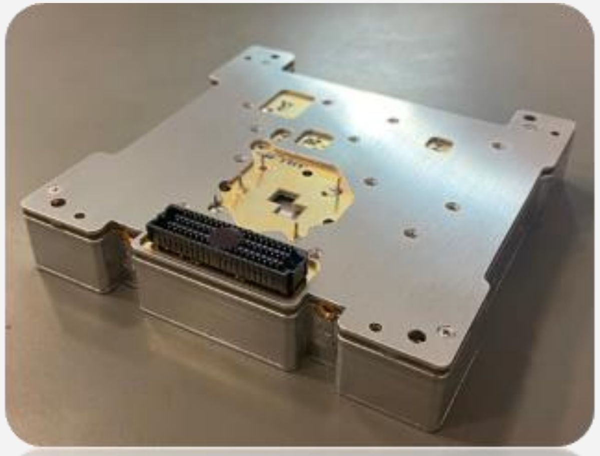


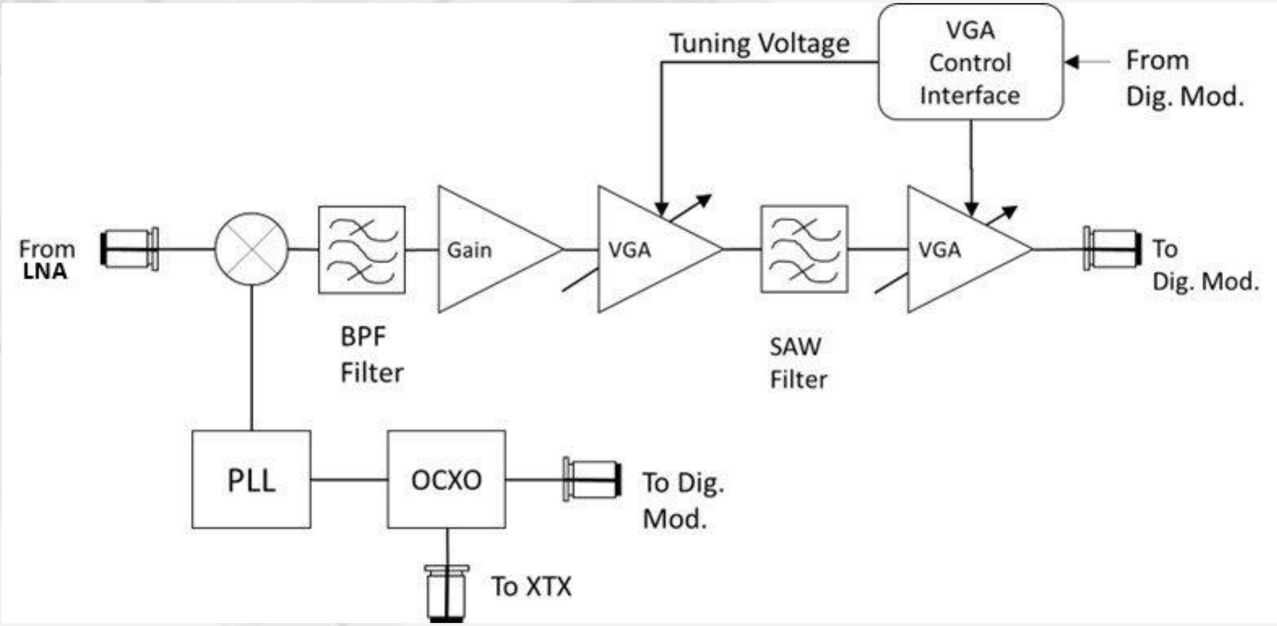
Three RF inputs from antennas with three different LNA chains are selectable by the Main Assembly via CAN bus.
They can work one at a time.

XRX Module

The architecture of XRX is based on a single Down-Conversion heterodyne architecture. The local Oscillator is a fully integrated PLL, phase locked to an OCXO stable oscillator, physically placed on the RX Board.
An option is available to replace the OCXO with an external Ultra-Stable Oscillator (USO) for improved frequency stability, Allan deviation, and phase noise, to allow Radio-science application of the X-ponder.

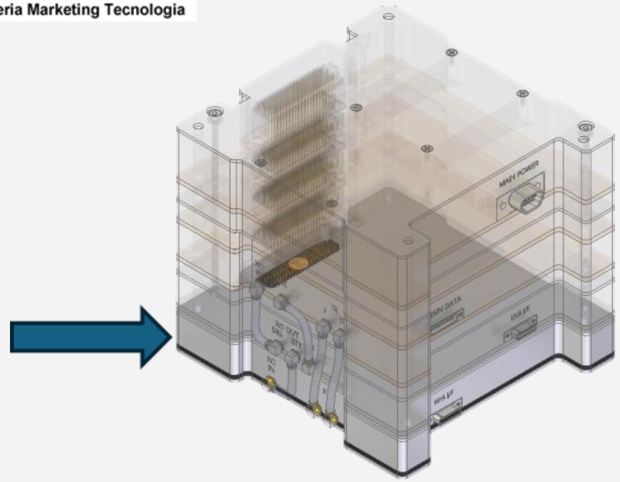


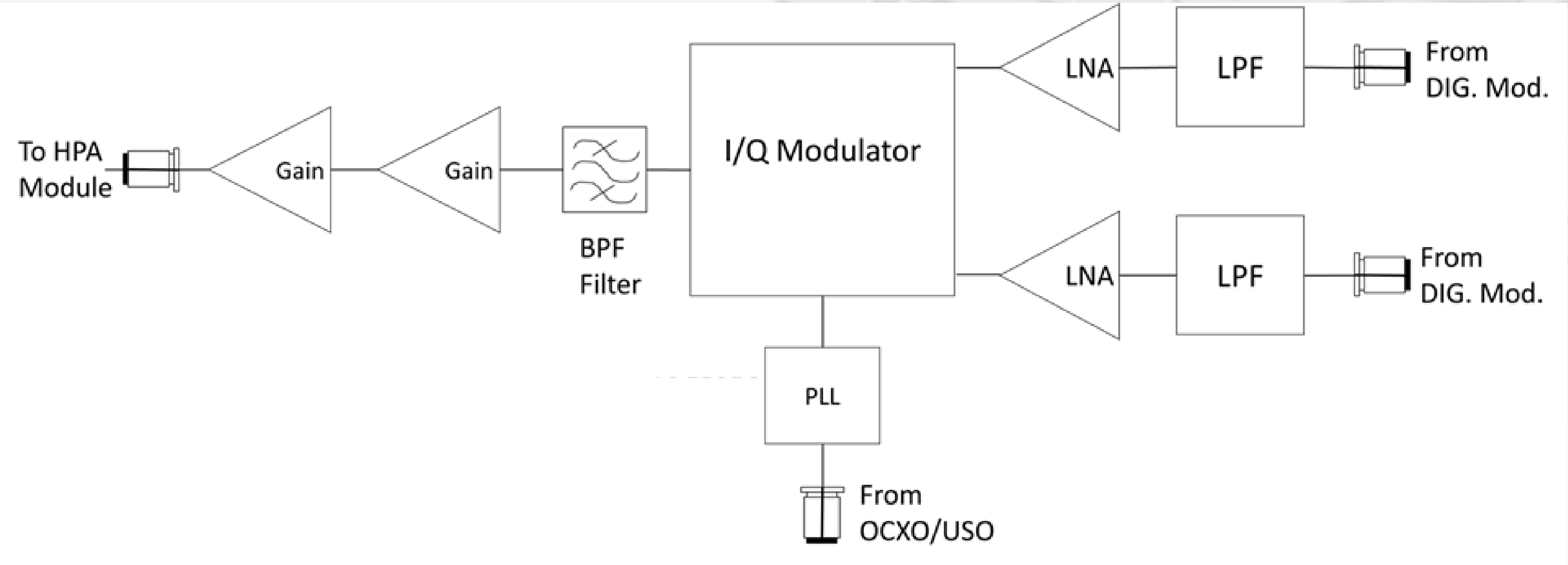


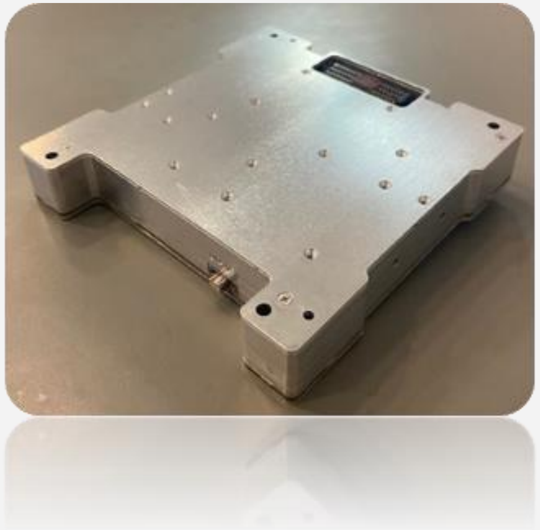


XTX Module

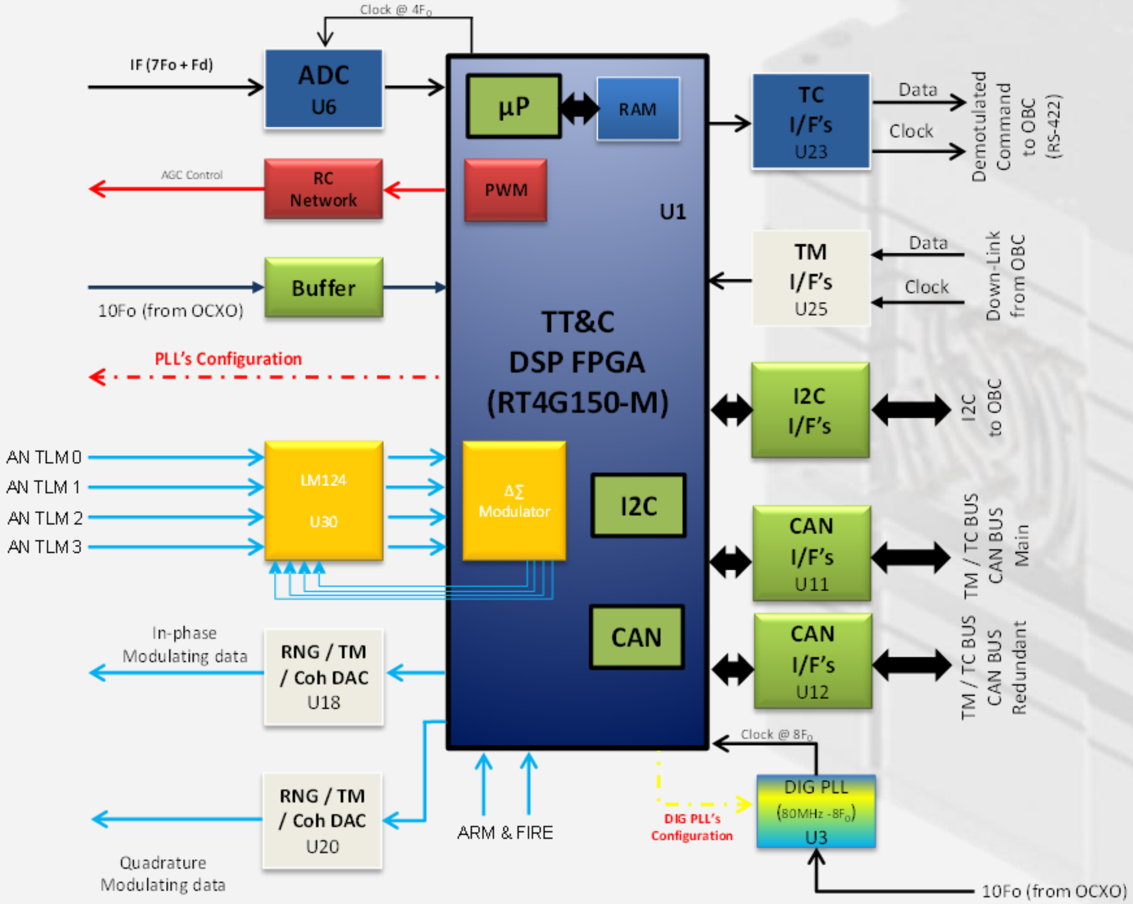
The Tx architecture is based on a X-band Vector modulator, driven by I/Q data signals provided by DACs in the Digital section.

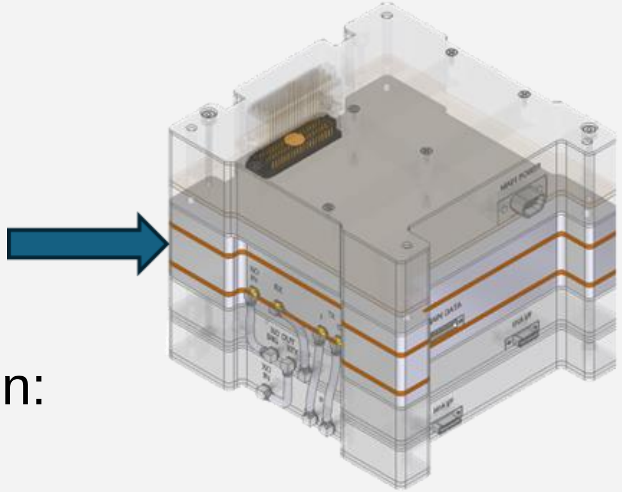




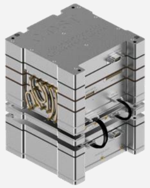


Digital Module





The digital module is based on:
Mother Board mounting the RT4G150 FPGA from Microsemi, ADC, DACs.
Daughter Board mounting secondary voltages regulators , TC/TM line drivers/ receivers and CAN bus interfaces.
The TT&C DSP core is recurring from the DST/KaT ASIC which have been designed, developed and qualified in the frame of Bepi Colombo program and then used in several follow-on missions such as ExoMars, Solar Orbiter, Euclid, JUICE. For this reason, it is mainly based on rad-tolerant devices compatible with deep space mission.



PCU MODULE

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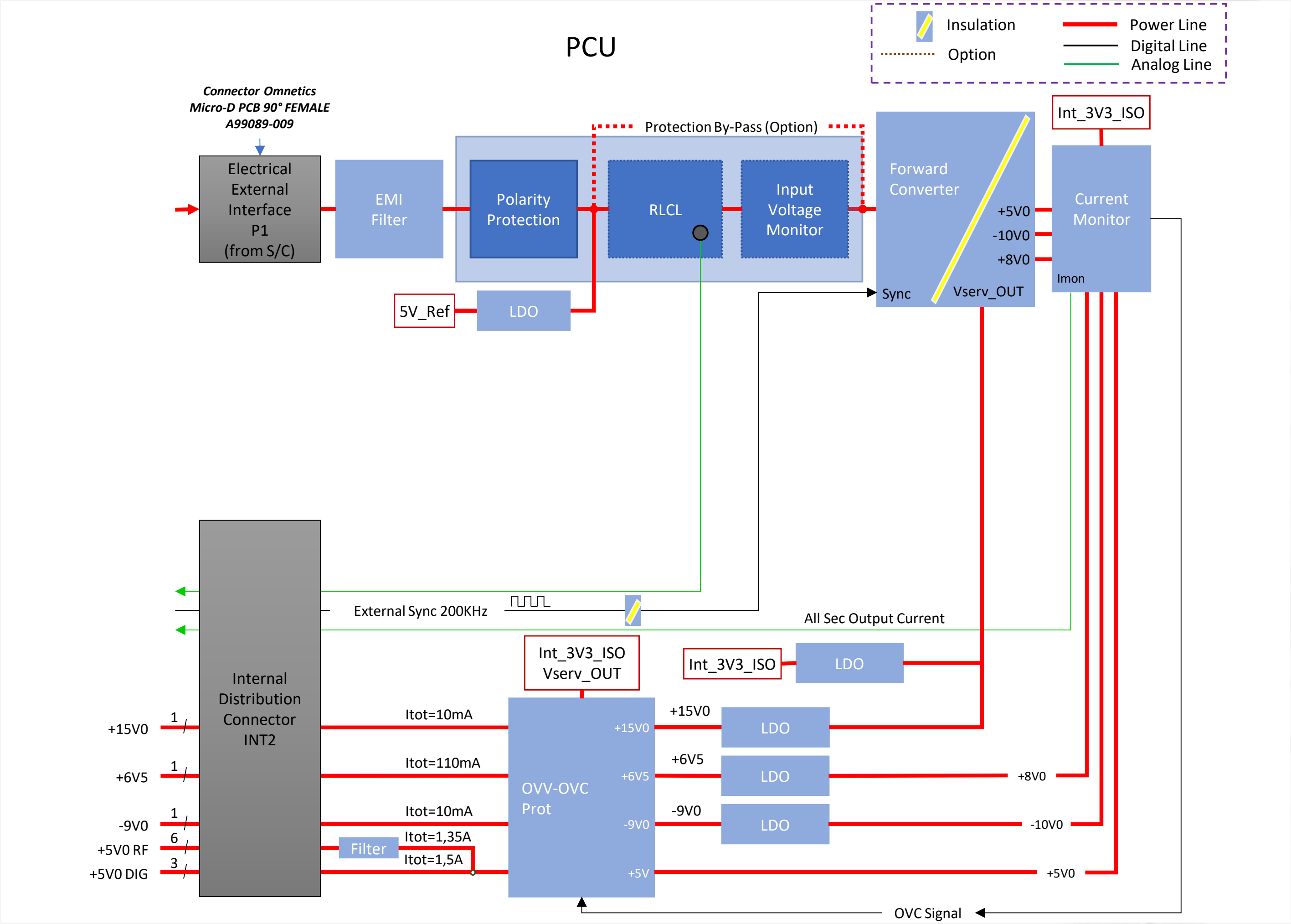

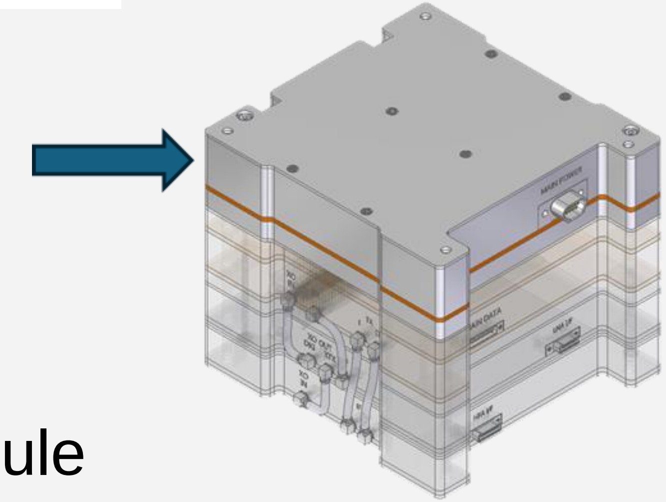

The PCU Module generates the power to the whole Main Assembly starting from the unregulated primary power bus provided by the S/C. The module works correctly in the range [24:34]V.

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HPA ASSEMBLY

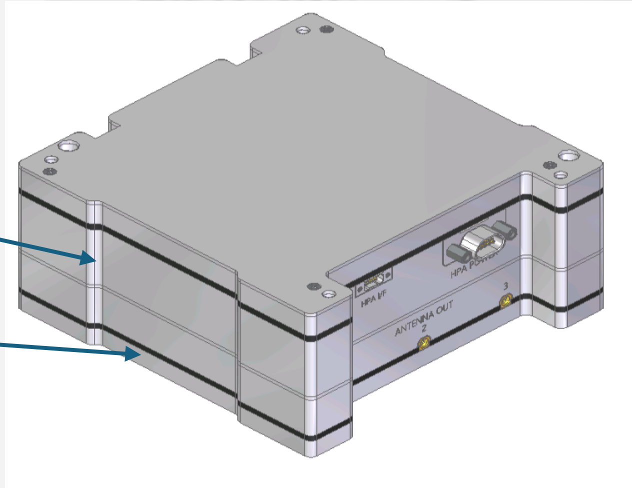
The HPA Assembly is formed by the **High-Power Amplifier Module** (up to 15W of output power, each channel – in total 3), and the relevant Power Conditioning Module, dedicated to all power needs (composed by DC/DC Converter, filters, LCL, etc..). This module is connected to the unregulated satellite power bus (24V-34V).

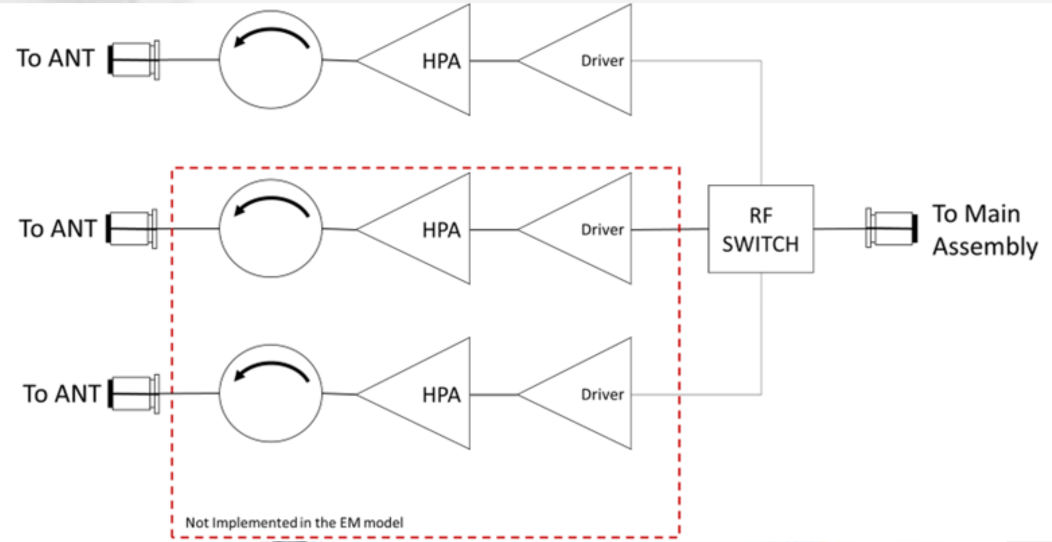
The three HPA channels are selectable by the Main Assembly through OBC CAN bus command. They can work one at a time.

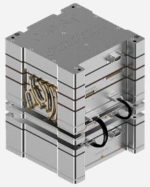
The HPA Assembly could be located closed to the antenna or in-stack mount with the main assembly.

HPA PCU Module

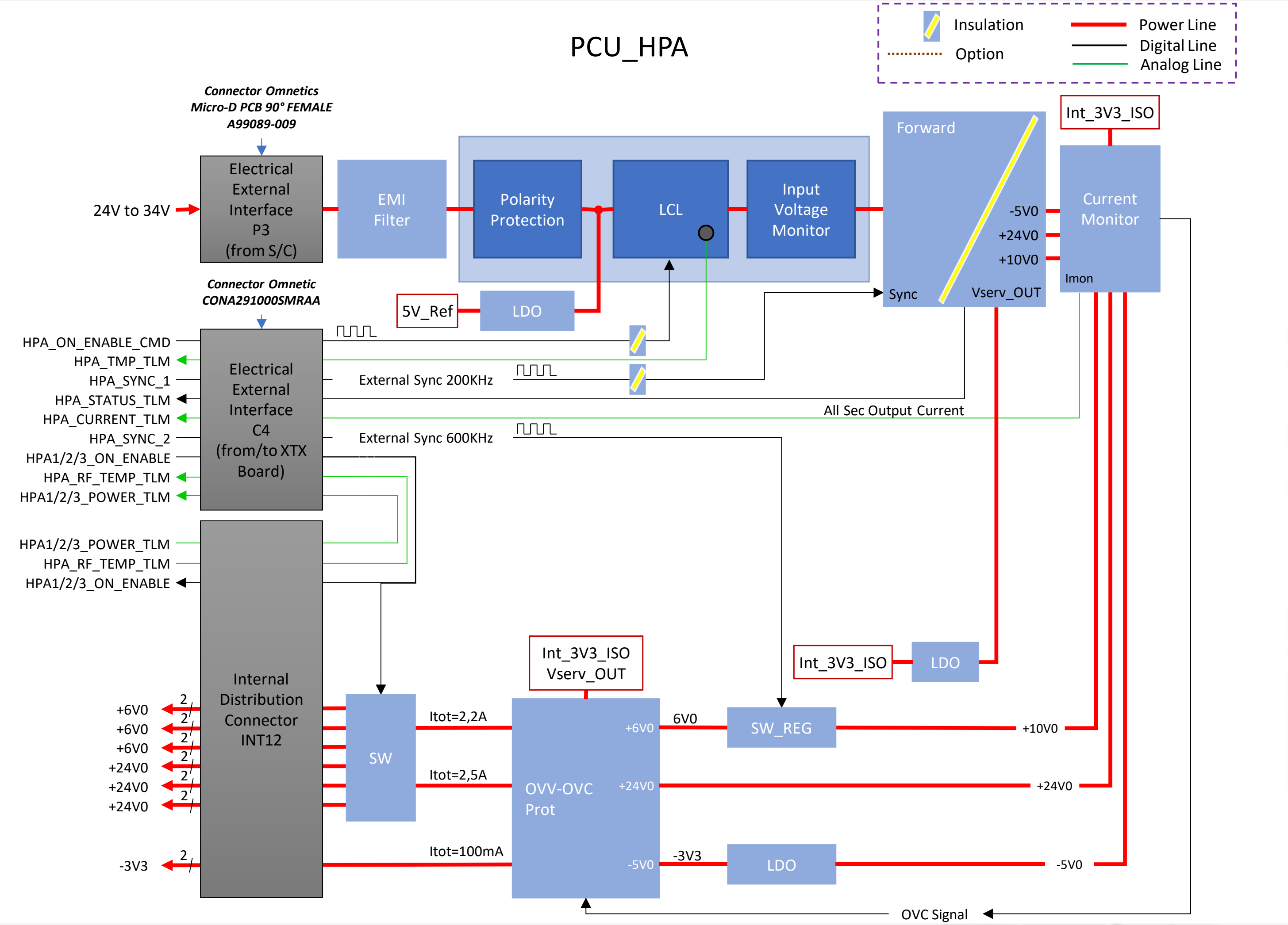
HPA RF Module

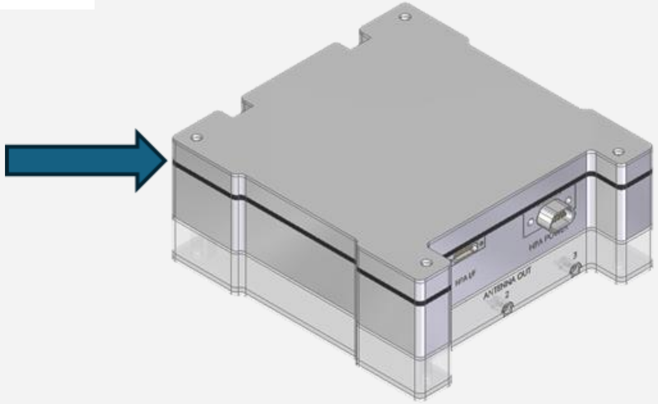






HPA PCU Module

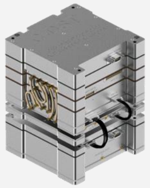




The HPA PCU Module Generates the power for the HPA Assembly starting from the unregulated primary power bus provided by the S/C. The module works correctly in the range [24:34]V. Total power capability of the board is about 75W

C-DST Datasheet (1)

Network Compatibility	ESTRACK
Design Lifetime	3 years
Frequency Bands (Uplink)	7145 MHz -7190 MHz (Cat. B missions) 7190 MHz - 7235 MHz (Cat. A missions)
Frequency Bands (Downlink)	8400 MHz -8450 MHz (Cat. B missions) 8450 MHz -8500 MHz (Cat. A missions)
Coherency	Coherent operations supported
Turn-around rations	749 / 880
Ranging	ESA STD ranging PN regenerative ranging
Navigation Support	2-way Doppler PN regenerative Ranging (in accordance to CCSDS 414.1-B-2) Delta-DOR (in accordance to CCSDS 401.0-B)
Volume	< 1,5U (94 mm x 94 mm x 131,5 mm)
Mass	1,4 Kg
Oscillator	Internal OCXO External USO – Ultra Stable Oscillator (100 MHz) *
OCXO Allan Deviation	< 1E^-10 at 1 sec



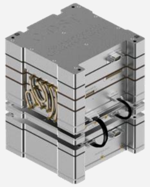
C-DST Datasheet (2)

TM/TC Interface	Redundant CAN bus CAN Bus or I2C* as backup HPC Command (ARM & Fire)	
Payload Data Interface	RS422	
Operation Modes	STBY RX – Signal Detection, Carrier Acquisition, Carrier Tracking and TC Tracking RX & TX	
Power Consumption	Operative Mode	POWER
	STBY RX RX & TX	7.7W 12.8W 94.4W @ 15W Output Power
Operative Temperature	-20°C + 50°C	
Non-Operative Temperature	-30°C + 60°C	
Uplink symbol rate	Up to 4000 sps	
Uplink modulation	PCM / PSK / PM (sine sub-carrier)	
Uplink encoding	BCH LPDC (128, 64)	
Carrier Tracking Signal Range	-60 dBm to -150 dBm	
Carrier acquisition threshold	-145 dBm	
Carrier tracking threshold	-150 dBm	

C-DST Datasheet (3)

Downlink symbol rate	Up to 60 ksps Up to 1 Msps * 8 Symbol rate selectable
Downlink modulation	PCM / PSK / PM (sine and square sub-carrier) SP-L *
Downlink encoding	Concatenated RS (255,223) and convolutional code rate ½ LDPC (2048,1024) Turbo rate ¼ *
RF Output power	15W @ antenna port

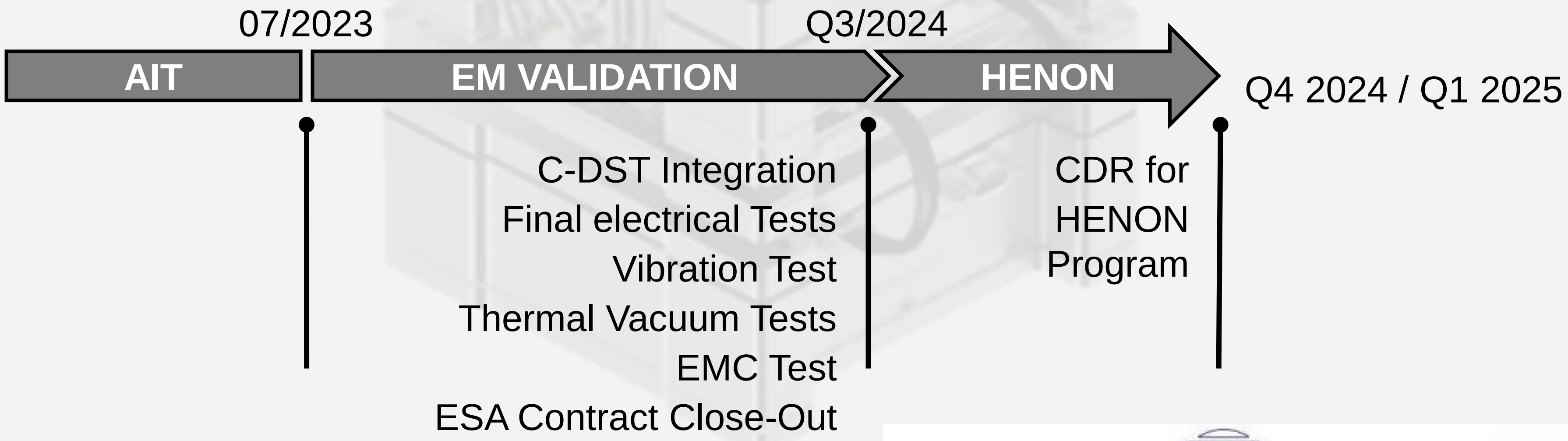
(*) Option available on demand



Conclusion

The main objective to design and X-Band Transponder compatible with Cubesat 6U and 12U for Deep Space mission has been reached with the C-DST design and development that appear very promising for several low-cost space missions already established.

Currently, the C-DST has been selected for **LUMIO** (Lunar Meteoroid Impact Observer – ESA mission), it is candidate for **HENON** (HEliospheric pioNeer for sOlar and interplanetary threats defeNce ASI/ESA mission), as part of **ALCOR** Program, and for **M-ARGO** (Miniaturised – Asteroid Remote Geophysical Observer – ESA mission)



C-DST
Nanosat X-Band TT&C
Transponder EM

(ESA Contract No .: 4000128163/19/NL/FE)

Thank You
for your attention

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