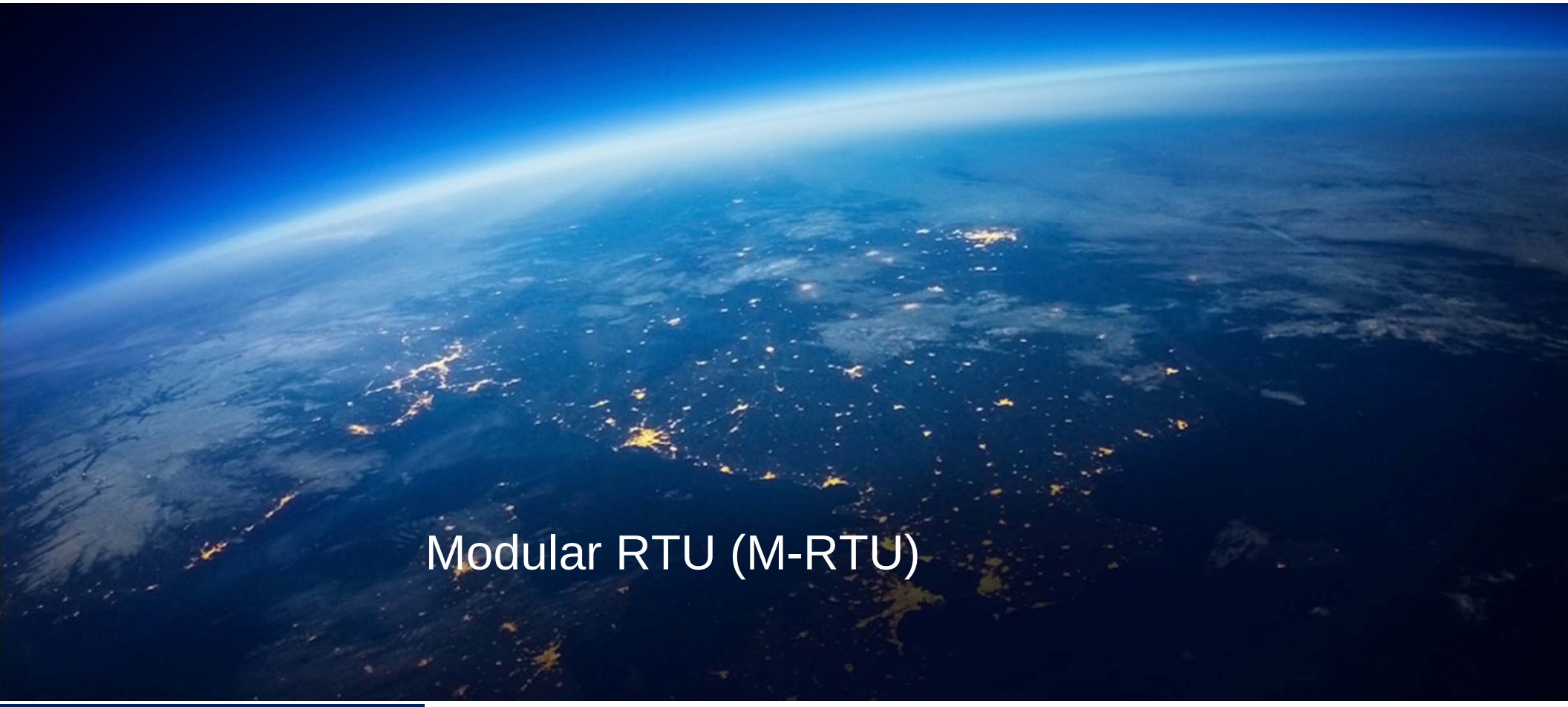

Modular RTU (M-RTU)

DEFENCE AND SPACE
Javier Goyanes
Jorge Peña
09/05/2017

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AGENDA

- Project Background
- Modular RTU Description
- Modular RTU Key features
- Modular RTU Architecture
- Modular RTU Interfaces
- Modular RTU Modules
- Modular RTU Qualification
  - MAIT SetUp
  - Mechanical Assessment
  - Thermal Assessment
  - EMC Assessment
- Summary

Project Background

Program frame; ***ESTEC/ITT AO/1-6819/11/NL/AT :***

Modular General Purpose RTU supporting advanced low speed , medium and high speed serial busses

The modular RTU was identified as a Building Block in the Avionics Embedded Systems Dossier and Roadmap updated in 2010 (AIM B: Building Blocks, B4-ECSS Compliant Modular RTU) .

The SAVOIR/SAG identified the modular RTU as a high priority building block. Modular RTU is one of the key avionics building blocks as the provided functionality is required by the majority of ESA missions.

RTU has been design to configure the unit easily for any kind of missions with a low NREC cost and high TRL category. First mission with 2 flight models is Proba-3.

Project Background

Development of a multi-purpose modular Remote Terminal Unit for Space applications.

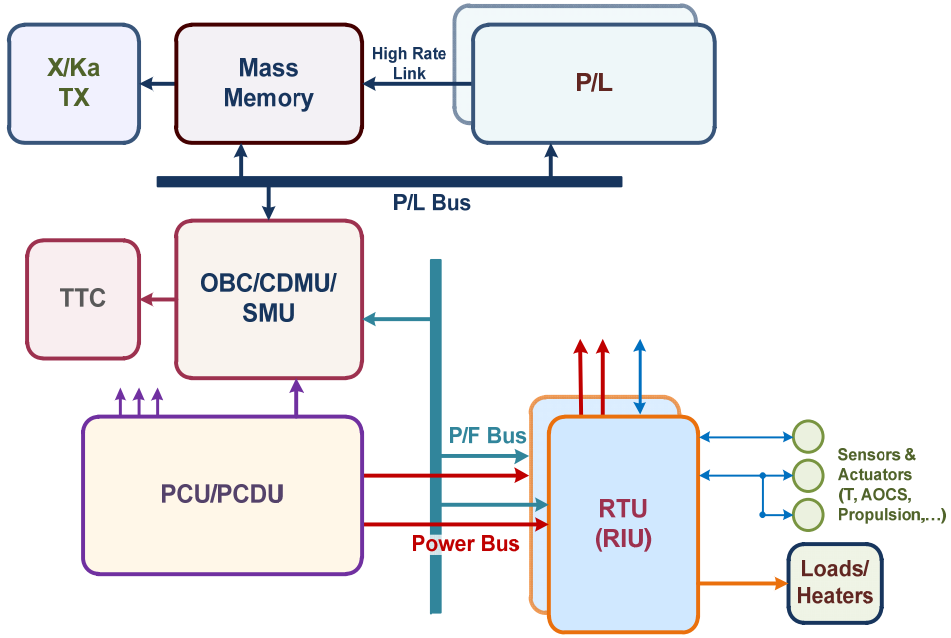
- Modular, flexible and easily missionizable RTU for Telecom Science and Earth Observation Platforms.
- The main objective was to develop a flexible, capability to be adapted without a re-qualification process and providing simplicity in repairing and reconfiguration.
- To develop a unit able to allocate third party modules with the possibility of adjust the unit to the mission needs.

M-RTU Description (1/3): what is a RTU?

The RTU is typically a full slave unit without intelligence on board totally controlled by the OBC.

typical tasks of a RTU is here presented:

- To gather the analogue and digital telemetry from sensors and units (Temperature, Pressure, Digital Status)
- To provide the conditioning for analogue sensors,
- To control AOCS actuators and sensors (as Reaction Wheels, Gyros, Star Trackers, Sun Sensors, GPS, Magnetometers, Magnetotorquers),
- To control the Propulsion S/s (Flow control Valves, Latch Valves, Catalytic Bed Heaters),
- To control Solar Array Drive Equipment,
- To distribute power to heaters,
- To distribute (in some cases also down/converting) power to active loads



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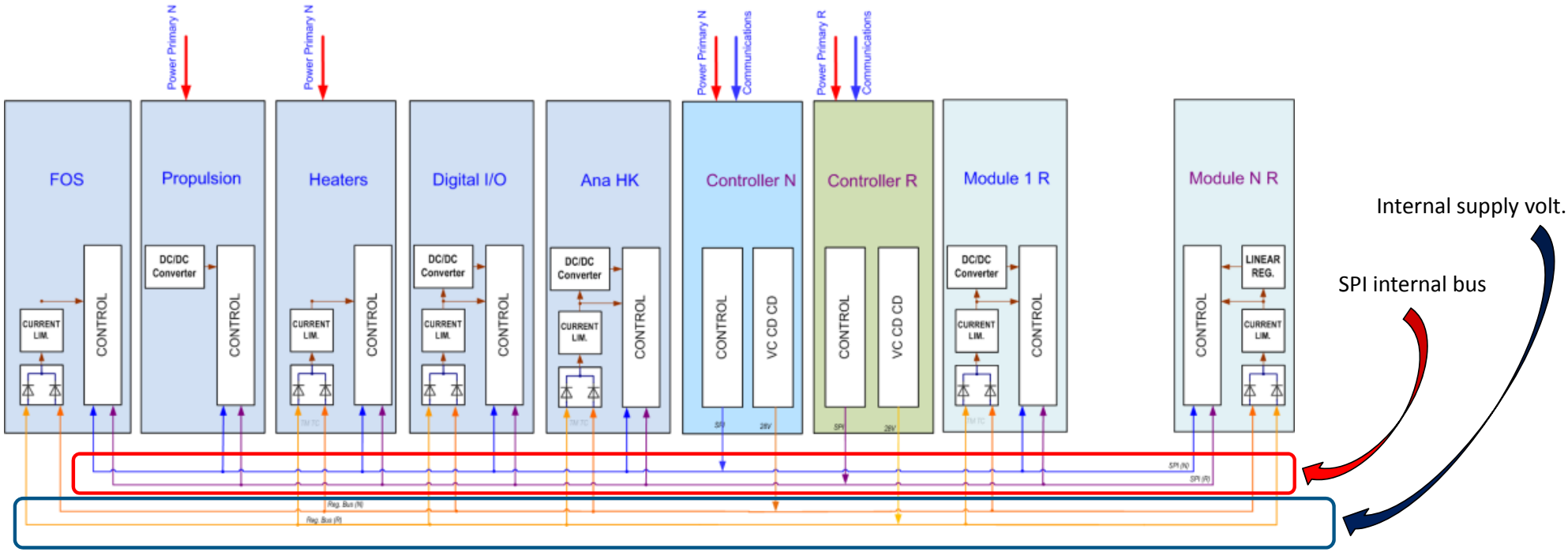
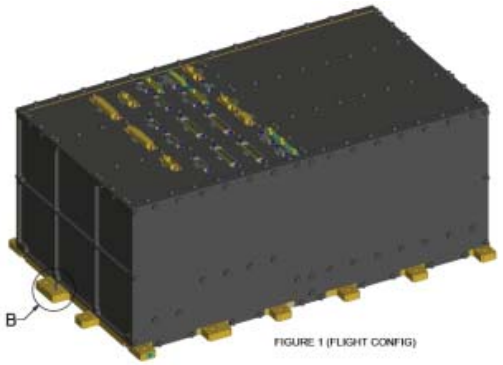
M-RTU Description (2/3): what is a RTU?

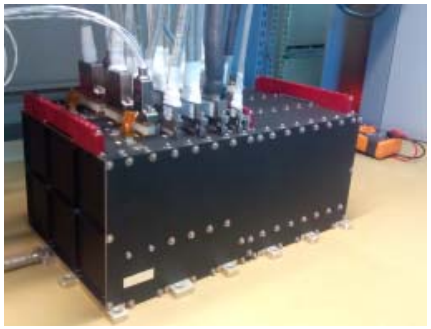
RTU2015 has been conceived as an assembly of different boards with standardized internal mechanical and electrical interfaces to the rest of the RTU2015 box

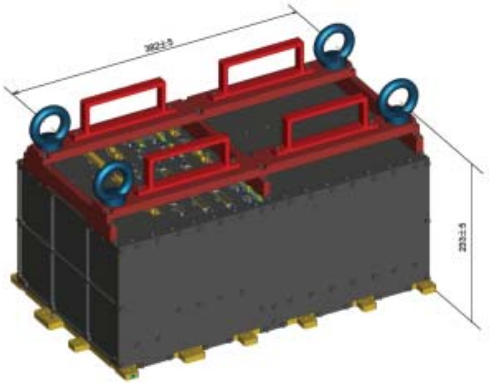


M-RTU Description (3/3): what is a RTU?

- Having the possibility of increasing or reducing size of the unit according to mission needs
- Qualifications covers 2+2 up to 10+10







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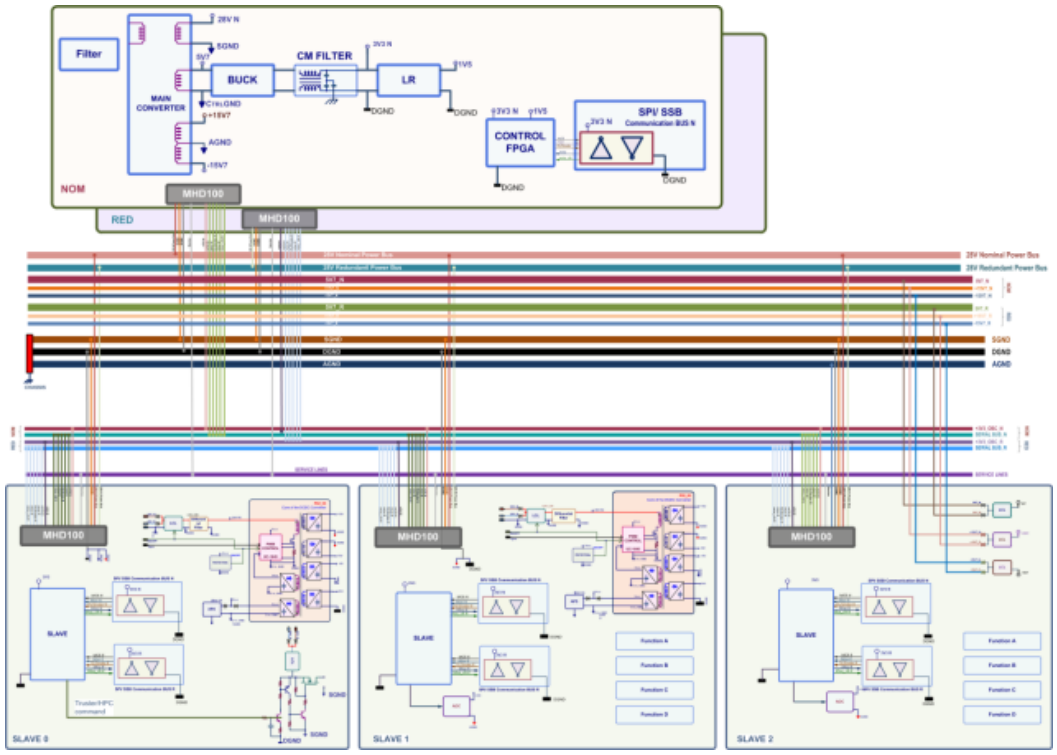
M-RTU Key features

- Architecture maximize the **modularity** and **upgradeability** becoming the key characteristic of all the modules.
- Use of self-contained modules and standardizing the internal connectors of the modules.
- All the slave modules will have the same **standard back plane connector** sharing this way the Standard Internal Electrical Interface.
- **Testing each module completely independently**
- Configuring the RTU as will be defined **adding, removing or duplicating** modules **without any impact or redesign in the final product**
- The unit has been designed minimizing PCB size in order to maximise PCB occupancy.
- **Third party modules can be included in the unit**

M-RTU Architecture

- Standarized Internal Electrical Interface.



- Power Lines
- Power status and Commanding
- House Keeping
- Communications
- Service lines

50	F	TH_N	TH_RTN_N	49	F	1	A	TH_R	TH_RTN_R	2	A
48	F	HK_VOLT_N	AGND	47	F	3	A	HK_VOLT_R	AGND	4	A
46	F	AGND		45	F	5	A	AGND		6	A
44	F	SERVICE_1_N	DGND	43	F	7	A	SERVICE_1_R	DGND	8	A
42	F	SERVICE_2_N	DGND	41	F	9	A	SERVICE_2_R	DGND	10	A
40	F			39	F	11	A			12	A
38	F	15V7_N	15V7_N	37	F	13	A	15V7_R	15V7_R	14	A
36	F	-15V7_N	-15V7_N	35	F	15	A	-15V7_R	-15V7_R	16	A
34	F	AGND	AGND	33	F	17	A	AGND	AGND	18	A
32	F	5V7_N	5V7_N	31	F	19	A	5V7_R	5V7_R	20	A
30	F	DGND	DGND	29	F	21	A	DGND	DGND	22	A
28	F	28V_N	28V_N	27	F	23	A	28V_R	28V_R	24	A
26	F	28V_N	SGND	25	F	25	A	28V_R	SGND	26	A
24	F	SGND	SGND	23	F	27	A	SGND	SGND	28	A
22	F	CMD_ON_N	DGND	21	F	29	A	CMD_ON_R	DGND	30	A
20	F	DGND	POWER_ON_STATUS_N	19	F	31	A	DGND	POWER_ON_STATUS_R	32	A
18	F	3V3_CONTROL_N	3V3_CONTROL_N	17	F	33	A	3V3_CONTROL_R	3V3_CONTROL_R	34	A
16	F	DGND	MISO_CLK_N	15	F	35	A	DGND	MISO_CLK_N	36	A
14	F	DGND	DGND	13	F	37	A	DGND	DGND	38	A
12	F	STROBE_N	DGND	11	F	39	A	STROBE_R	DGND	40	A
10	F	MOSI_N	MISO_N	9	F	41	A	MOSI_R	MISO_R	42	A
8	F	DGND	DGND	7	F	43	A	DGND	DGND	44	A
6	F	DGND	CLK_N	5	F	45	A	DGND	CLK_R	46	A
4	F	DGND	DGND	3	F	47	A	DGND	DGND	48	A
2	F	HARD_ADDRESS[0]	HARD_ADDRESS[1]	1	F	49	A	HARD_ADDRESS[2]	HARD_ADDRESS[3]	50	A

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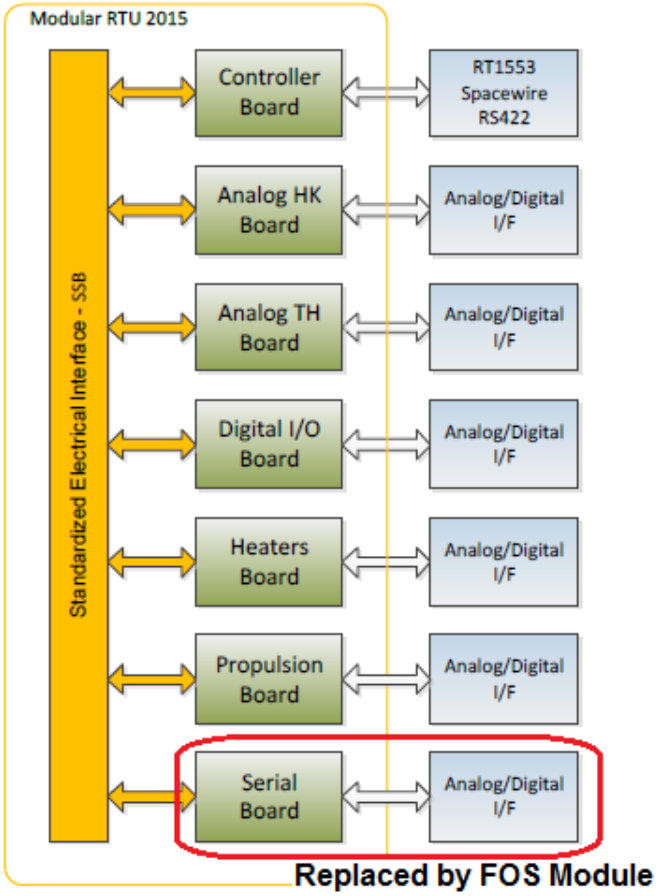
M-RTU Interfaces



INPUTS	CONTROLLER
MIL BUS 1553B	2 (A & B)
UART RS422	2 (A & B)
SpaceWire(SpW)	2 (A & B)
APS	2
Pulse Per Second (PPS)	2
HK TM	2 per module

INPUTS	ANA HK
Sun Sensor Acq.	10
Voltage Acq. (+/-5V or 0 to +5V)	46
Voltage Acq. (+/-10V)	6
Thermocuples Acq.	15
Thermistors Acq.	56
OUTPUTS	ANA HK
Accelerometers Power Supply	2
DAC outputs	4

OUTPUTS	PROPULSION
Cad Bed Heaters	8
Pressure Transducers	4
Thruster Valves	12
Latching Valves	6

INPUTS	DIGITAL I/O
Voltage Acq. (+/-5V or 0 to +5V)	16
Voltage Acq. (+/-10V)	
Thermistors Acq.	53
BiLevel Digital 0-5V Acq.	16
BiLevel Switch Acq.	16
BiLevel RS422 Acq.	4
Synchro signals	4
OUTPUTS	DIGITAL I/O
RS422 Low Level Command	3
Low Level Command	8
Hig Power command	32
Synchro signals	8

OUTPUTS	HEATERS
Heaters	20

INPUTS	FOS
Fiber sensors Adq.	40

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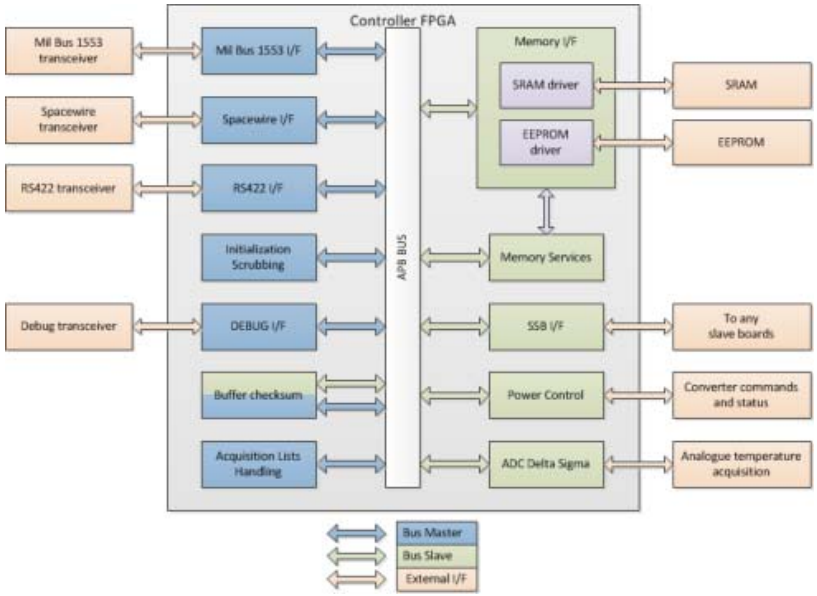
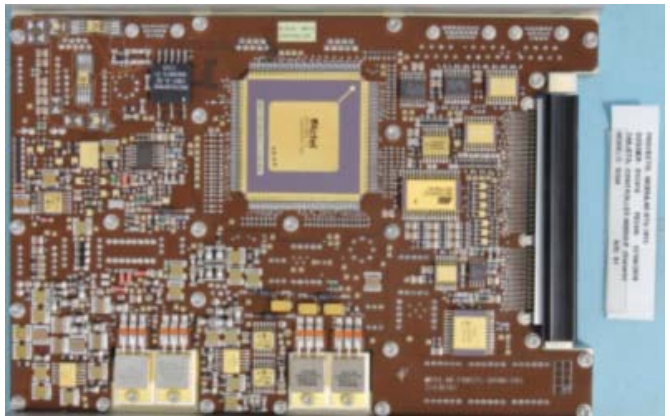
M-RTU Modules

Controller:

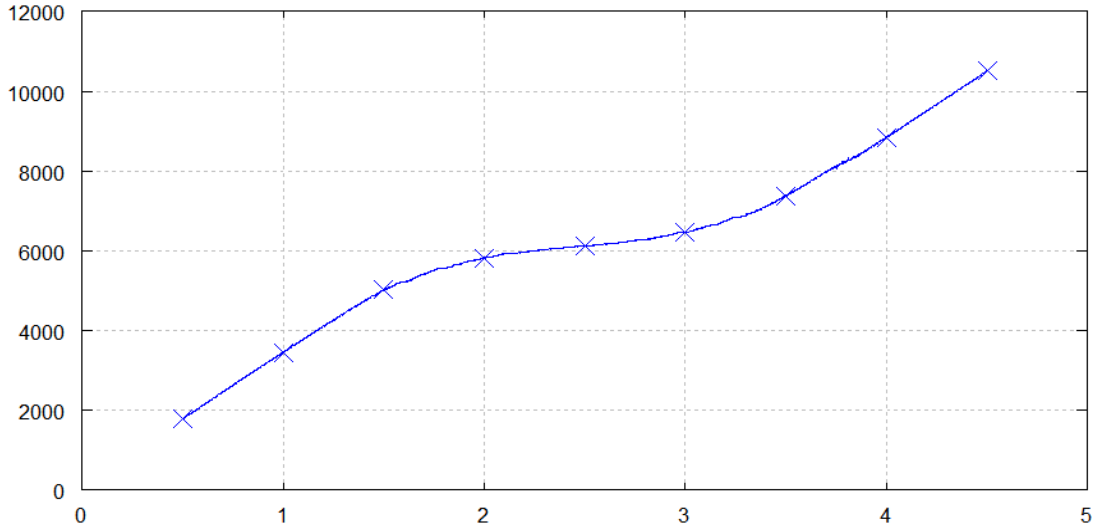




M-RTU Modules

Controller innovation wrt standard:

- Several communication interfaces
- 12 bits Sigma delta integrated FPGA
- High configurable slave modules
- High efficiency converter with low load
- Memory to store different configurations

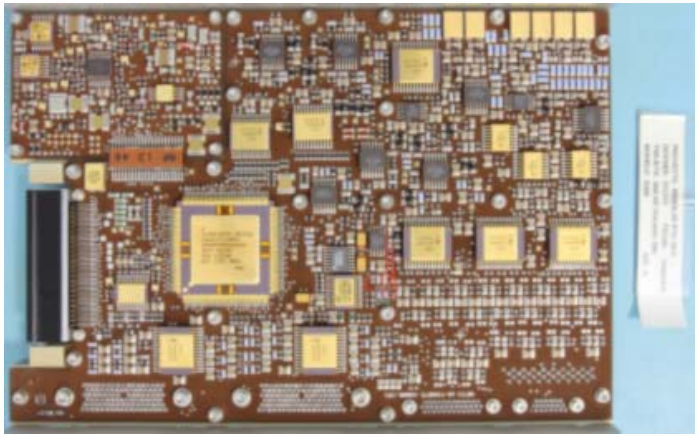


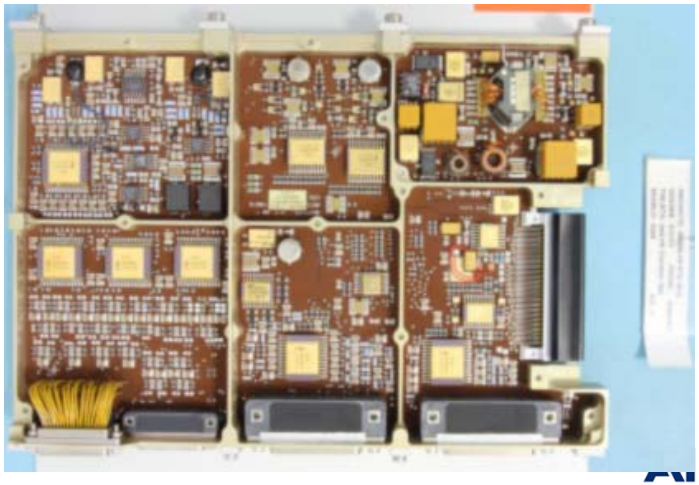
- ADC -> 20 LSB drift between cold/hot
  -> 5 LSB 3 sigma stability in 1000 sample

M-RTU Modules

Analogue HK:

- One specific module for Analog Acquisitions
  - 32 General purpose Acquisitions [AN1, AN2 && AN3]
  - 8 pressure transducers
  - 10 analogue interfaces for Coarse Sun position Sensors (Current Telemetry)
  - 6 analogue interface for accelerometers/ Magnetometers
  - 4 DAC Outputs with a dynamic range selectable individually among the following values: 0/+5V, -5/+5V, 0/+10V, -10/+10V
  - 53 TH acquisitions
  - AIV for SAS and MAG

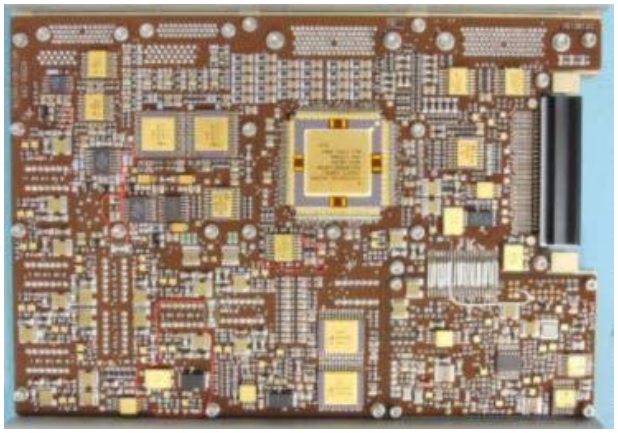


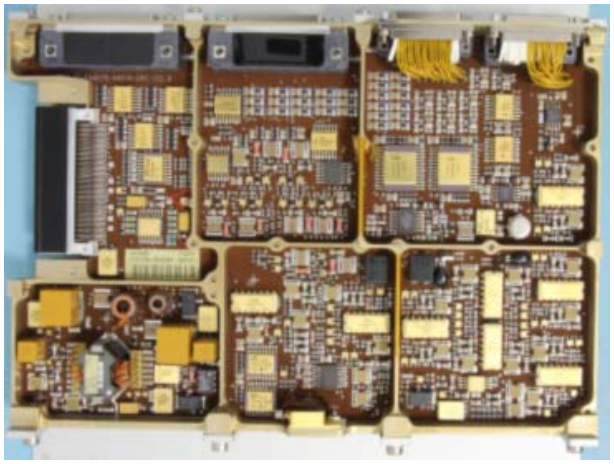


M-RTU Modules

Digital IO:

- 8x LV_HPC Low Voltage High Power Command Drivers
- 12x HV-HPC High Voltage High Power Command Drivers
- 12x HC-HPC High Voltage High Power Command Drivers
- 8x LPC, providing an output voltage in the [4.4, 5.5] (V) range.
- 3x SLP RS422 pulses
- 4x Bi-level RS422 signals
- 16x BDM && 16x BSM
- 4x UART interfaces
- 4x Sync signal Inputs
- 8x Sync signal Outputs
- 16 Analog Acquisitions
- 53 Thermistor ANY or ANF, 2 ANP & 1 34TD25A





M-RTU Modules

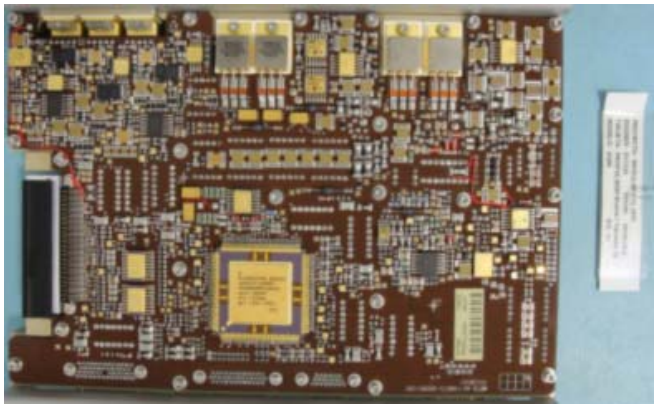
Propulsion:

ColdGAS

- 4x 28V thruster valves
- 4x 12V thruster valves(configurable to 28V)
- 2x 28V latching valves
- 2x 20V supplies for pressure transducers (configurable to 28V)

MONOPROPELLANT

- 8x CAT BED Heaters
- 4x 28V thruster valves
- 4x 12V thruster valves (configurable to 28V)
- 2x 28V latching valves
- 2x 20V supplies for pressure transducers (configurable to 28V)



CV capability 200W@95%

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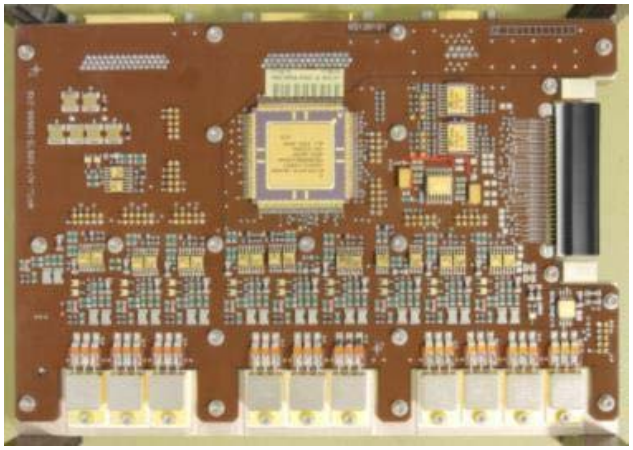
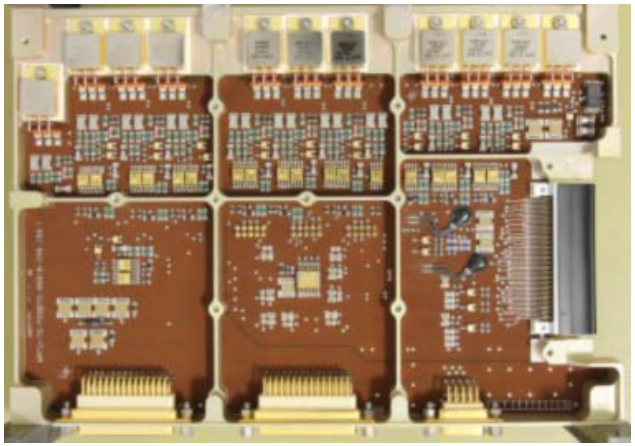
M-RTU Modules

Heaters:

- 20x 30W heaters,
- Maximum delivered power of 600W

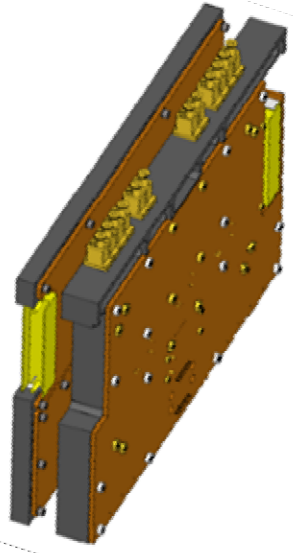


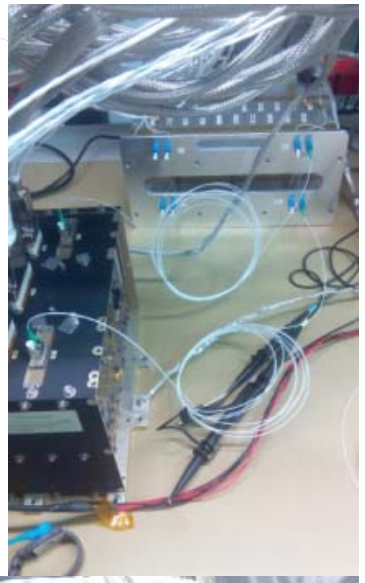


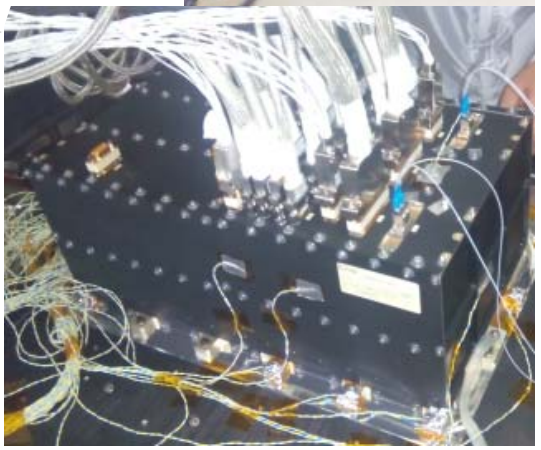
M-RTU Modules:
Concept validation

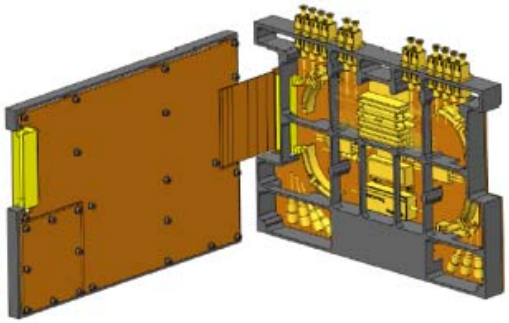
Third Party Module: FOS

- During the qualification of the Modular RTU a third party module was included to test the concept and to qualify the module.
- FOS: Fiber Optic Sensors, The FOS demonstrator is composed by an interrogation unit (IU) plus a set of FBG sensors interconnected by a Optical fiber Harness (OH). The IU was designed to be integrated in a modular Remote Terminal Unit (RTU).







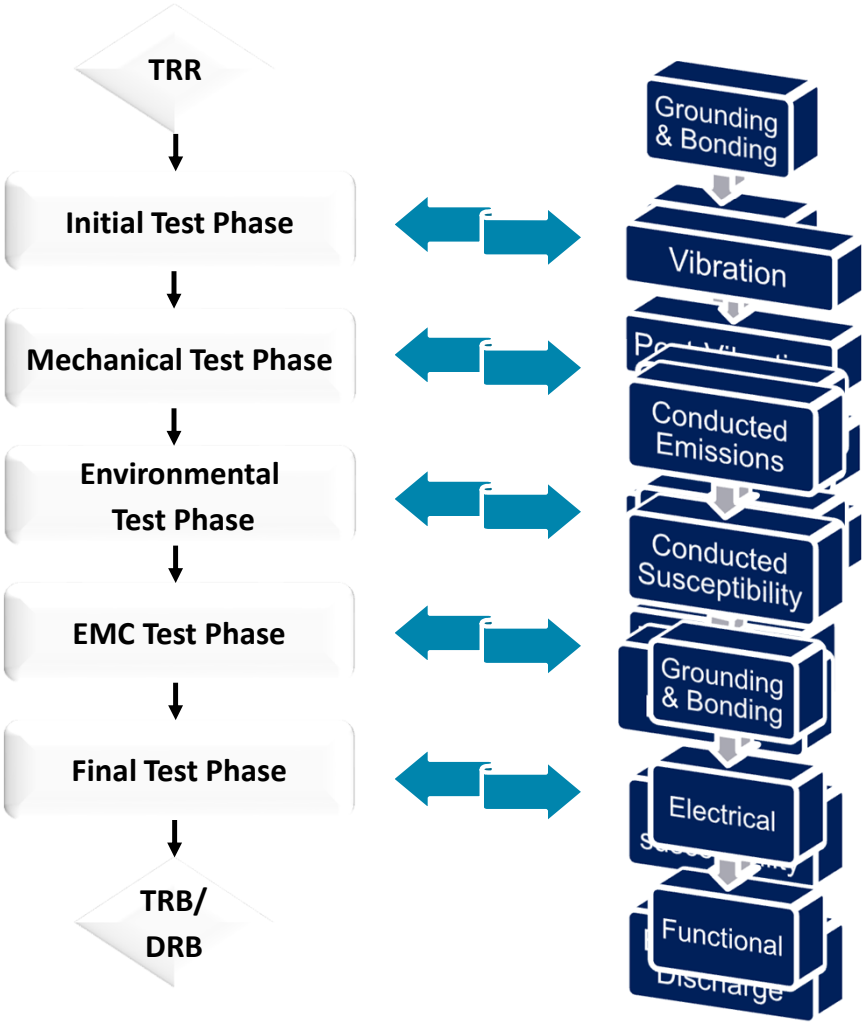


M-RTU Qualification

Modular RTU is fully qualified.

According ECSS-E-10-02 The equipment is typically classified according to the following categories:
***Category A*:** Off-the-shelf equipment requiring no modification which has been subjected to a qualification test programme for space applications at least as severe as that imposed by the actual project specifications. → no qualification
***Category B*:** Off-the-shelf equipment requiring no modifications that have already been tested and qualified but subjected to a different qualification programme or to a different environment → delta qualification
***Category C*:** Off-the-shelf equipment requiring minor design modifications. A delta or full qualification test programme shall be decided on a case-by-case.
***Category D*:** Newly designed and developed equipment or existing equipment requiring major re-design. A full qualification test programme shall be imposed.

According ECSS-E-10-03 the Qualification consist on: *Qualification testing shall be performed to provide evidence that the space segment element or equipment performs in accordance with its specifications in the intended environments with the specified qualification margins.*



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M-RTU MAIT SetUp

Modular RTU was manufactured, assembled and qualified in controlled environmental conditions:

- Temperature: 22ºC ± 3ºC
- HR: 55% ± 10%

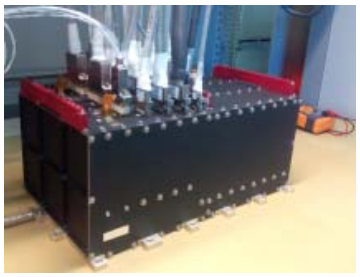
The MAIT activities will take place in four clean areas or controlled environments as below:

- **Class ISO 8 standard clean room** according to ISO-14644 (previously Class **100.000** according to the old FED-STD-209E) for:

o Mechanical parts assembly

o PCBs population, Vapour Phase Reflow Soldering, Hand Soldering, Inspection and intermediate cleaning.

o Vibration test, EMC



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M-RTU Ambient Verification

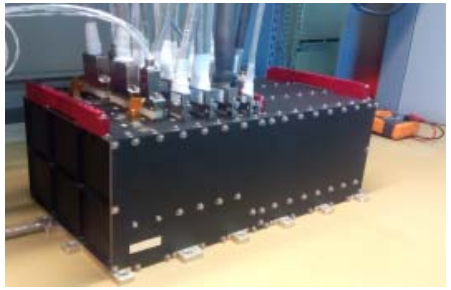
INITIAL TEST

- EQM was submitted to a characterization and verification ambient test (complying with ESTEC/ITT AO/1-6819/11/NL/AT requirements).

- Electrical tests shall include application of expected voltages, impedance, frequencies, pulses, and wave forms at the electrical interface of the space segment equipment.
- Functional tests shall verify the complete function of the space segment equipment and Performance tests shall verify that the space segment equipment performances, under the specified environment, are compliant with the performances specification.

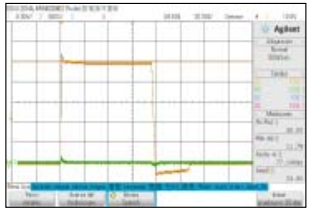
FINAL TEST

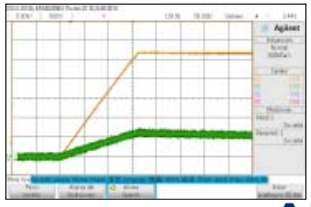
- EQM was submitted to a Final Validation test at ambient test to verify the good health of the unit after the Qualification.



BDM_RS422 Signals Low State

Condition	Measured Value	Expected Values	Status
BLV_ST2 TM (SBDL#4ALL OFF)	2000	2000	OK
BLV_ST2 TM (SBDL#1 ON)	2001	2001	OK
SBDL ACQ 1 Voltage (V)	0.506	-	-
SBDL ACQ 2 Voltage (V)	-0.496	-	-
SBDL ACQ 3 Voltage (V)	-0.497	-	-
SBDL ACQ 4 Voltage (V)	-0.497	-	-
BLV_ST2 TM (SBDL#2 ON)	2002	2002	OK
SBDL ACQ 1 Voltage (V)	-0.496	-	-
SBDL ACQ 2 Voltage (V)	0.506	-	-
SBDL ACQ 3 Voltage (V)	-0.497	-	-
SBDL ACQ 4 Voltage (V)	-0.497	-	-
BLV_ST2 TM (SBDL#3 ON)	2004	2004	OK
SBDL ACQ 1 Voltage (V)	-0.496	-	-
SBDL ACQ 2 Voltage (V)	-0.496	-	-
SBDL ACQ 3 Voltage (V)	0.507	-	-
SBDL ACQ 4 Voltage (V)	-0.497	-	-





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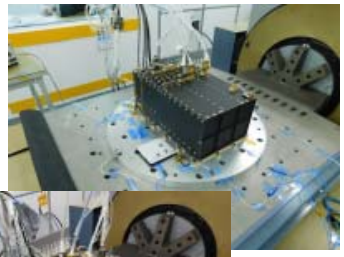
M-RTU Mechanical Assessment

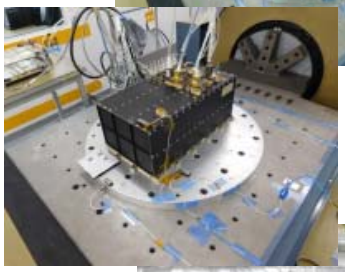
VIBRATION TEST

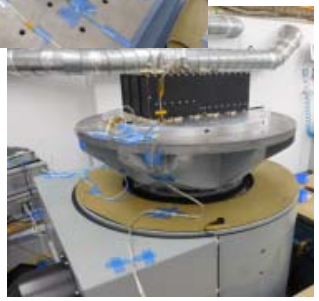
- EQM was submitted to a typical Qualification loads for an earth observation programme (complying with ESTEC/ITT AO/1-6819/11/NL/AT requirements).

Axis	Frequency(Hz)	Qualification
Perpendicular to mounting plane (1 axis)	20-80	+3 dB/oct
	80-200	0.5 g^2/Hz
	200-400	0.3 g^2/Hz
	400-2000	-6 dB/oct
	g rms	15.4
Parallel to mounting plane (2 axes)	20-80	+4 dB/Oct
	80-1000	0.1 g^2/Hz
	1000-2000	-3 dB/oct
	g rms	12.8
All	Duration (Seconds)	150 s

Axis	Frequency [Hz]	Qualification
All axes	5-20	Max. Shaker Amp
	20-100	20 g (0 – peak)
Sweep Rate		2 oct/min
Sweep Direction		1 sweep up and down







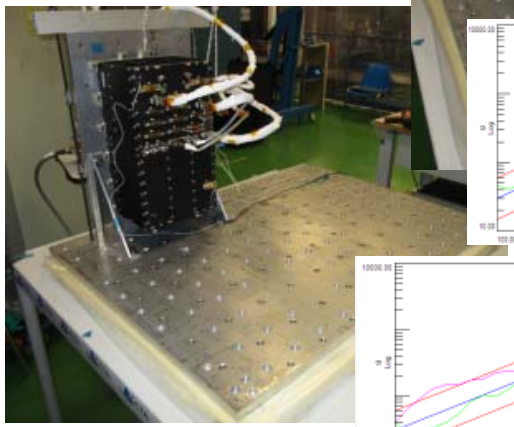
Mechanical Qualification successful.

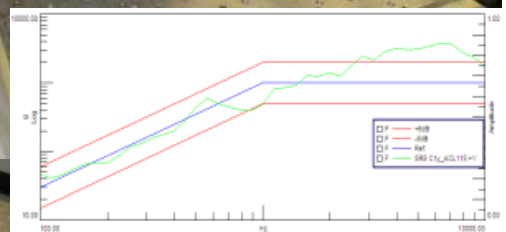
SHOCK TEST

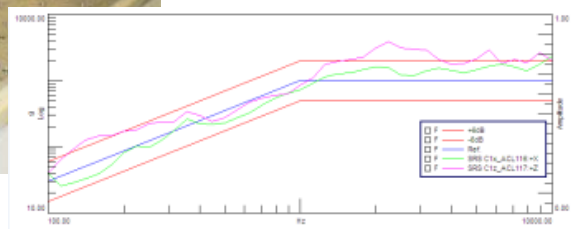
- EQM was submitted to a Qualification loads:

Frequency (Hz)	Acceleration (g)
100	30
1000	1000
10000	1000
Number of shocks per axis:	3

Table 11: Shock test levels







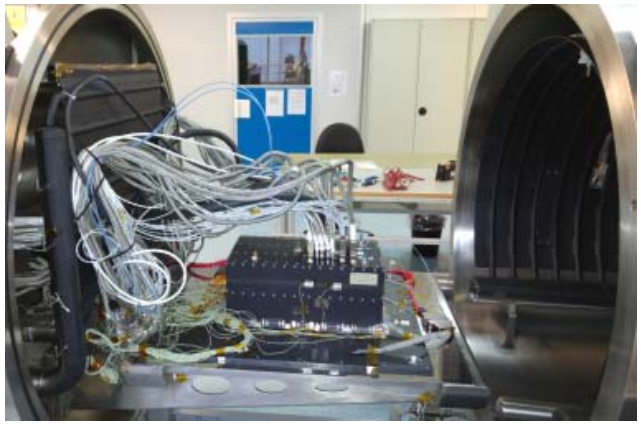
M-RTU Thermal Assessment

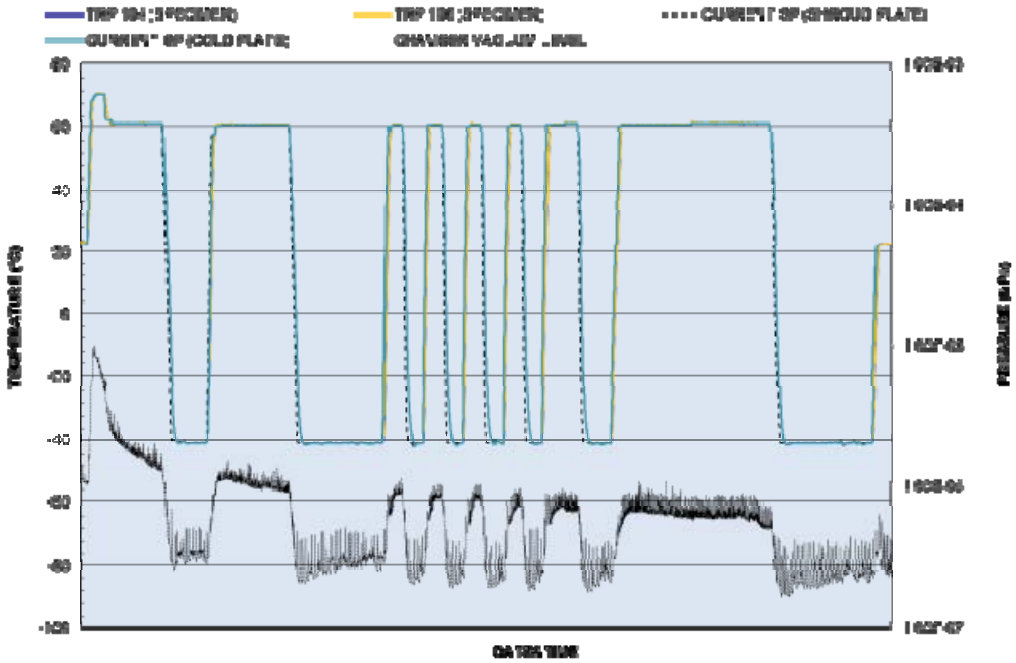
THERMAL VACUUM TEST

- EQM was submitted to a typical Qualification loads for an earth observation programme (complying with ESTEC/ITT AO/1-6819/11/NL/AT requirements).

Environmental Qualification successful → Full functionality of the unit achieved at hot and cold plateau.

	Non-operative		Operative		Start-Up	
°C	TOP, min	TOP, max	TNOP, min	TNOP, max	TSU, min	TSU, max
Qualification temperature	-40ºC	+70 ºC	-40ºC	+60 ºC	-35 ºC	+60 ºC



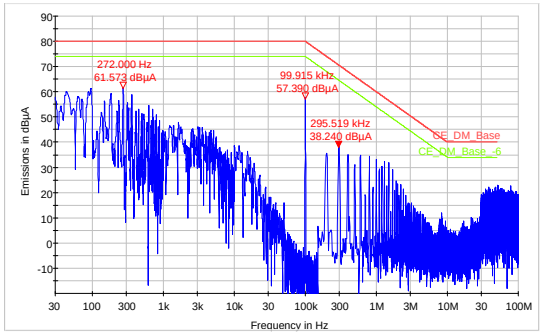


AIRBUS

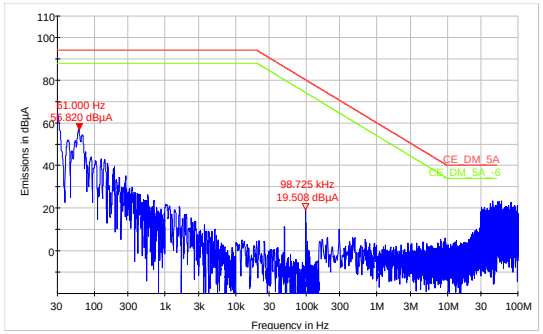
M-RTU EMC Compatibility Assessment (1/3)

CONDUCTED EMISSIONS

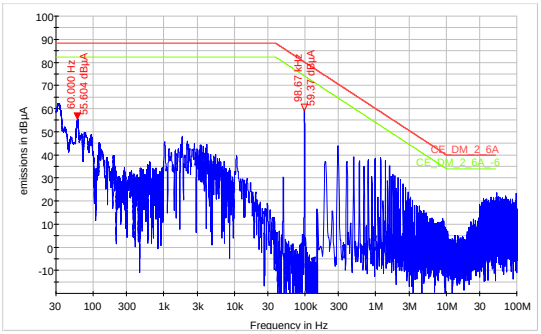
RTU Modular EQM CE FD DM on Bus CNTRL



RTU Modular CE FD DM on Bus HEATER



RTU Modular EQM CE FD DM on Bus PROP



No emissions over the specified limits in frequency.

CONDUCTED SUSCEPTIBILITY

Sine Wave Injection

Sine wave modulation (50% AM), modulation freq. of 1 kHz in 50 kHz - 50 MHz range. Frequency sweep will be at least 2spots/octave stops for taken measurements.

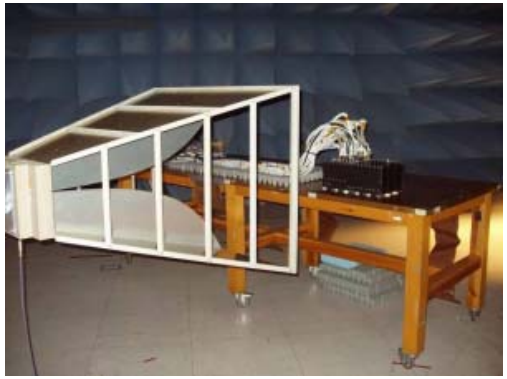
No Susceptibility detected.

Transient Injection

Injection Mode	DM	CM
RTU Power voltage	+26V	+28V
Pulse Amplitude	+2V and -2V (inverse injection)	+28V and -28V
Duration	2 msec	10 msec (± 1msec)
Pulse Rise Time	< 100msec	< 1ms
Repetition Freq.	4 msec	10 Hz
Applied Time	> 3 min	> 3 min

M-RTU EMC Compatibility Assessment (2/3)

Frequency Range MHz	Field Level for units hidden the RF antenna (peak values)	Notes
2024 - 2026	30 dBµV/m	TT&C
1565 - 1585	30 dBµV/m	GPS L1
1217 - 1238	30 dBµV/m	GPS L2
2400 - 2450	30 dBµV/m	ISL
2035,5941 BW=0.15MHz	30 dBµV/m	Earth-Space Link
2047,7491 BW=0.15MHz	30 dBµV/m	Earth-Space Link



RADIATED E-FIELD

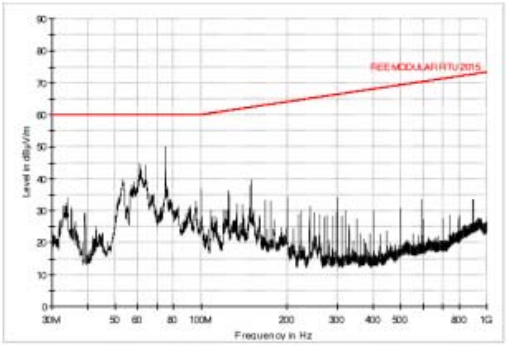


Figure 3. E Field Radiated Emission Test. EUT ON. Vertical Polarization

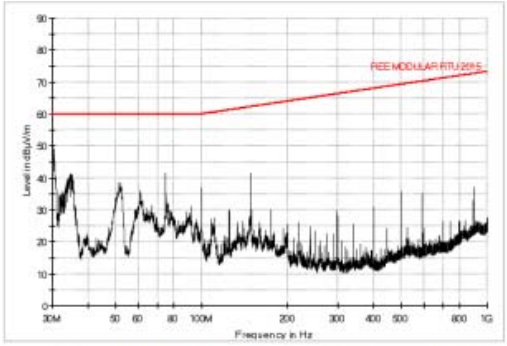


Figure 4. E Field Radiated Emission Test. EUT ON. Horizontal Polarization

No emissions over the specified limits in frequency.

SUSCEPTIBILITY E-FIELD

Frequency Range	Electric Field Strength (rms)
30 MHz - 18 GHz	2Vrms/m

No Susceptibility detected.

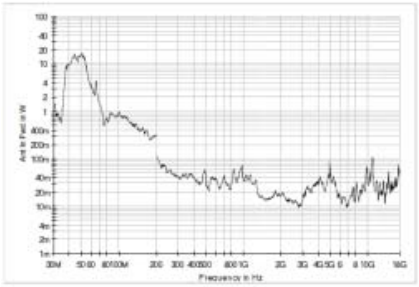


Figure 34. E Field Radiated Susceptibility Test. Antenna Power. Horizontal Polarization

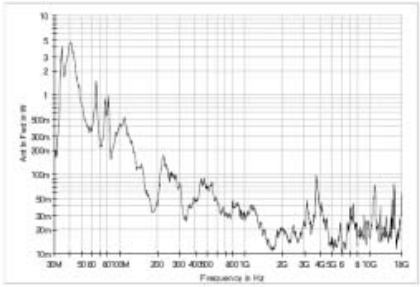


Figure 36. E Field Radiated Susceptibility Test. Antenna Power. Vertical Polarization

AIRBUS

M-RTU EMC Compatibility Assessment (3/3)

Conducted discharge

This test shall be performed according to ECSS-E-ST-20-07C Rev 1 § A.15 (units man-handled during normal operations)

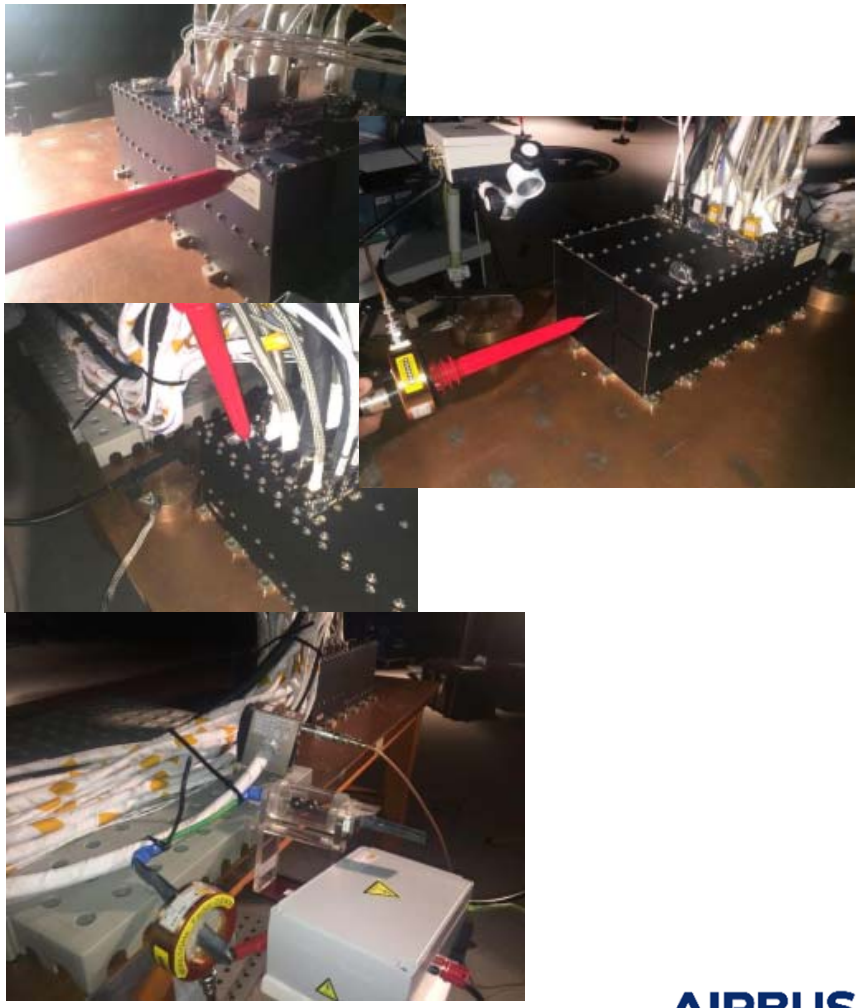
Magnitude	Energy	Pulse Duration (half amplitude)	Rise Time (10%-90%)	Duration	Repetition Rate
10 kV	10 mJ	100 nsec. ±30%	≤ 10 nsec	≥ 3 min	10 Hz

Table 6-19 Conducted Arc Discharge parameters

Radiated discharge

ESD Generator: Voltage of 10 kV.
Spark gap: typical value is 6 kV.
C (Capacitance): value is 50 pF (TBC)
Damping resistor: typical value is 47 ohm.
Choke resistor: minimum value is 10 kohm.
High voltage source: could be a dc source, a choke resistor of more than 10 Mohm is used.
Discharge circuit: floating and tightly coupled 20 cm along the harness of the EUT.
Transient current pulse: a goal is 30 amp, 30 ns duration at mid-height (TBC).
Repetition rate: 1 Hz for at least 5 minutes or with 15 positive and 15 negative pulses.

No Susceptibility to ElectroMagnetic Discharges detected.



Summary

- Modular RTU has fulfilled the technical expectations.
- Unit Modularity concept and third-parties included in the Modular RTU has been assessed.
- Qualification has been achieved with no major issues.
- There is an on-going flight mission based on the qualified RTU unit (Proba-3).
- The Modular RTU will be the baseline unit for future ESA missions .

Thank you

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E-mail: Javier.Goyanes@airbus.com

AIRBUS

APPENDIX

Applicable Documentation

Applicable Documents for the RTU2015 programme

By applying in an extensive way ECSS compliant interfaces (ECSS-E-ST-50-12C, ECSS-E-ST-50-13C, ECSS-E-ST-50-14C, draft ECSS-E-ST-50-15C, ECSS-E-ST-50-51C, ECSS-E-ST-50-52C) instead of the proprietary ones that are often used today, the opportunity is open for equipment suppliers willing to develop an EQM version of a modular and upgradeable unit than can be used across different missions.

This is exactly in line with the building block approach and philosophy.

REF.	DOC. NUMBER	TITLE
[AD-0]	Appendix 1 to ESTEC/ITT AO/1-6819/11/NL/AT	Modular General Purpose RTU 2015 Statement of Work
[AD-1]	ECSS-E-ST-20C	Electrical and Electronic
[AD-2]	ECSS-E-ST-50C	Communications
[AD-3]	ECSS-E-ST-50-12C	SpaceWire Links, Nodes, Routers and Networks
[AD-4]	ECSS-E-ST-50-13C	Interface and Communication Protocol forthe MIL-STD-1553B Data Bus Onboard Spacecraft
[AD-5]	ECSS-E-ST-50-14C	Spacecraft Discrete interfaces
~~[AD-6]~~	~~ECSS-E-ST-50-15 Draft~~	~~CAN-CANOpen Interface~~
[AD-7]	ECSS-E-ST-50-51C	SpaceWire protocol identification
[AD-8]	ECSS-E-ST-50-52C	SpaceWire - Remote memory access protocol
[AD-9]	ECSS-E-ST-10-06 / ECSS-E-ST-10 Part 6A	Functional and Technical Specifications
[AD-10]	ECSS-E-10-03	Space engineering – Testing
[AD-11]	MIL-1553B Notice 2	Digital Time Division Command/Response Multiplex Data Bus
[AD-12]	ECSS-Q-ST-30-02C	Failure modes, effects and criticality analysis (FMECA)
[AD-13]	ECSS-Q-ST-60-02C	ASIC and FPGA Development Standard
[AD-14]	ECSS-E-ST-20-07C	Electromagnetic compatibility
[AD-15]	ECSS-E-ST-32-10C rev 1	Structural Factors of safety for SpaceflightHardware
[AD-16]	ECSS-Q-ST-70-36C	Material selection for controlling stress-corrosion cracking
[AD-17]	SAE AS 4111	Validation Test Plan for the Digital TimeDivision Command/Response MultiplexData Bus Remote Terminals
[AD-18]	TEC-EDD/2007,32/GF Issue: 1 rev: 1 20/11/2008	RASTA Interface Control Document (ICD) –Onboard Software
[AD-19]	TEC-EDD/2007,31/GF Issue: 1 rev: 1 07/07/2008	RASTA Interface Control Document (ICD) –Hardware
[AD-20]	RASTA User's Manual	RASTA Users Manual