SITAEL

CAN/CANOPEN IMPLEMENTATION ON SMALL SATELLITE PLATFORMS

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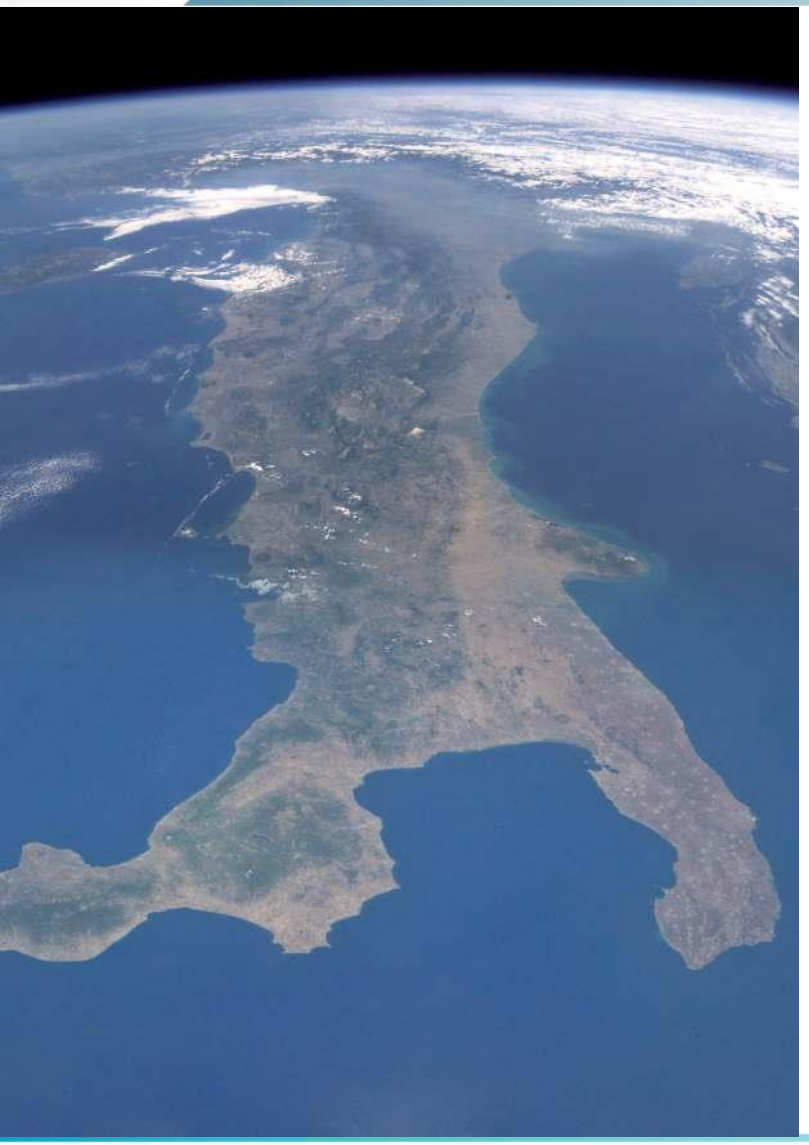
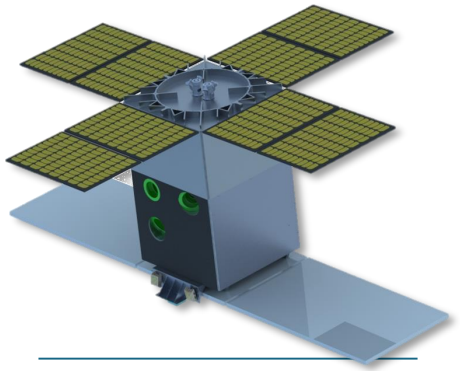
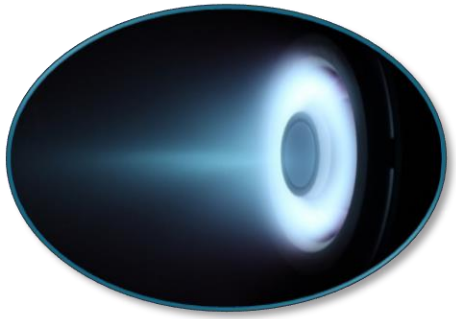
CAN In Space Workshop, 11-14 June 2019 Gothenburg

Overview: The Largest Privately Owned Italian Space Company





SMALL SATELLITES



ADVANCED PROPULSION

SPACE AVIONICS

380 highly qualified employees

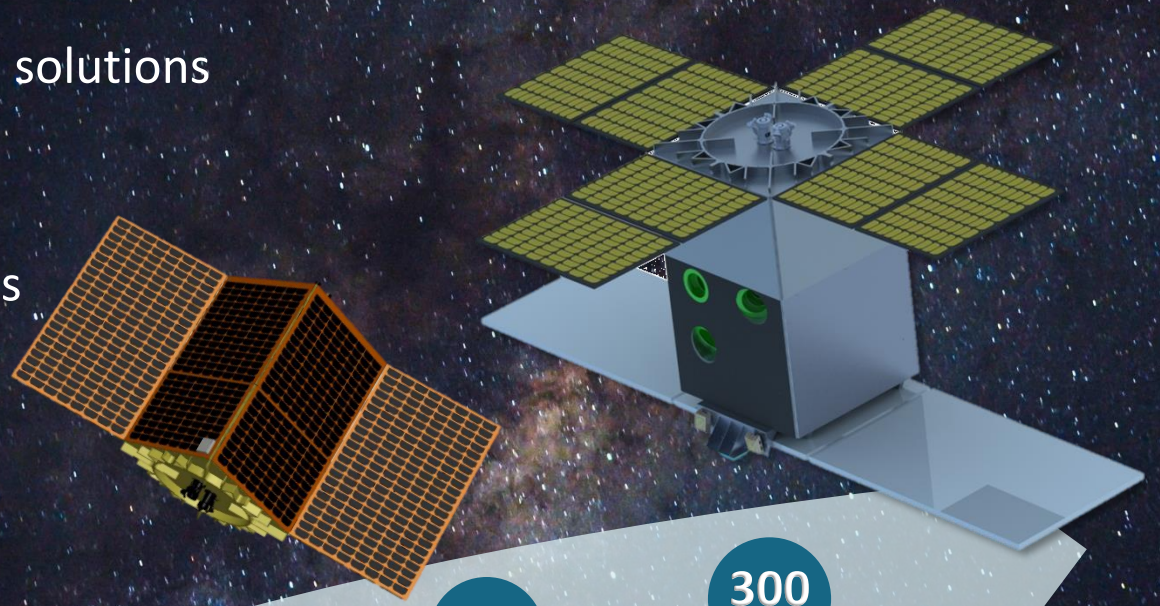
34,2 average age

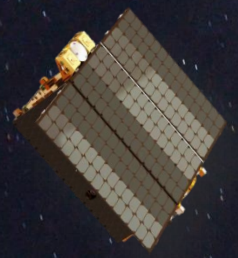
State-of-the-art facilities

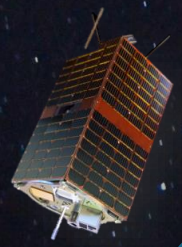
Turn-key solutions

Complete Small Satellite Product Line

- Smart, modular, scalable solutions
- All-electric platforms
- Wide range of possible missions and applications
- From **50kg to 300kg**







50 kg

75 kg

100 kg

200 kg

300 kg

Telecom HTS / Science

Earth Observation

IoT / M2M

IoD/IoV

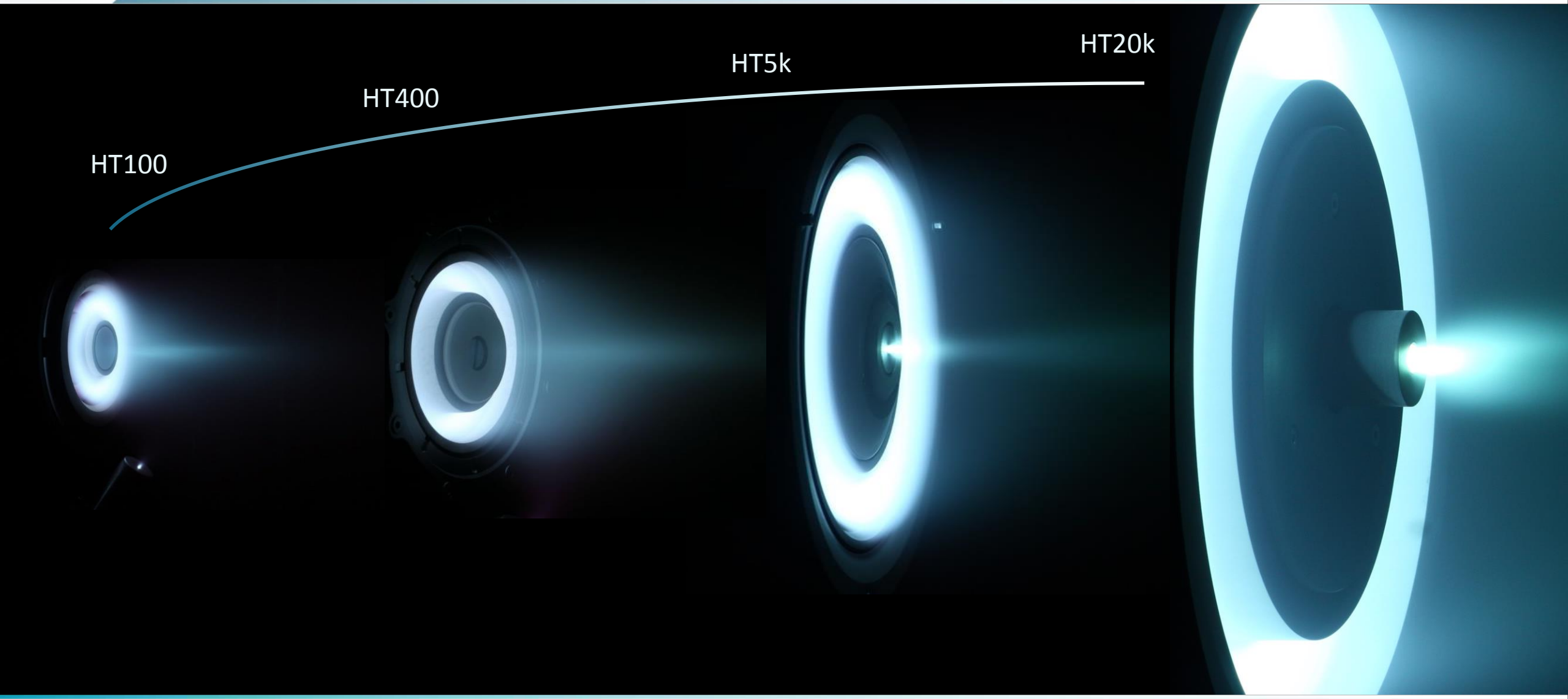
ESEO

μHET SAT

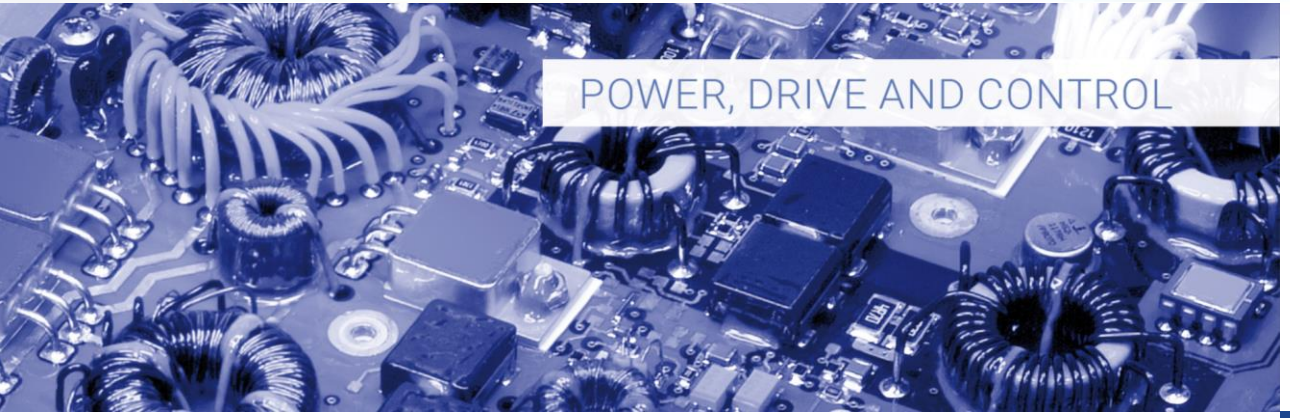
STRIVING
IN ORBIT VALIDATION

PLATiNO

A Wide Portfolio of Hall Effect Propulsion Systems



Hi-Rel and COTS Based Space Avionics



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High, Low and Medium Voltage Power Supplies

Drive Electronics for Cryocoolers

Power and Processing Units for Electric Propulsion

Instruments Units

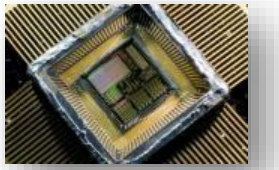
EGSE, Unit Testers

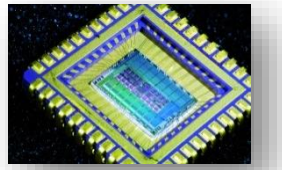
«

On Board Computers

»

ASIC





IP Cores

Outline

- SITAEL experience with the CAN bus
- Why CAN on small platforms?
- Topologies and components
- CANopen services configuration
- Results from the first mission

SITAEL CAN Bus Experience

1999

HurriCANe ALPHA version is provided by ESA for completion and verification against BOSCH testbenches

2000

First ASIC prototypes in DMILL CMOS 0.8um process

Collaboration with Alenia Spazio and Roscosmos to develop a new CAN bus controller with 3 mailboxes and uCU I/F (CASA2) for ATV fully compliant with CAN 2.0B protocol

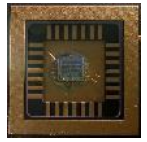
2002

The new CAN bus Controller (HurriCANe core version 5.0) is delivered to ESA

CASA2 is licensed to ATMEL and manufactured with MG2RTP Rad-hard Sea of Gate (P/N AT7908E).

2004

CANTRAN ASIC and AmCAN IP Core are developed and tested in the frame of an ASI contract.



2007

HurriCANe core IP update (version 5.2.3) - last by SITAEL

2009

Final Presentation of ESA Integrated Payload Processor Module (IPPM) with CANbus for housekeeping as instrument bus or avionic bus in alternative to MIL-STD-1553

2012

ESEO Phase C0/C1/D/E1 development start.

2013

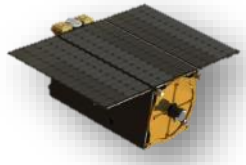
CANopen Controller IP Core (CCIPC) is delivered to Thales Alenia Space in the frame of an ExoMars Contract

2015

CCIPC improvement for SATCOM Payload and Platform Management

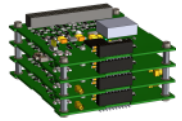
2016

uHETSat – in orbit validation of SITAEL HT100 Thruster



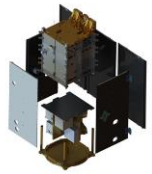
2017

SCAT – C-band transceiver module for small satellites

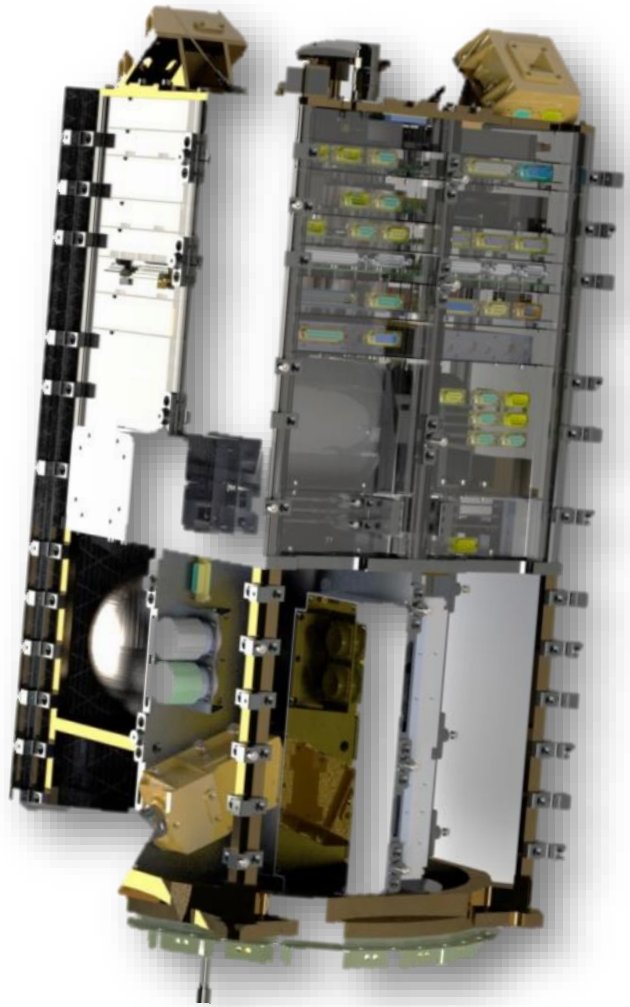


2018

STRIVING – Service for in orbit validation / demonstration

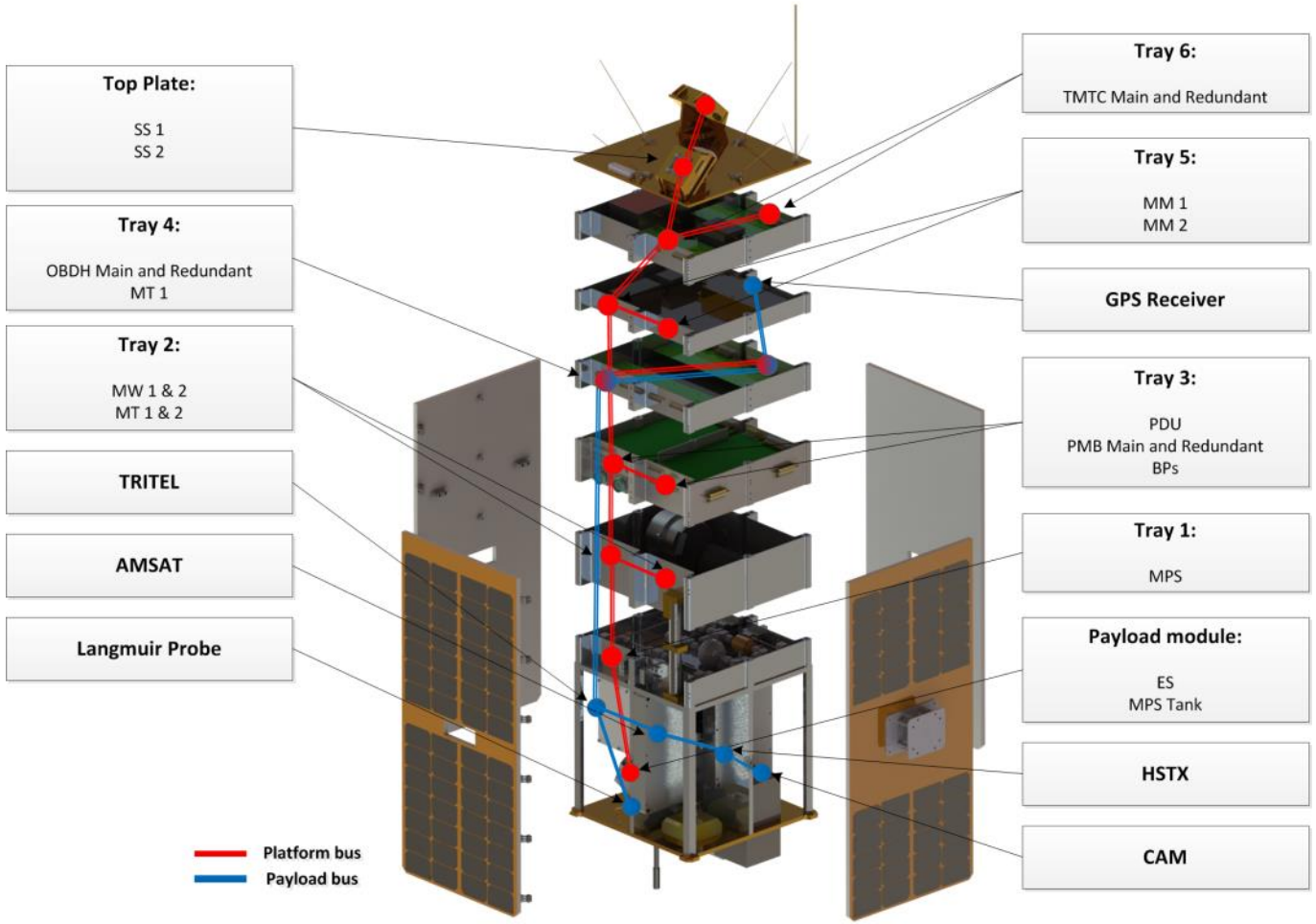


CAN in Micro-satellites – why?



- 50kg platform, based on COTS components.
- Technology demonstration missions, an opportunity for SITAEL to get “hands on” and make the team gain experience.
- All developed internally: structure, power conditioning and distribution, solar panels, sensors and actuators, OBC and data handling.
- The CAN is selected for platform and payload bus.
  - ✓Low cost.
  - ✓Widely used in terrestrial application, consolidated technology with wide spread know-how.
  - ✓Large availability of components for development, both integrated in microcontrollers or as independent controllers.
  - ✓Large availability of software support, including higher level protocols (CANopen) and tools (Vector CANoe).

CAN view of a Micro-satellite (1/2)

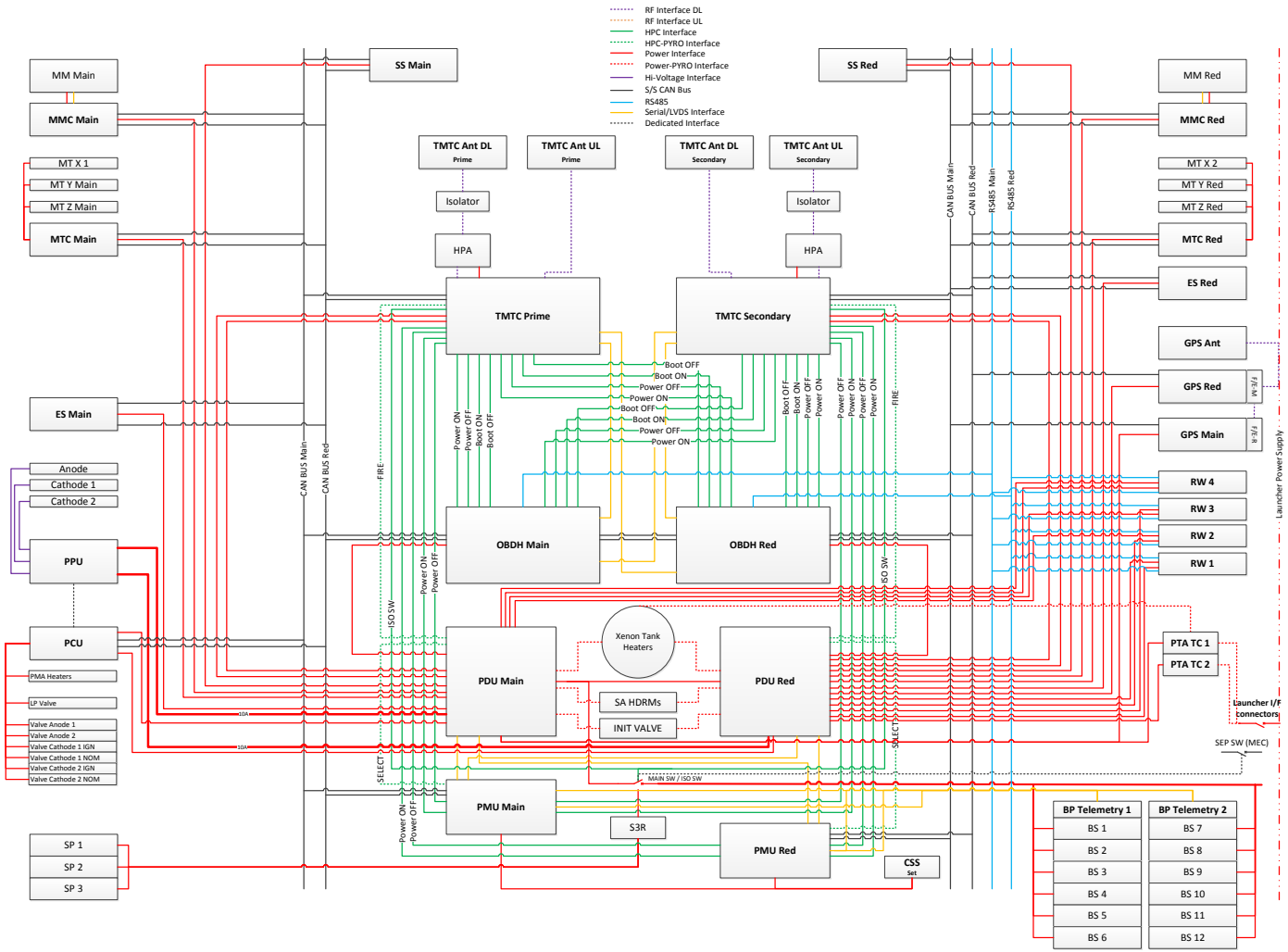


Two CAN busses: the platform and payload bus. The OBC is the only node which is connected to both.

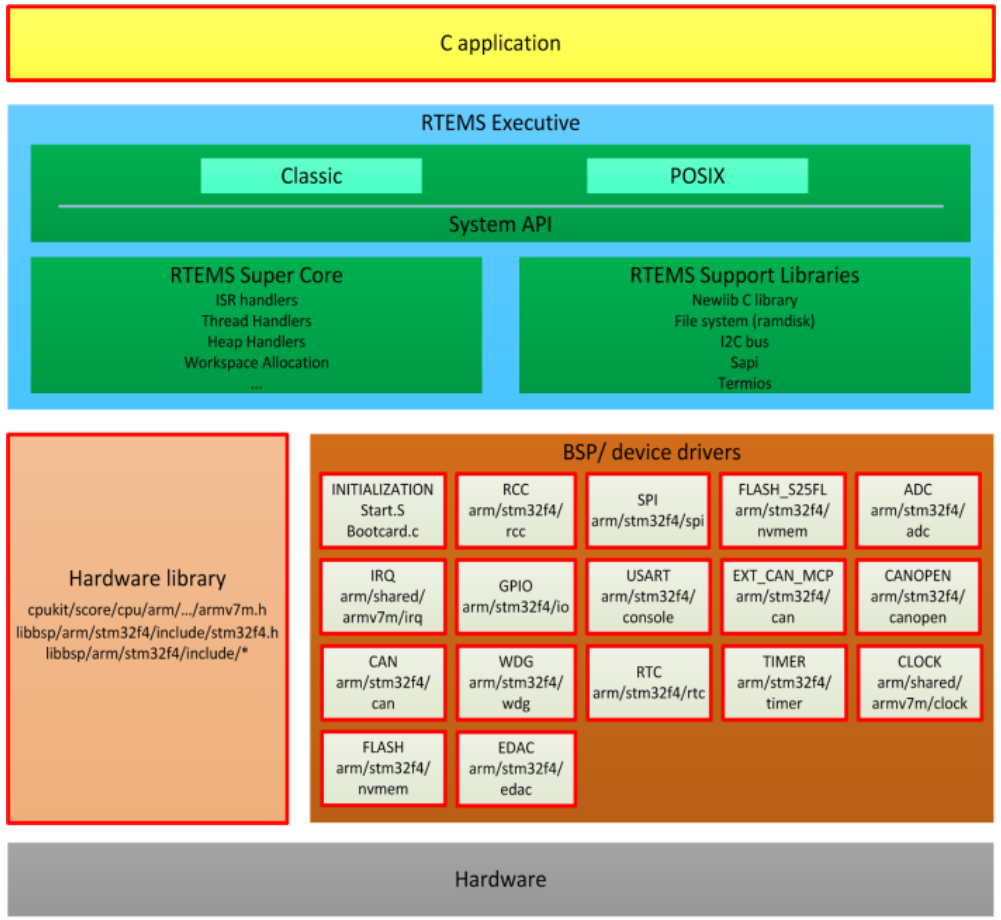
- 21 nodes in total;
- All nodes are based on the same microcontroller, an ARM Cortex M4 (105MIPS @ 84MHz);
- Re-use of:
  - Electronics building blocks (uC, DC-DC, LCLs, memories, interfaces);
  - SW (RTEMS, device drivers, comm. protocol stacks);

CAN view for a Micro-satellite (2/2)

- Master/Slave; the OBC with the role of master, although in some of the platform safe modes with no OBC availability, Master role is assigned to the TMTC subsystem (in charge of Essential TM and Essential TC);
- 1Hz cycle; the cycle is statically partitioned for data exchange with each node. Late communication is aborted in the current cycle;
- On-board data acquisition and commanding (through CANopen stack) takes ~30% of the OBC CPU;



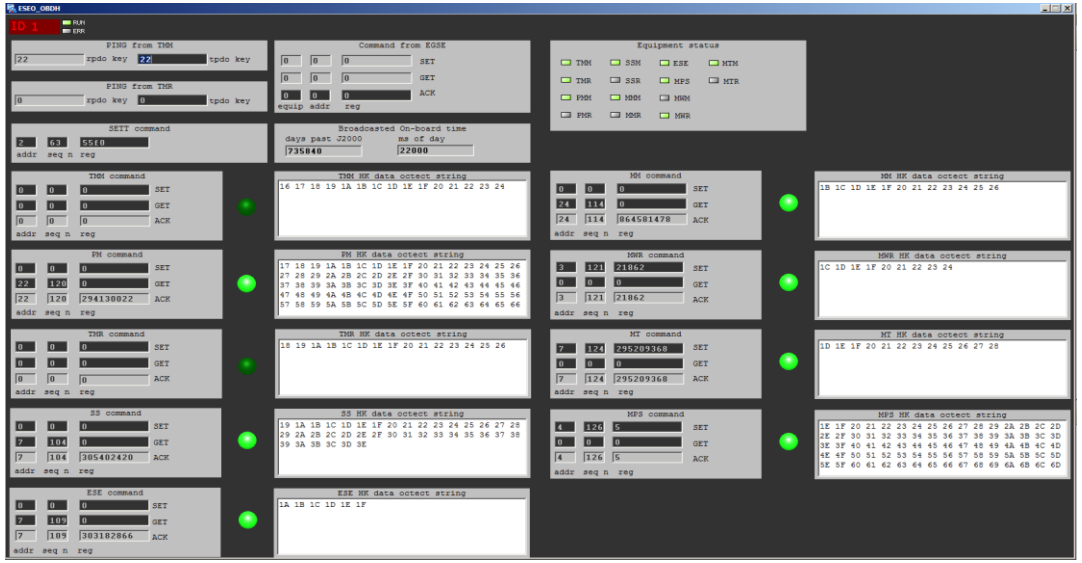
Software IF (1/4)



- CANopen implemented in form of a SW stack, starting from Vector code:
  - ✓ CAN controller device driver embedded in RTEMS
  - ✓ CANopen software stack integrated in RTEMS
  - ✓ Same approach for masters and slaves
  - ✓ Stack updated to:
    - Include multiple SDO client channels (same approach used for servers)
    - Expand Rx/Tx buffer length
    - Remove dead code (unused services)
    - Improve metrics
  - ✓ No criticality B qualification;

Software IF (2/4)

- ESEO CANopen implementation (OBC):
  - ✓ 43 TPDOs
  - ✓ 24 RPODs
  - ✓ 19 SDO clients
  - ✓ Heartbeat producer/consumer with master role
  - ✓ Manages two busses, platform and payload
- Footprint (controller driver + CANopen + add-on custom layer + API)
  - Non-volatile: 110 kbytes
  - Volatile: 16 kbytes



Bus Statistics

	CAN 1	CAN 2
Bus load [%]	9.46	0.00
Peak load [%]	9.49	0.00
Std. Data [fr/s]	209	0
Std. Data [total]	4651	0
Ext. Data [fr/s]	0	0
Ext. Data [total]	0	0
Std. Remote [fr/s]	0	0
Std. Remote [total]	0	0
Ext. Remote [fr/s]	0	0
Ext. Remote [total]	0	0
Error frame [fr/s]	0	0
Error frames [total]	0	0
Chip state	Simulated	Simulated

Housekeeping data collection

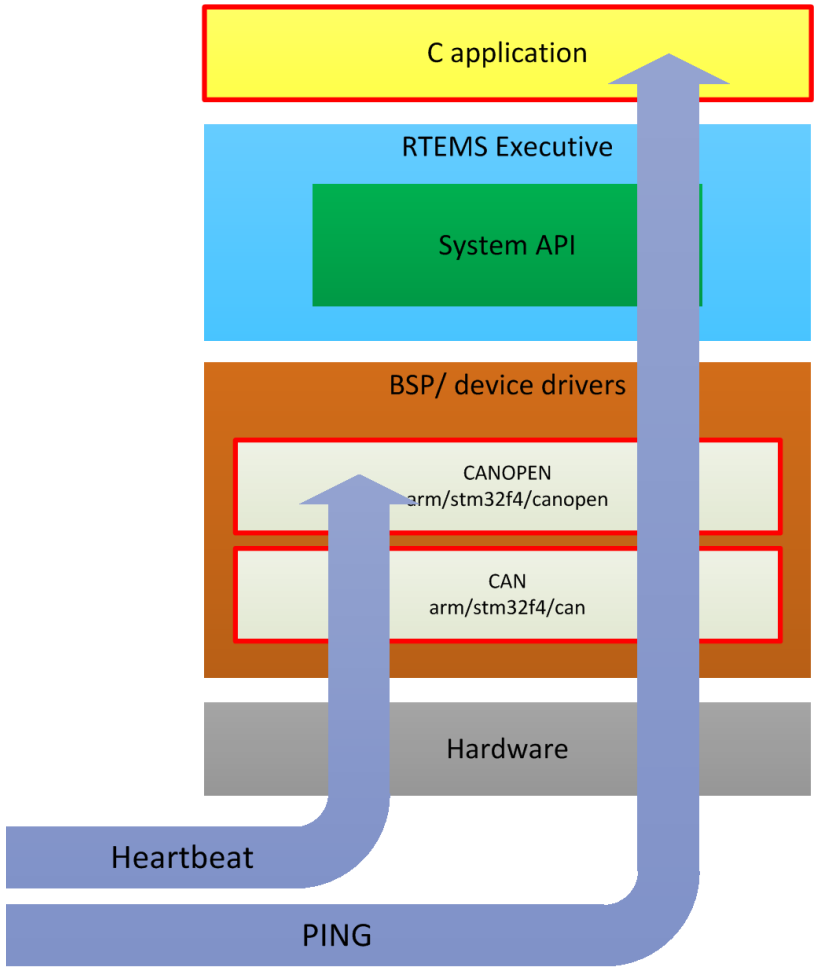
- Housekeeping data collection is based on **SDO segmented transfer**
  - ✓ Many data types collected in data structures, with signed and unsigned integers, 32 and 64 bits floating point values; From few bytes to hundreds bytes;
  - ✓ Platform housekeeping data set refreshed periodically by the units; generally 1Hz, higher rate is foreseen only for a small subset of parameters (eg main bus voltage is automatically sampled up to 1KHz in case of under-voltages);
  - ✓ Master/Slave configuration: the OBC issues SDO uploads to the units periodically, with a pre-defined sequence;
  - ✓ Master role can be reconfigured: there are specific safe modes where the OBC is unavailable, the TMTC can issue the same HK data request using SDO protocol;

On-board time distribution

- On-board time distribution is based on **broadcasted PDOs**
  - ✓ Master/Slave configuration: OBC is keeping on board time, and broadcasting it with 1 TPDO. Every other is receiving with 1 RPDO.
  - ✓ Time is kept and broadcasted in form of Days past J2000 plus milliseconds of day.
  - ✓ Units autonomously propagate time in case the service goes missing (safe mode)

PING service for essential subsystems

- PING service is established as part of essential subsystems FDIR policies;
- It is based on **PDOs**
- Master/Slave configuration: the TMTC (which incorporates Essential TM/TC) issues PING requests to the OBC and power subsystems;
- If the PING answer goes missing, platform FDIR algorithm operates (rebooting, switching to redundant)



On-board commanding

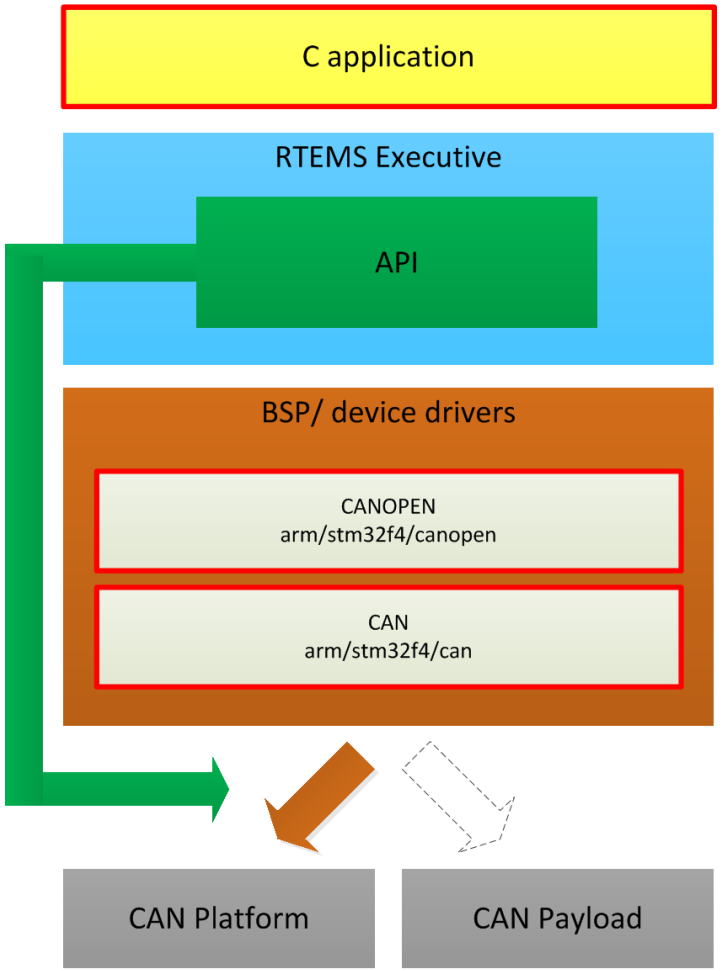
- On-board commanding is based on **PDOs**
  - ✓ Additional protocol layer is added on top of CANopen to ensure command reception and/or execution acknowledge;
  - ✓ Error codes handling includes invalid command, no answer or late acknowledge;
  - ✓ PDOs command data field is fixed:
    - 1 byte specifying the access type (read or write);
    - 1 byte carrying a sequence number used to correlate ACK
    - 4 bytes specifying data to be written (a parameter, or bit-per-bit command definition)
  - ✓ Master/Slave (TMTC can take Master role in safe mode)

Bus redundancy management

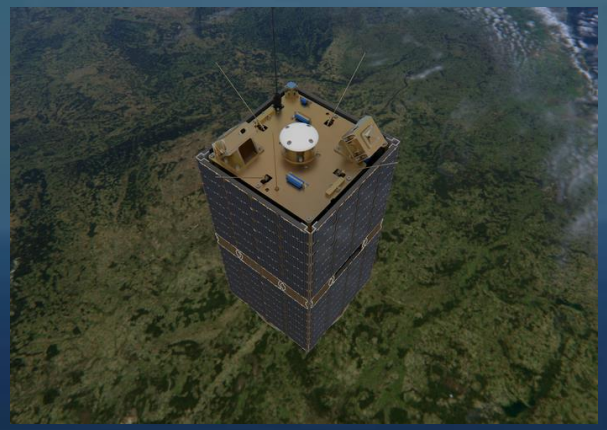
- Bus redundancy is managed with **Heartbeats (ECSS-like):**
  1. A master node periodically broadcasts heartbeats on the active CAN bus;
  2. If a units misses a number of heartbeats, it switches to the redundant and start producing heartbeats on it, to inform the master;
  3. The master switches to the redundant bus, and start broadcasting heartbeats on it;
  4. Every other unit switches to the redundant;

Multiple bus management

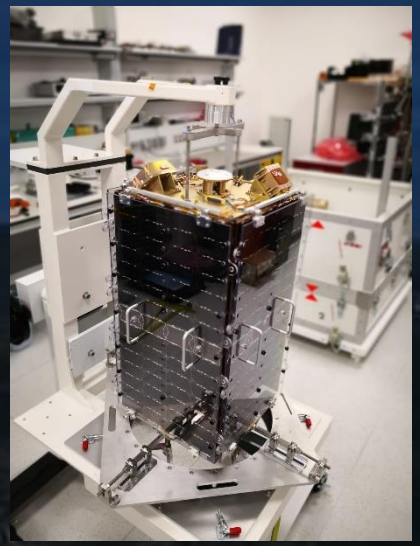
- A single stack handles two busses.
- To reduce footprint:
  - ✓ Implemented a single stack instance
  - ✓ An additional layer between the stack and the driver switches bus according to the addressed units



CAN in orbit



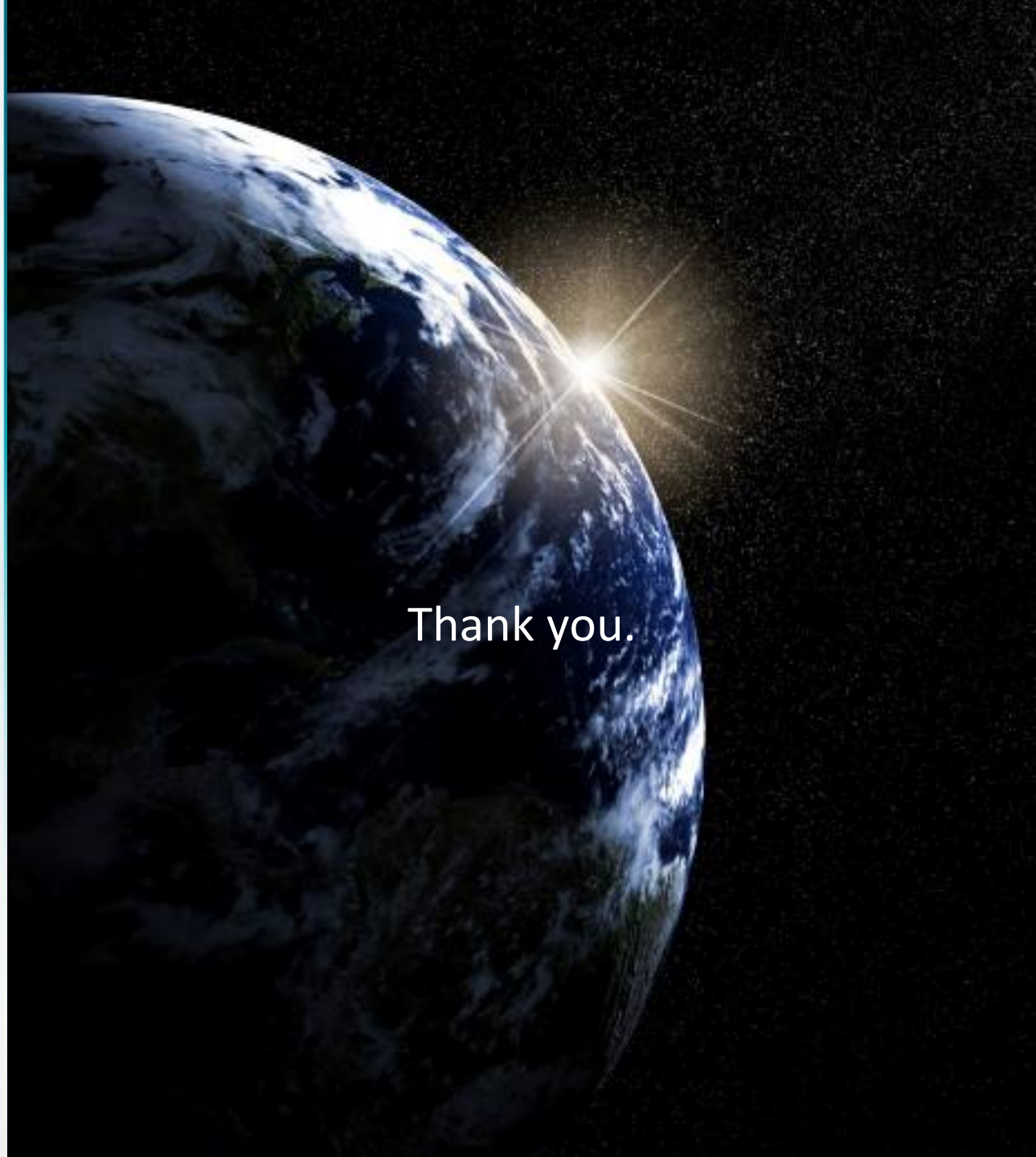
- ESEO launched with SSO-A on 3 December 2018.
- More than 70M SDO transactions
- More than 500M PDO exchanged
- No autonomous switch between Main and Redundant experienced so far



What's next?

- The next micro-sat (uHETsat) will be launched next year, currently we are testing PFMs and approaching satellite integration;
  - Reduced the development from 6 years to 3 years.
  - Many lesson learned from the first mission, but on-board data handling is the same implementation.
- Platform future developments:
  - Replace the microcontroller with rad-tolerant latch-up immune device (not available when we started years ago);
  - CAN-FD adoption (if available on the uC), interest is in the larger data payload per frame, which improves protocol efficiency;

SITAEL



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