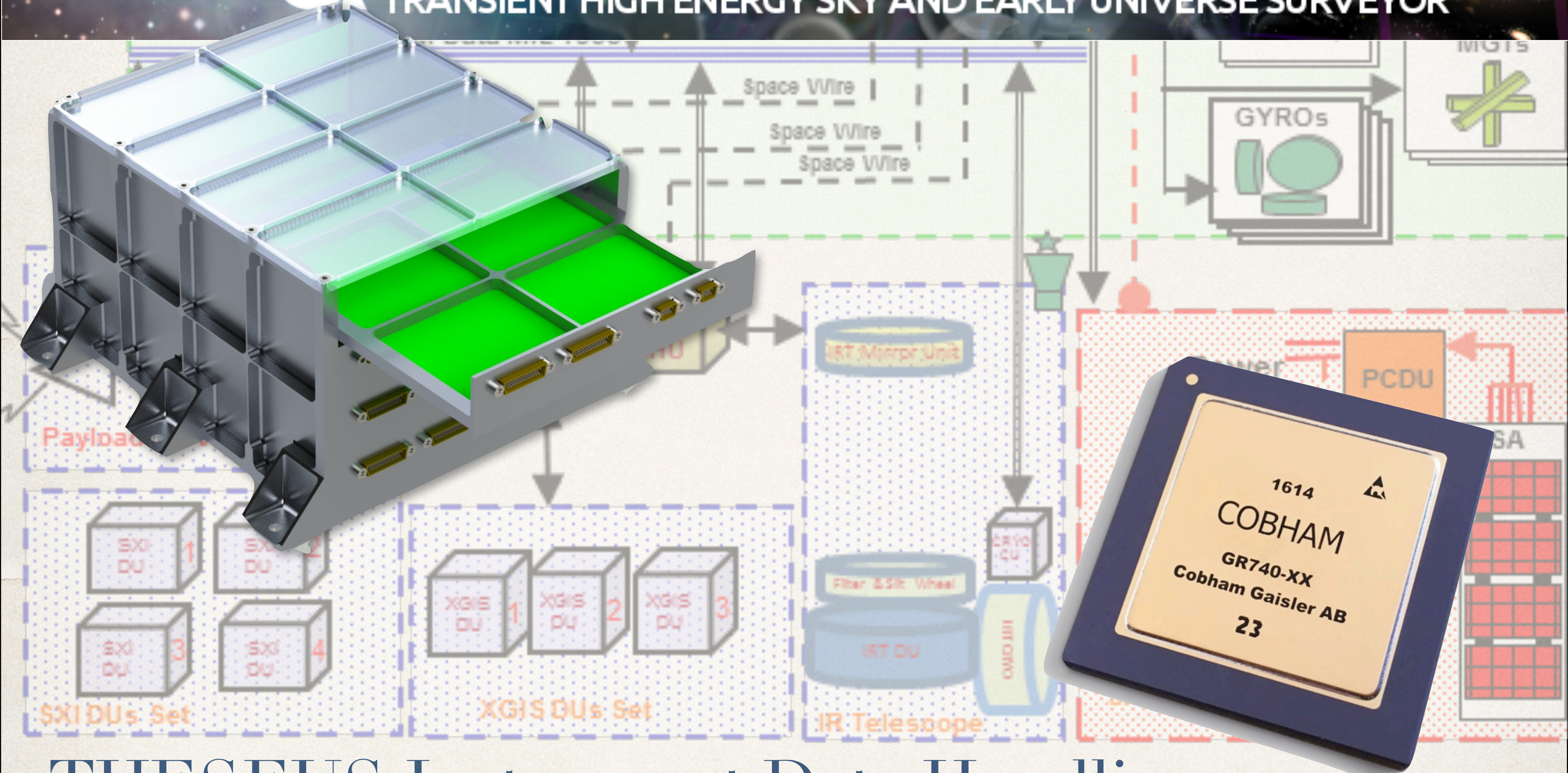
theseus

TRANSIENT HIGH ENERGY SKY AND EARLY UNIVERSE SURVEYOR



THESEUS Instrument Data Handling

05.10.2017 - THESEUS workshop - Napoli

Dr. Chris Tenzer, Institut für Astronomie und Astrophysik, Universität Tübingen

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I-DHU Description

The three THESEUS **Instrument Data Handling Units** (I-DHUs) are the **TM/TC interfaces** between the instruments and the Spacecraft Service Module (SVM). In addition, they have **power distribution, instrument control, data processing and data storage** functionality.

Our proposed baseline I-DHU design consists of **two** different **cold redundant boards** (total of four boards) within **one mechanical box (same hardware design for all instruments).**

The **Power & Analogue HK Board** will perform the following tasks:

- **Distribute** and switch on/off the **primary power to the instrument subsystems**
- Generate required **low voltages for the I-DHU** itself
- Generation of **housekeeping data** about voltages, currents, temperatures
- Possible location of the mass memory

The **Data Processing Board** will perform the following tasks:

- Interface (TM/TC) to the spacecraft, **distribution/execution of commands**
- **PPS synchronisation** and timing signal distribution to instruments
- Instrument **health monitoring**
- **Science data monitoring**, digital housekeeping
- Real-Time **data processing** (instrument related software)
- **Mass memory** handling

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developed by IAAT, contributions by instrument teams

System Design Overview

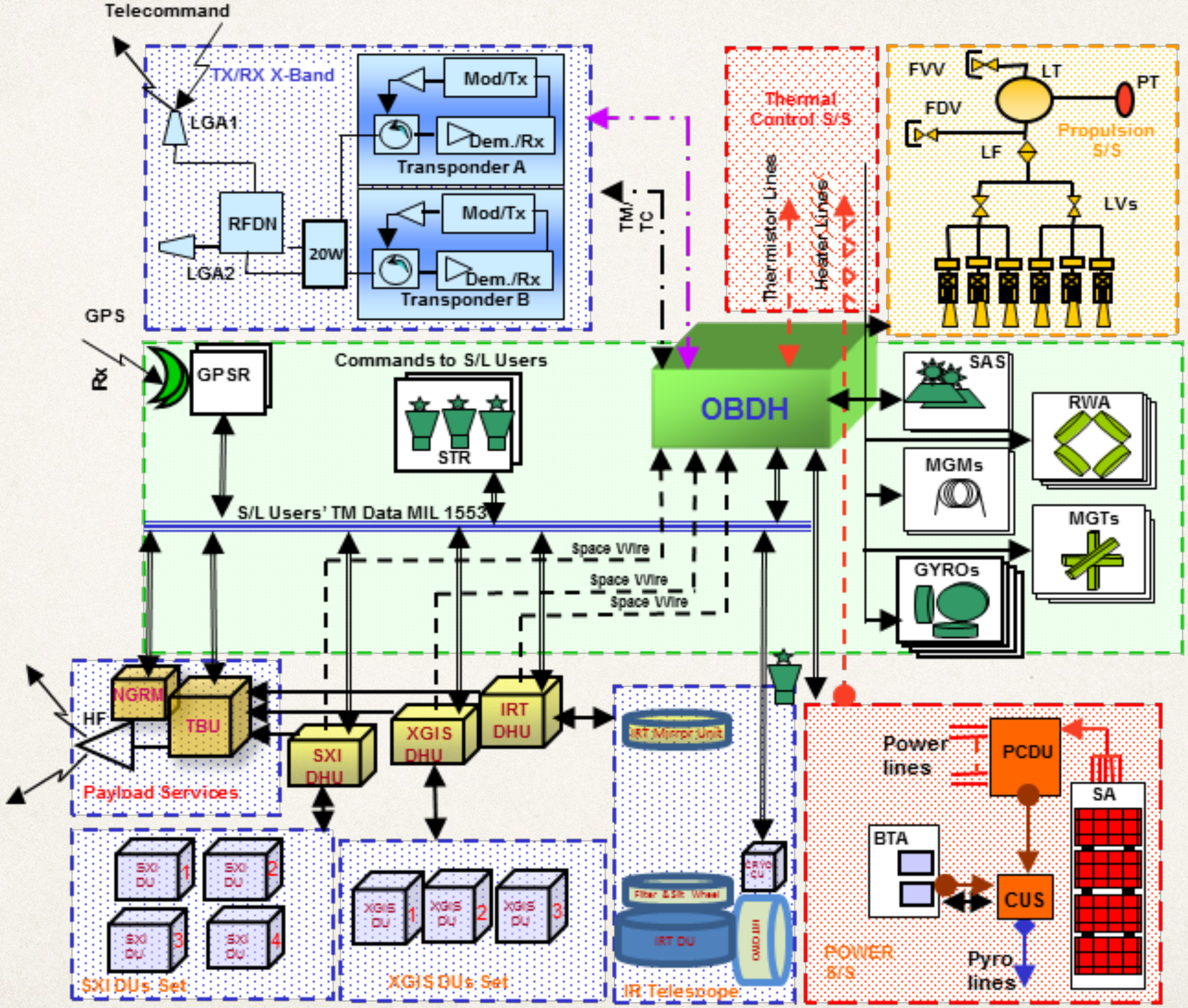
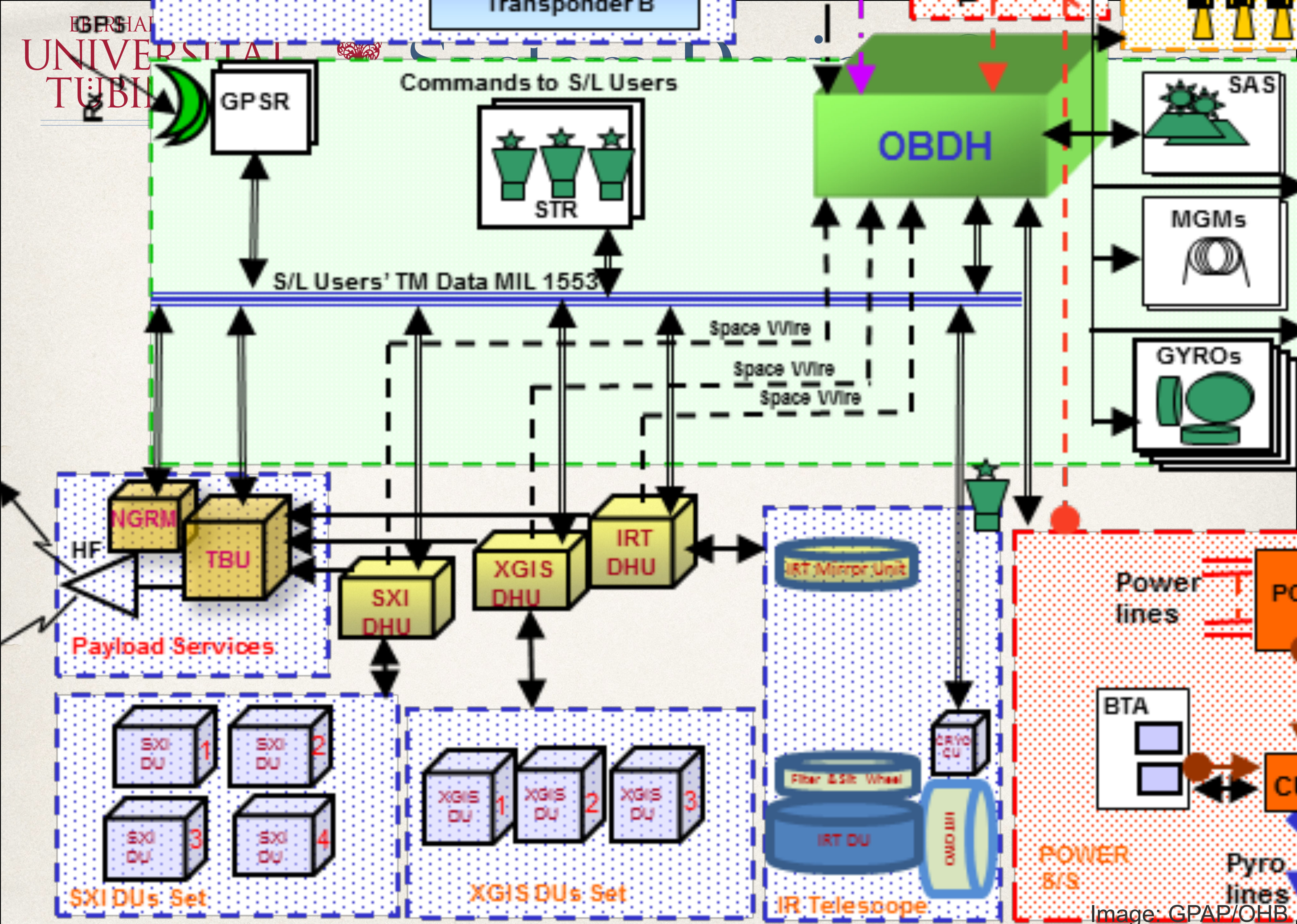


Image: GPAP/OHB



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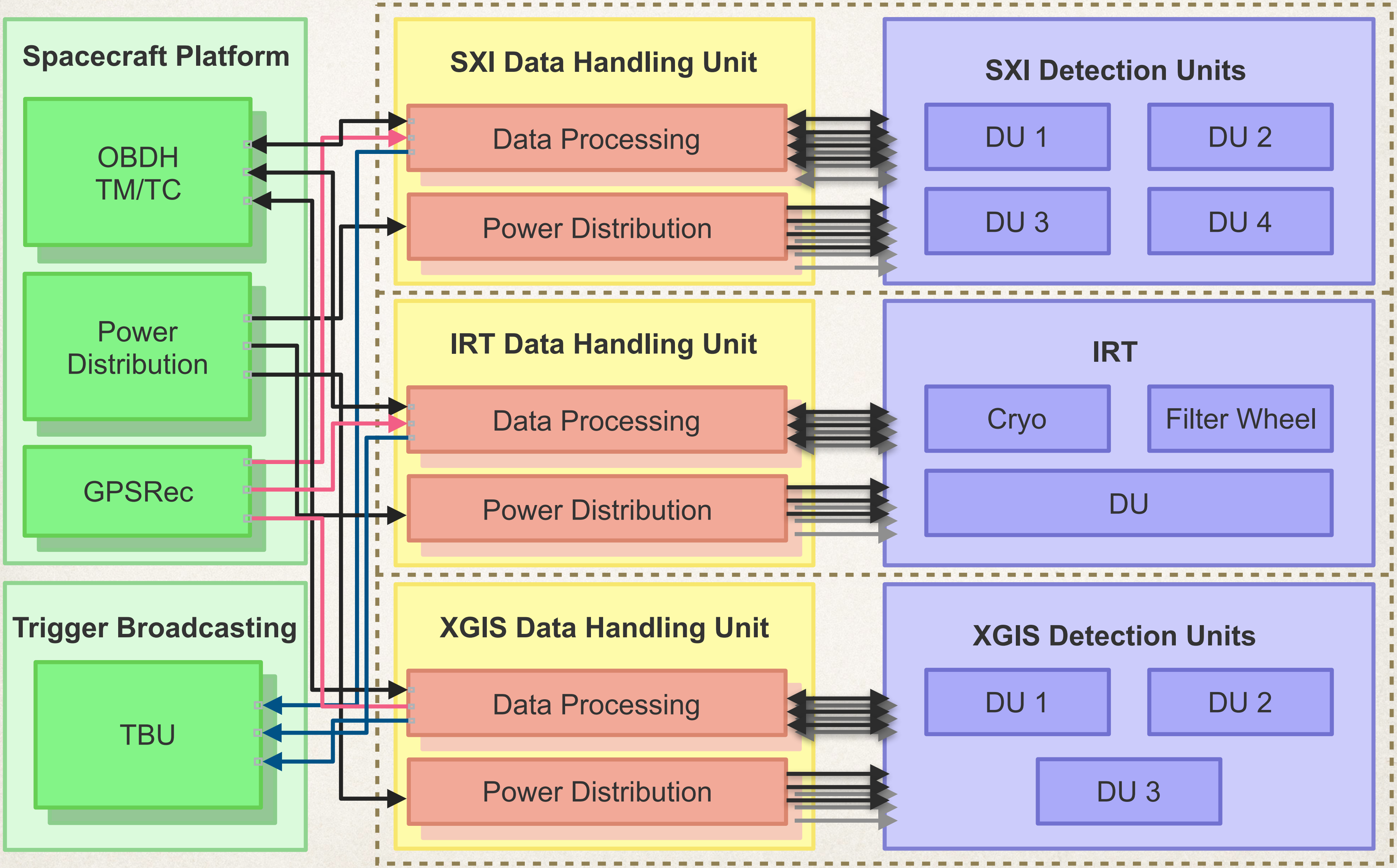
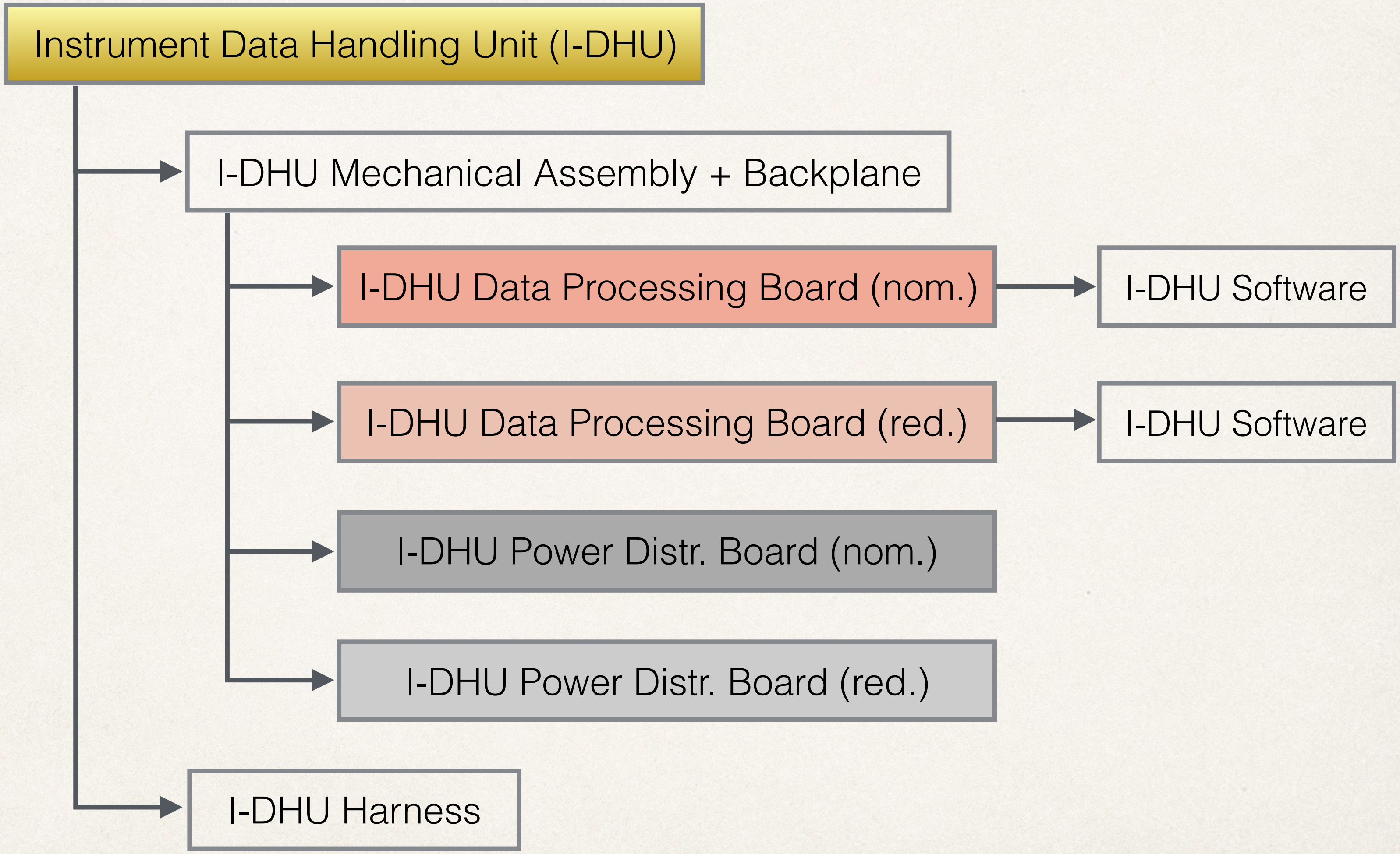
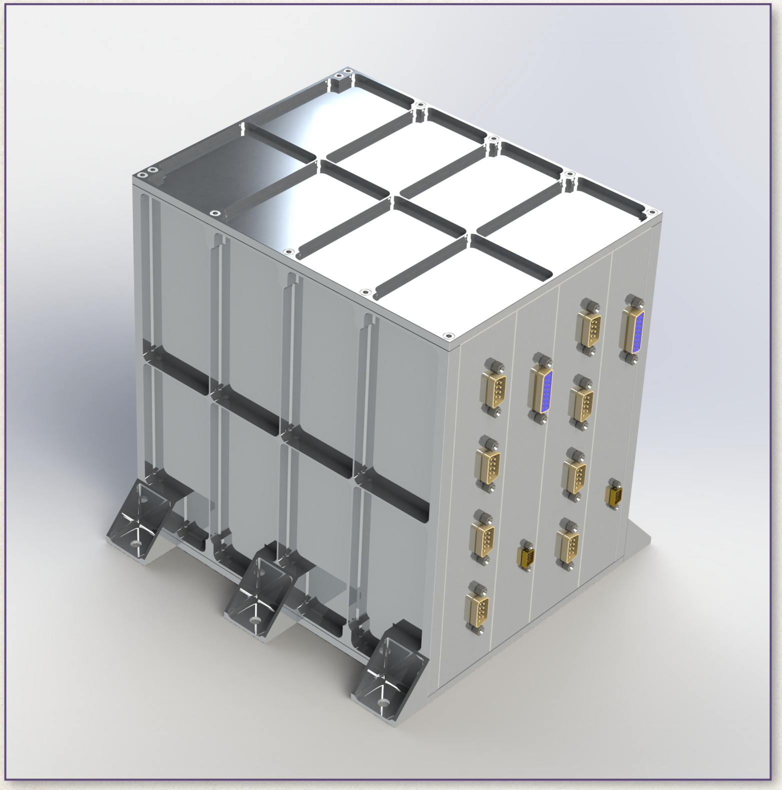
Design Overview



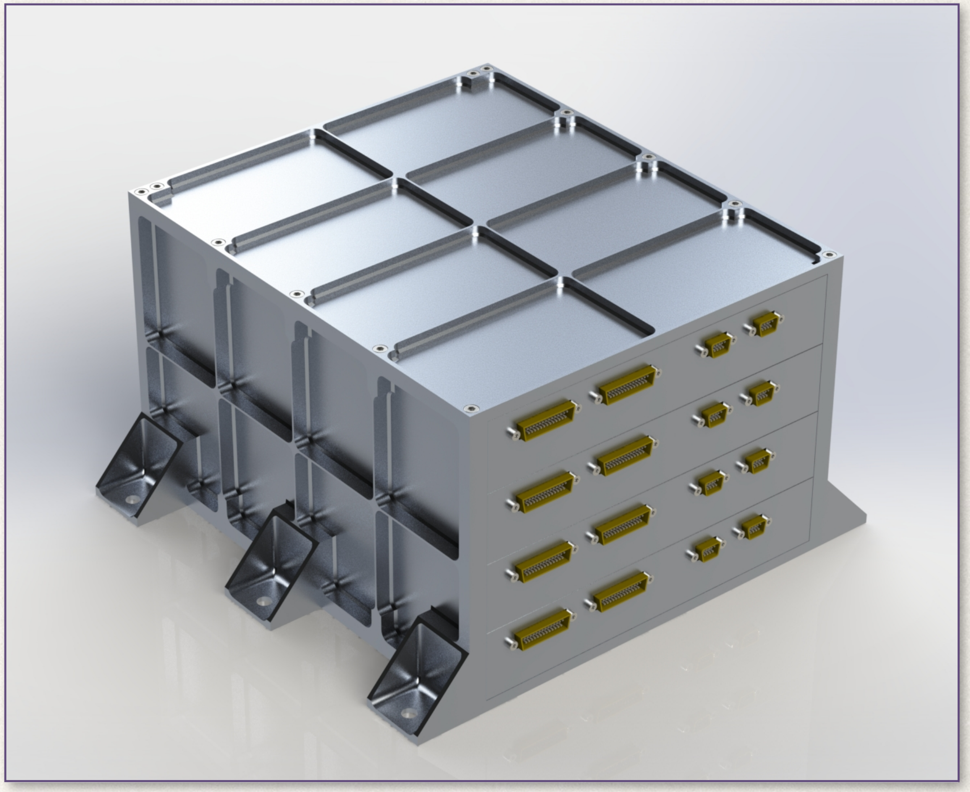
Component Tree



DHU Mechanical Design



Possible design of the I-DHU box (aluminum)
Dimensions L: 210 mm, W: 210 mm, H: 180 mm



Possible design of the I-DHU box (aluminum)
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DHU Mechanical Design

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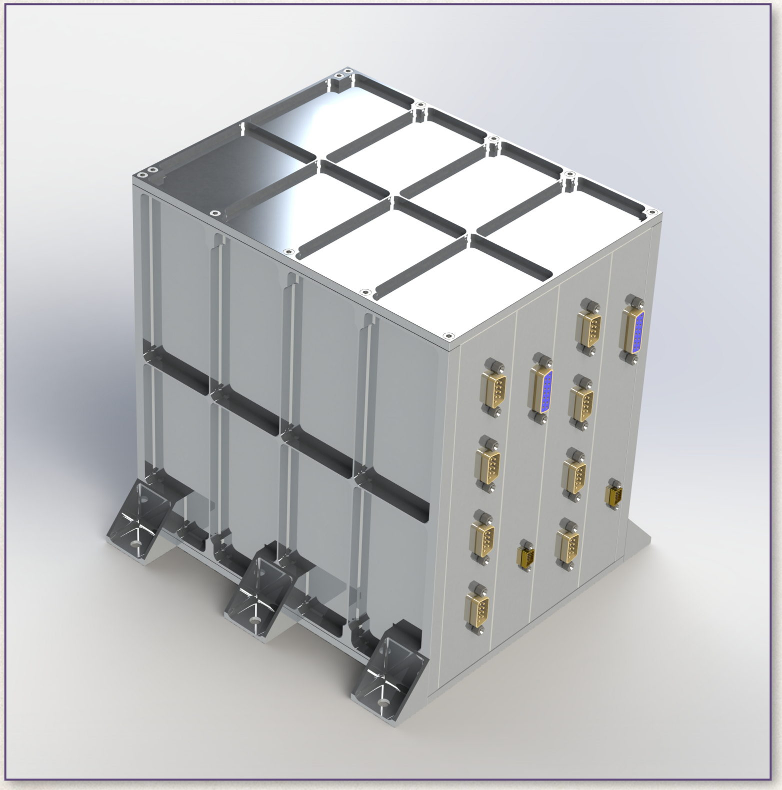

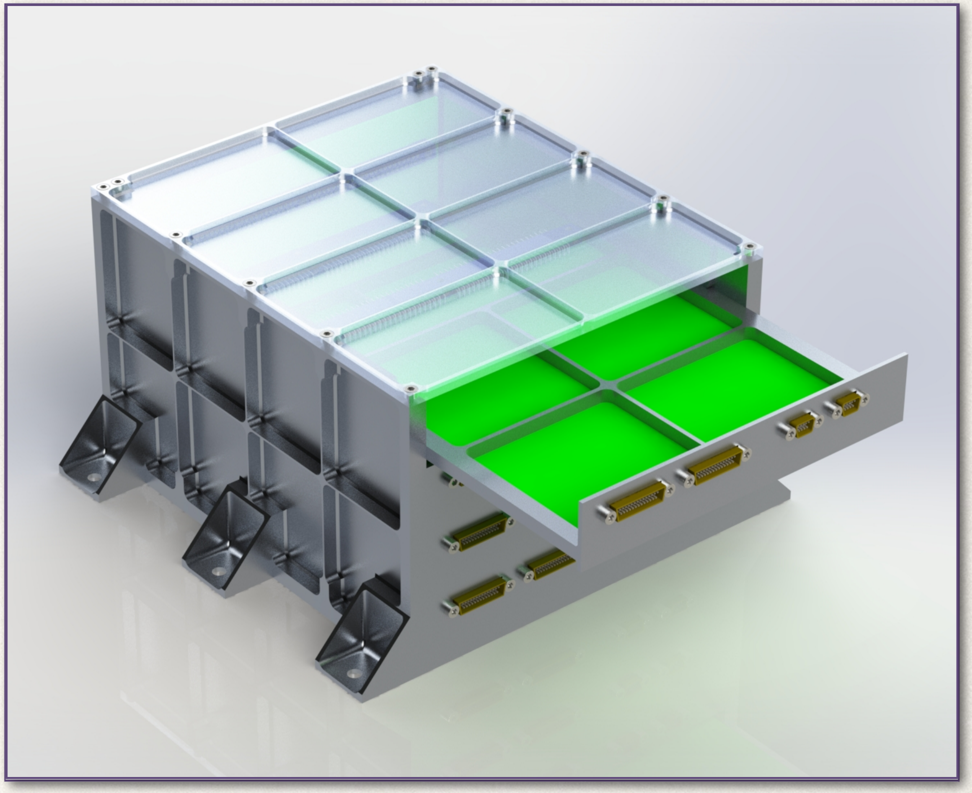

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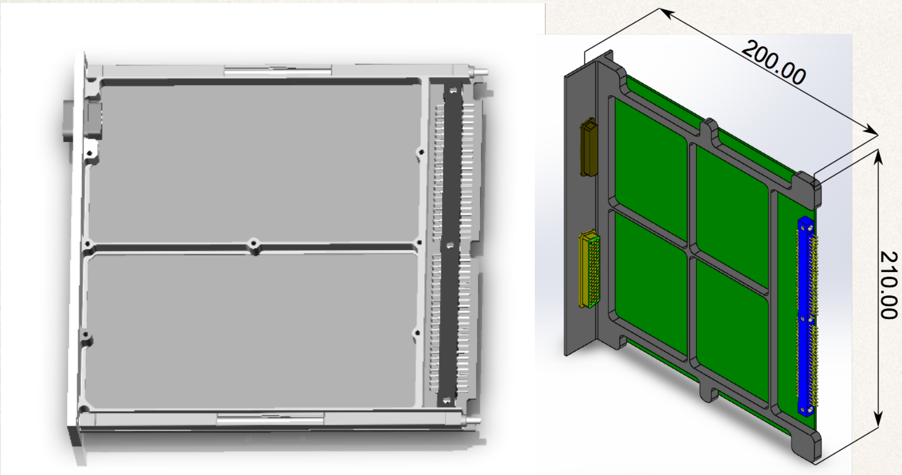
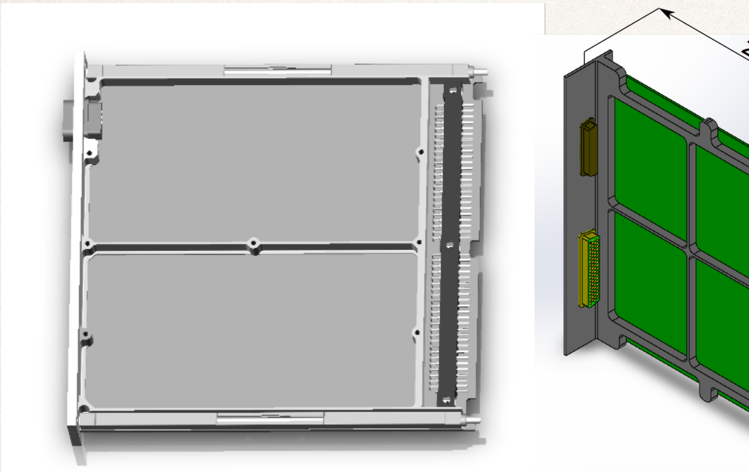


individual boards

DHU Mechanical Design



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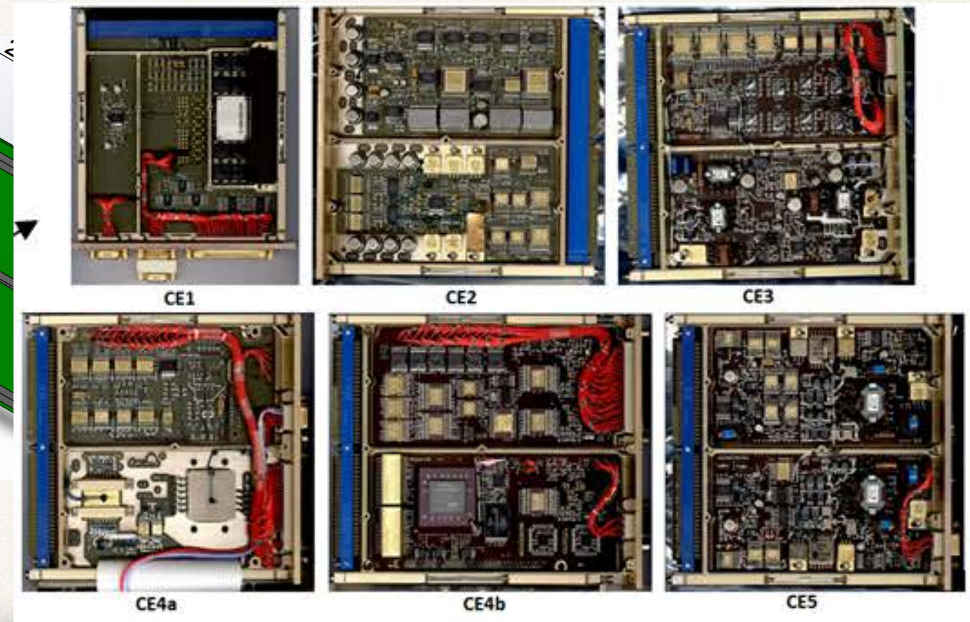
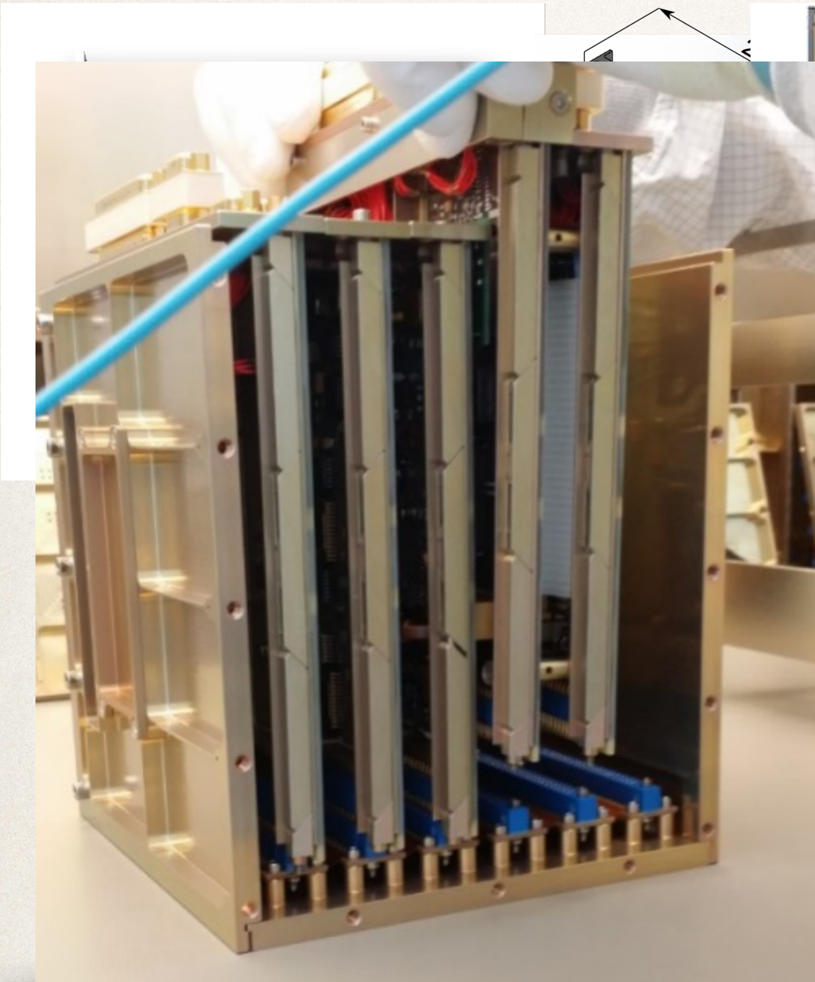
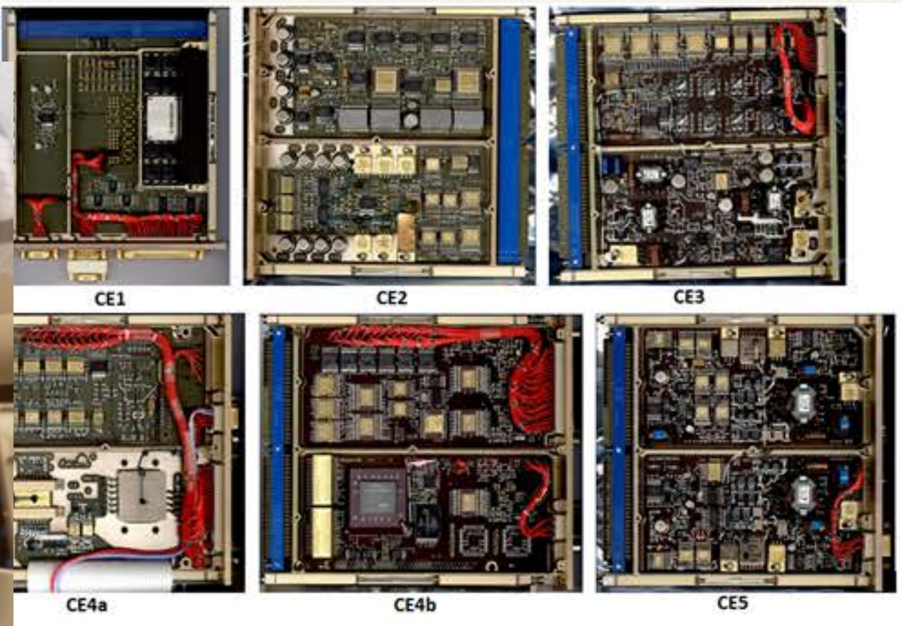


eROSITA heritage

DHU Mechanical Design



assembly with open side



eROSITA heritage

DHU Mechanical Design

mounting on the telescope

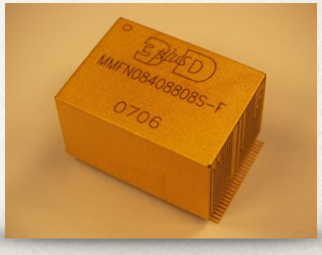
Power Distribution Board

The **Power Distribution Board** will handle the following tasks:

- Receive the 28 V primary power from the Service Module
- Generate required low voltages for the I-DHUs
- Distribute the 28 V primary power to the subsystems
- Generate TBD other high and low voltages for the respective instrument
- Generate and collect its own HK data (voltages, currents, temperatures and operational parameters)

Baseline for the **mass memory**: 32 GByte Flash NAND memory cell array

- designed for ESA space applications, large flight heritage
- radiation tolerance: Total Ionizing Dose (TID) up to 50 krad(Si)
- low power consumption
- memory management by the I-DHU

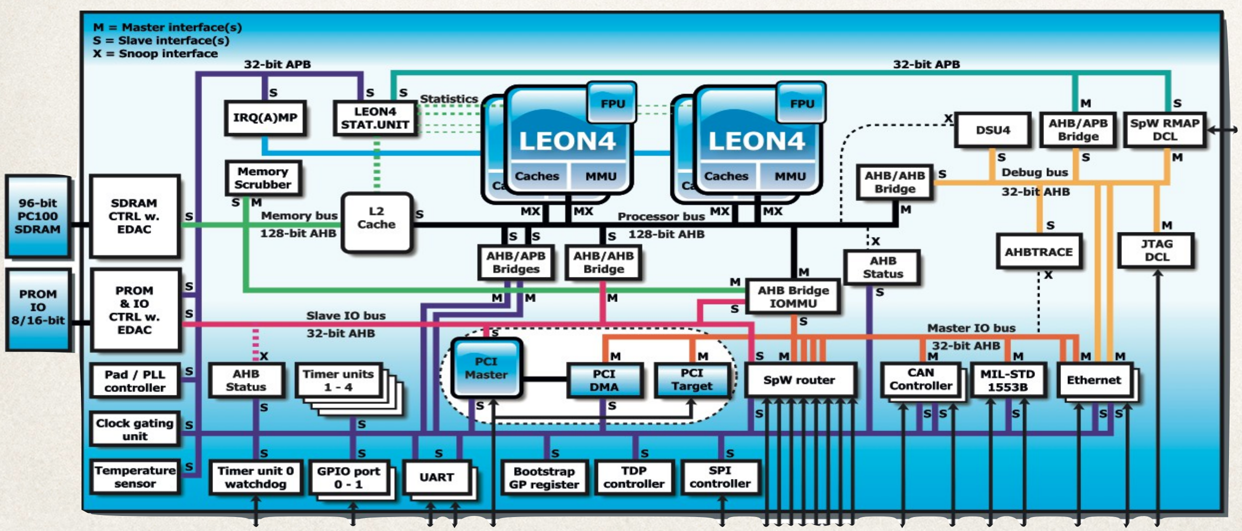


Data Processing Board

The **data processing board** performs the CPU functions of the I-DHUs. It hosts the central processor, the time distribution circuits and the HK collection circuits.

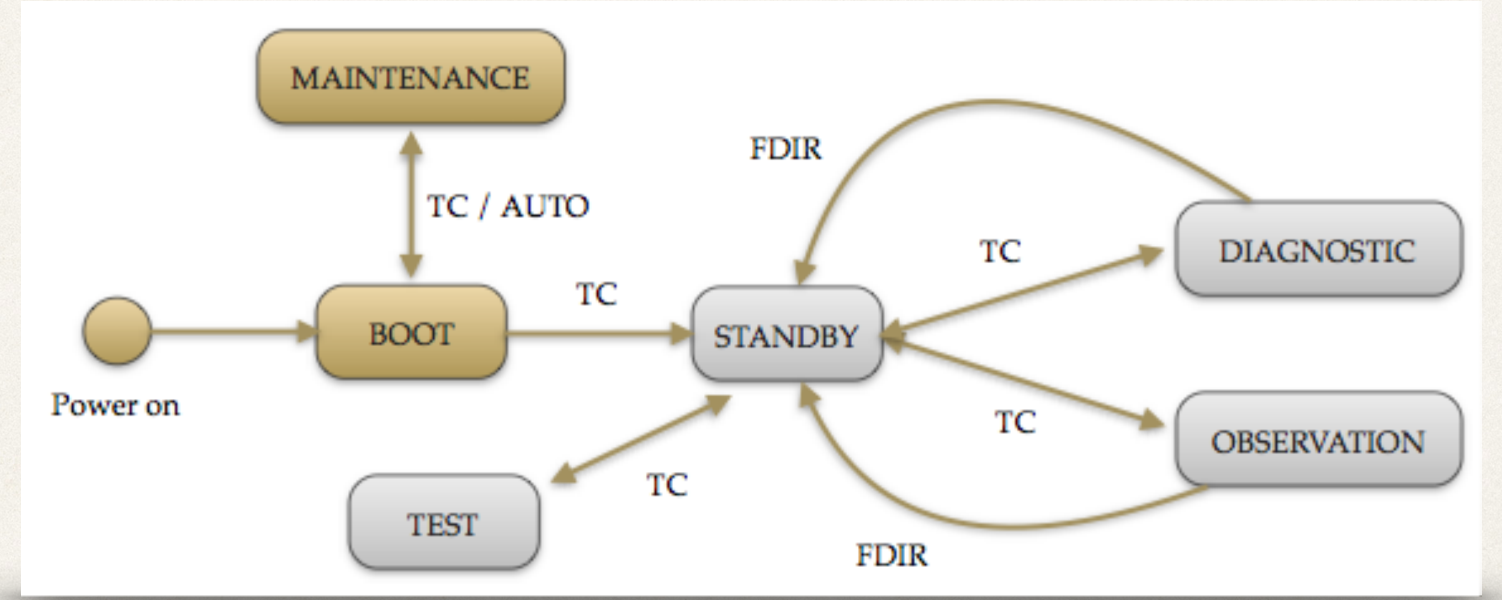
The **baseline processor** for the data processing board is the GR740 with the following features:

- Quadcore LEON 4FT with dedicated FPU and MMU
- External memory support
- Eight SpaceWire ports, maximum 200 Mbps full-duplex data rate
- CCSDS/ECSS 5-channel Telecommand decoder, 10 Mbps input rate
- CCSDS/ECSS Telemetry encoder, 50 Mbps output rate
- MIL-STD-1553, CAN, High Speed Ethernet



On-board Software

The software is being written in C using RTEMS, a real-time executive system, which allows to schedule the software tasks at different priorities, communicating with each other with messages and events. There will be a "**Basic**" software, stored in a reliable PROM, that allows to perform basic health management and memory management: to receive, store and execute patches or new software and an "**Operation**" software, stored in an EEPROM.



Overview of the I-DHU operation modes and transitions

On-board Software

The **standard functionality and tasks of the software** cover:

- Setup and monitoring of DUs, on/off switching
- Telecommand relay and execution
- Manage the data compression and packetisation
- Manage the I-DHU memory
- Time management (distribution of PPS tags, time reset, time synchronization)
- Monitoring of the time synchronisation
- Observation management: autonomously following an observation schedule
- FDIR functionalities

Instrument specific tasks of the software cover:

- Collection of science data
- Monitoring of science data (event rates, data quality, generation of digital HK data)
- Perform calibration tasks
- Real-time data processing (instrument software)

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Instrument Specific Tasks

The software for the instrument specific tasks will be developed by the respective instrument group in close collaboration with the DHU team. A **software simulator for the GR740 processor is available** to estimate the performance and computing load of algorithms. There are also evaluation boards available to test the code in hardware.

For the **SXI data processing and burst trigger**, the following processing is foreseen:

1. Extract frames from the CCD at $\Delta T=2$ s
2. Apply event reconstruction algorithm to the frames to give an event list with positions in CCD pixels and a pulse height.
3. Convert the pixel positions into a local module coordinate frame which is aligned to the cross-arms of the PSF.
4. Accumulate counts in the 1-D histograms.
5. Subtract the fixed source/background pattern from the histograms.
6. Scan the histograms for significant peaks and extract candidate positions for further analysis.
7. Set up the cross-arm mask at candidate positions to look for significant peaks. Calculate an accurate position in the local module coordinate frame for the peak.
8. Convert this position into global sky coordinates (quaternion).
9. Check positions against on-board catalogues to weed out known sources.
10. Communicate unidentified transients to the Spacecraft.

Instrument Specific Tasks

For the **XGIS**, the following data processing is foreseen:

- discriminate between Si and CsI events
- for CsI events, evaluate the interaction position inside the bar (3D position sensitive detector)
- rejection of background
- event rate of each module in different energy bands and time binning
- pixel by pixel event histograms in different energy bands and time binning
- produce images in the 2-30 keV range for each unit in a defined integration time
- 100 s ring buffer of all above data products for the XGIS trigger

For the **XGIS burst trigger:**

- Qualification of the SXI triggers: look for excess count rates in respective XGIS unit
- Autonomous XGIS GRB trigger based on data rate
- Autonomous XGIS GRB trigger based on images

For the **IRT:**

- follow-up observations of bursts need to be autonomously programmed.
- image processing (adding, subtracting, source detection) and spectral processing

Interfaces

I-DHU interface to spacecraft:

- SpaceWire link (nom. + red.) for TC, HK and health and science data
- highly precise PPS signal (nom. + red.) for on-board time synchronization
- 28V power (nom. + red.)
- Additional TBD lines on one connector for switching, analogue status and HK (nom. + red.)

The main interface between I-DHU and spacecraft will make use of the full SpaceWire standard. From electrical interfaces and cable design to the data transmission it will be fully ECSS-E-50 compliant. The I-DHU can support the CFDP protocol for data access by the spacecraft.

Following the requirements for redundancy, the two boards inside each DHU will be cold redundant (independent of each other) and both the nominal and redundant boards will have individual interfaces to the spacecraft.

Interfaces

I-DHU interfaces to instruments:

- 28V power
- other TBD voltages?
- SpaceWire link for science data, TC, HK and health
- OBT_1MHZ: the ultra-stable clock signal used for the photon time tagging. It is generated in the DHU.
- OBT_PPS: the 1 Pulse Per Second signal managed by the DHU. It is used to perform the photon time tagging and synchronize the instruments.
- Additional dedicated lines for reset, switching, status and HK (number TBD)

I-DHU Mass Estimate

The masses reported here are extracted from the CAD-Models and part files for the PCBs. The latter are at this point in time only rough estimations and based on values from similar previous designs. The harness includes the cables to the DUs (assumes a length of 1 m). Depending on the final location of the I-DHUs on the platform, the values need to be scaled accordingly.

Part Description	No. of Units	Mass (CBE, Kg)	Margin %	Mass/Unit (Kg)	Total (Kg)
I-DHU mechanical case	1	1.500	20%	1.800	1.800
I-DHU backplane motherboard	1	0.400	20%	0.480	0.480
I-DHU harness to a single DU	e.g. 4	0.480	20%	0.576	2.304
I-DHU harness to Trigger Unit	1	0.160	20%	0.192	0.192
			Total Housing + Harness		**4.776**
Data Processing Board	2	0.700	20%	0.840	1.680
Power Distribution Board	2	0.600	20%	0.720	1.440
			Total PCBs		**3.120**
Total I-DHU box with harness					**7.896**

I-DHU Power Budget

The power budget reported here is based on estimations from the datasheets and measurements from previous similar designs.

Part Description	Units	Power (CBE. W)	Margin %	Power/Unit (W)	Total (W)
Data Processing Board	1	12.000	20%	14.400	14.400
Power Distribution Board	1	6.000	20%	7.200	7.200
DHU harness to DUs loss		0.400	20%	0.480	0.480
	nominal operation incl. conversion efficiency				**22.080**

Thank you