High-performance on-board computer, data handling and SDR platform for cubesats

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Motivation

Need of a space-qualified platform with:

- High-throughput processing capabilities
- Versatility and reliability
- Easy configuration and use

Solutions available lack of enough power and/or adaptability → custom solutions often needed → overhead to projects

Aim: **General-purpose high-performance solution**

In-house knowledge and resources → reduce costs, shorten design & development time, application of lessons learned from other projects and missions.

Team and background

Joint effort of different institutes collaborating inside IEEC: Group of experts from successfully accomplished space missions.

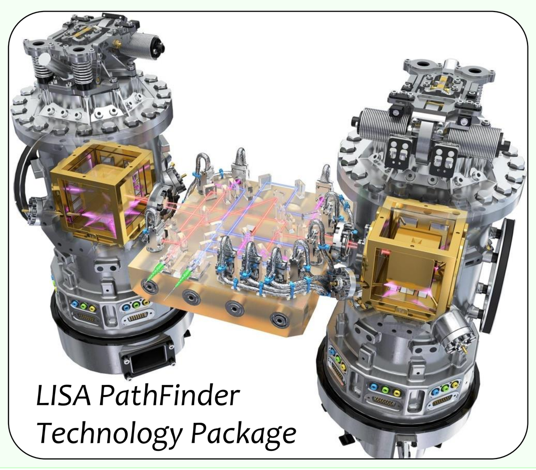
ICE / IEEC-CSIC:

Software for critical applications in space

Data Management Unit of ***LISA PathFinder***

- Processing computer, diagnostic sensors
- Mission critical flight software

Currently working on ***LISA*** (ESA L3 mission)



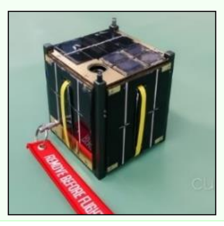
LISA PathFinder Technology Package

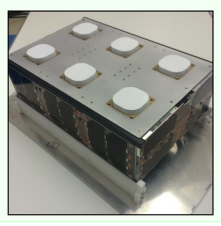
CTE / CRAE / UPC:

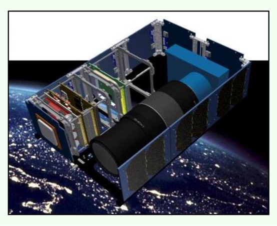
Successfully launched 1 cubesat

Working on 3 "***[3]Cat***" ("cubecat") missions:

- ***[3]Cat-4***: ESA's "Fly your satellite" program
- ***[3]Cat-5 A/B***: FSSCAT Copernicus Masters winner







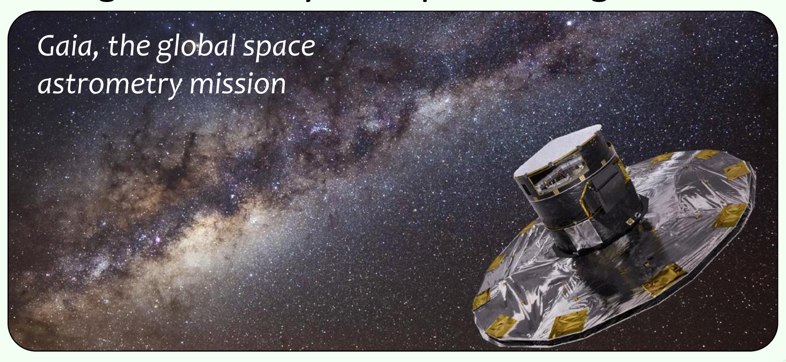
ICCUB / IEEC-UB:

•***SO/PHI***:

- Image Stabilization system based on tracking camera.
- Space-qualified hardware and firmware

•***Gaia***:

- On-board data handling and compression
- On-ground daily data processing

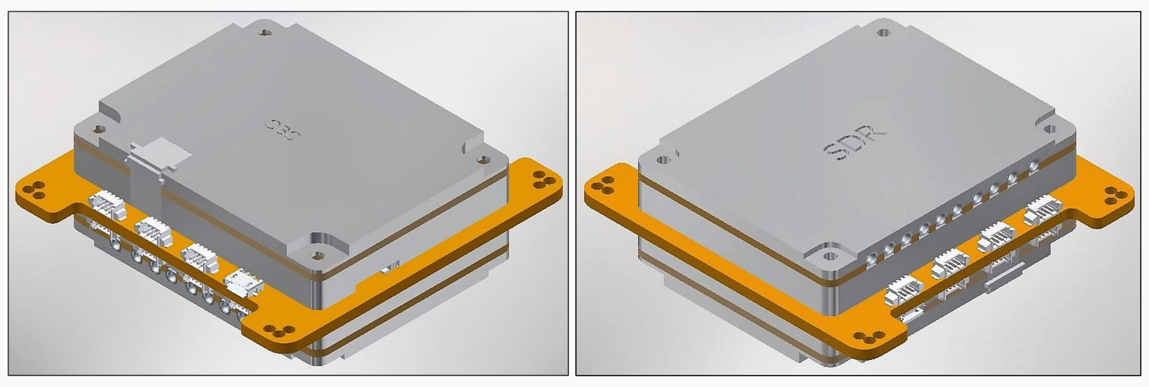


Gaia, the global space astrometry mission

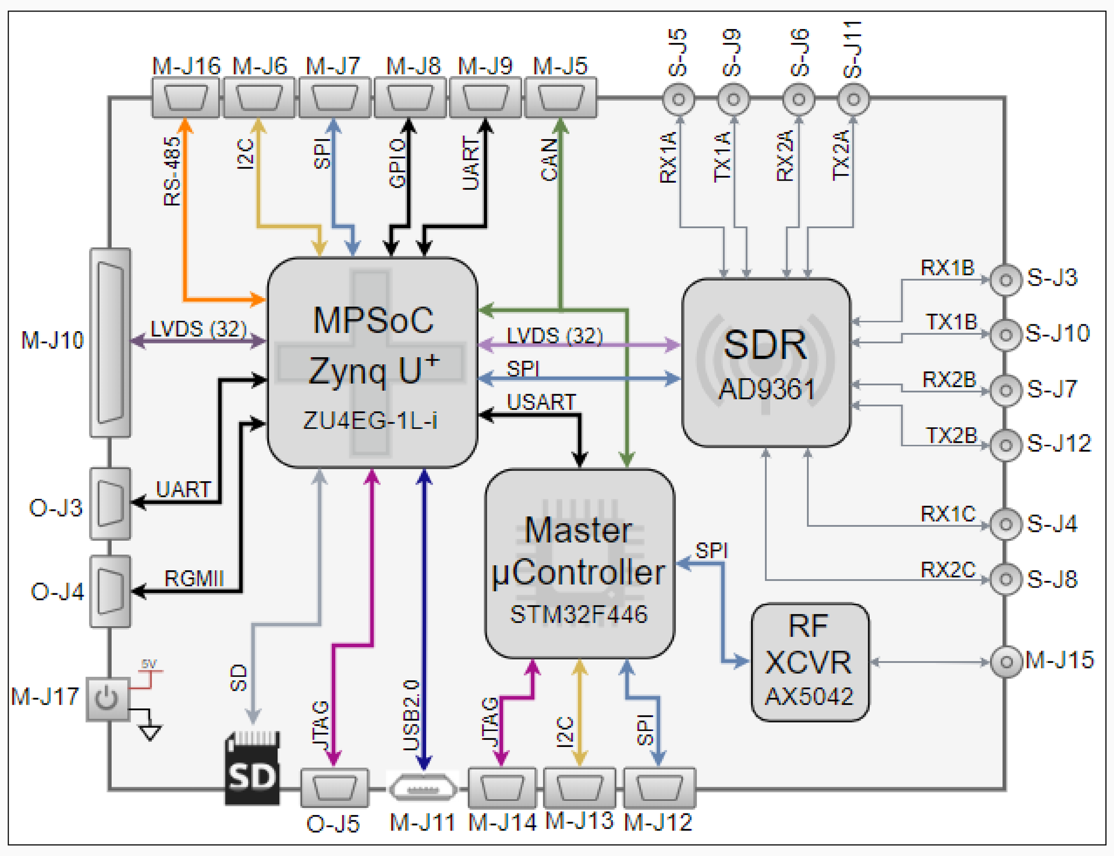
Overview

Hardware split in 3 boards:

- Motherboard, with On-Board Computer (OBC)
- Daughterboard, with On-Board Data Handling (OBDH)
- Daughterboard, with Software Defined Radio (SDR)



General Mechanical Structure



General Electrical Architecture

Overall operation:

- First power-up in orbit → only OBC Acquire telemetry, comms with ground, monitor all subsystems, activate power supply to OBDH and SDR
- OBDH → control payload(s), process data, handle SDR
- SDR → communications and navigation

All internal power supplies:

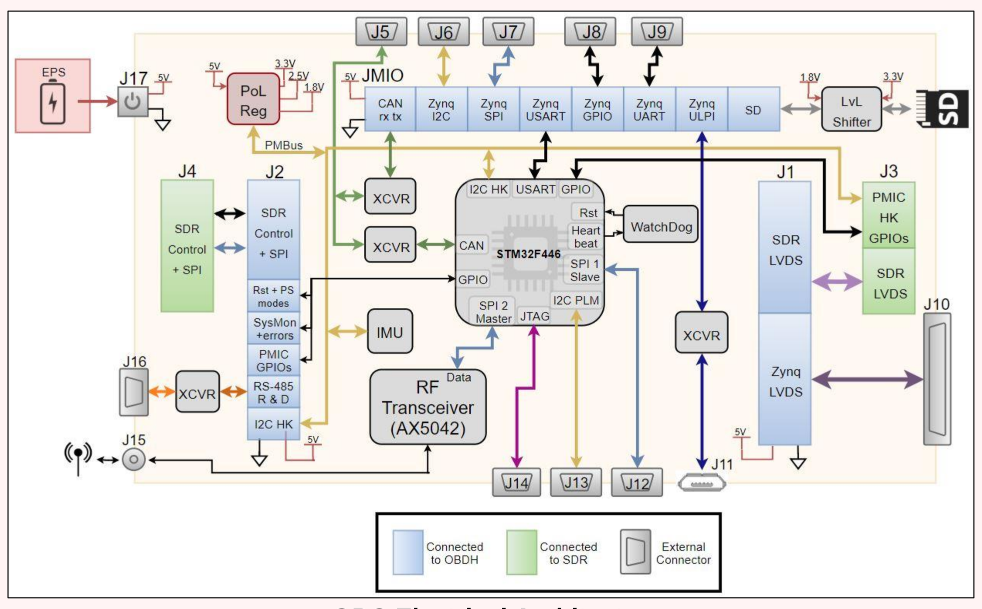
- Large set of protections (OVP, OCP, thermal…)
- Provide housekeeping data
- Allow changing voltages and sequencing

Optional components and external connectors on the motherboard depending on mission needs.

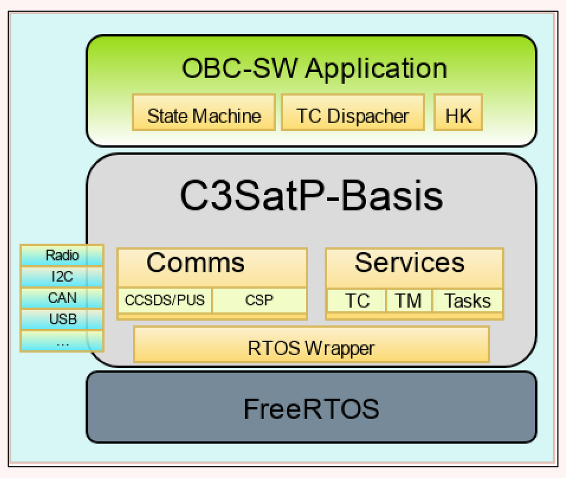
On-Board Computer (OBC)

- STM32F446RE µC (ARM® Cortex®-M4 32-bit 180 MHz), DSP and FPU, 512 Kbytes Flash.
- External Interfaces : I2C, SPI, USART and CAN interface
- Inertial Motion Unit (Bosch), 9 deg. freedom (accelerometer, gyroscope, magnetometer)
- Ultra-low power RF transceiver (On Semi), 434 MHz ISM band, simultaneous RX + TX

Software running under FreeRTOS and in charge of spacecraft control and ground commanding and housekeeping.



OBC Electrical Architecture



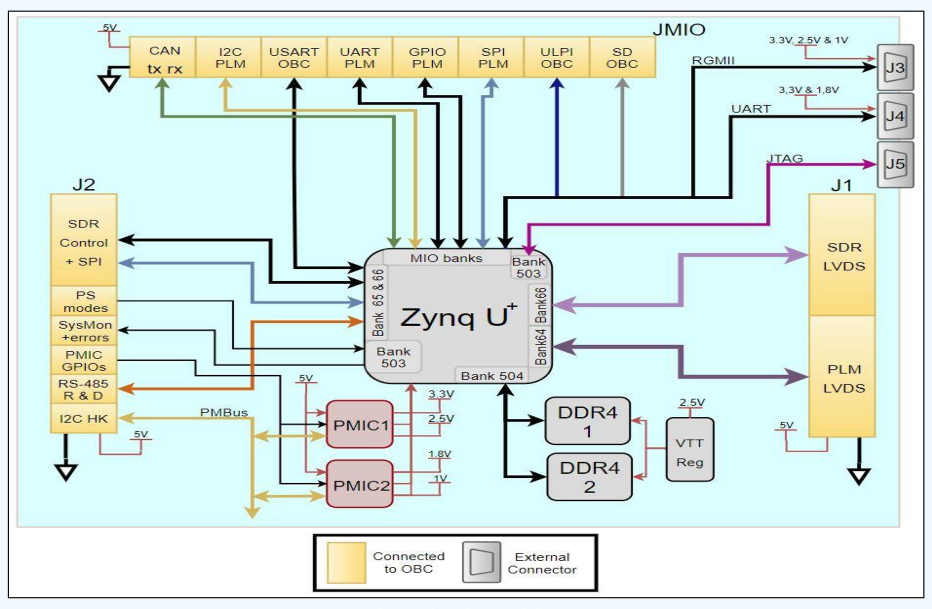
OBC Software Architecture

On-Board Data Handling (OBDH)

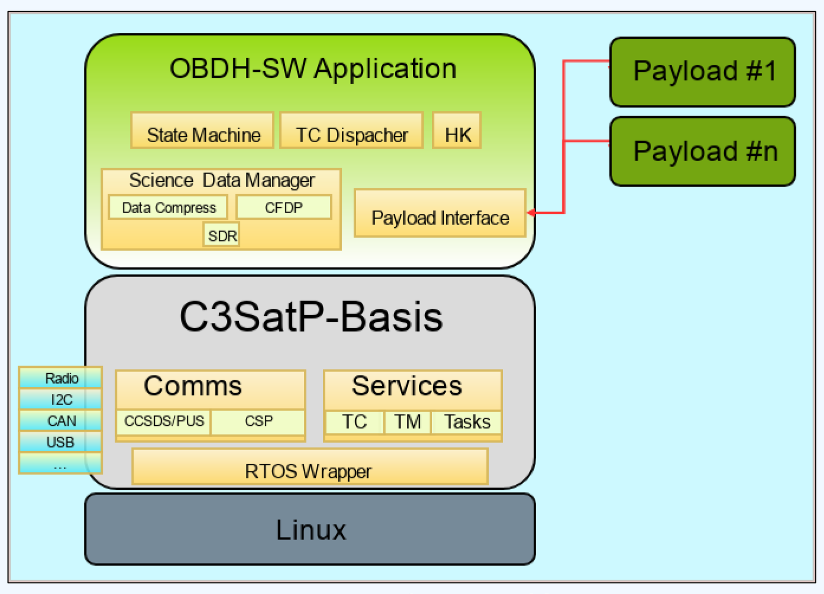
- Zynq Ultrascale+ XCZU4EG-1L-i (low power, industrial temperature range), High number of programmable logic resources: 192K logic cells, 18.5Mb memory, 728 DSP slices, 0.72V Core Voltage, Single Event Latch-up less likely to occur with low core voltage. Enhanced ECC for Single-Event Upset
- 2 ARM Cortex-A53 1.5GHz for computing + 2 ARM Cortex-R5 600MHz for real-time. 1GB DDR4 with EDAC
- External Interfaces: I²C, SPI, CAN, RS-485, UART

Control Software based on Linux using Cortex-A53 processing system with same architecture as OBC with Data storage implementing CCSDS File Delivery Protocol and Management of payload(s).

Collect and compress data using FAPEC compressor (time series, lossless/lossy, images, multi/hyperspectral…).



OBDH Electrical Architecture



OBDH Software Architecture

Software Architecture

- Extremely modular and reusable with core inherited from the LISA PathFinder Payload Software services and methodologies.
- Following ECSS-E-40 and ECSS-Q-80 standards for software engineering for Space.
- Designed for multi platform : Hardware (Texas Instrument, STM32, ERC32, Leon, x86), Operating System (FreeRTOS, RTEMS, Linux) and multiprotocol (CCDS/PUS, CSP, CFDP, …)
- Based in micro-services approach.

Software Defined Radio (SDR)

Based on AD9361 with Wide range supported: 70MHz – 6GHz

- 6 receiver inputs (2 simultaneous)
- 4 transmitter outputs (2 simultaneous)
- Fully configurable through SPI interfaces
- 12 LVDS RX/TX data lines, up to 240MHz clock
- RX/TX channels optimized for ISM 434 MHz, ISM 2.45 GHz and wide range band

High radiation resiliency

Use cases and conclusions

- Image processing: on-going study about adding a commercial camera
- EMI scanner to detect spoofing (ESA safety application)
- GNSS signal processing, either navigation or science
  E.g.: ionosphere monitoring, radio occultation, (late) solar flares detection
- Any mission requiring fully autonomous on-board massive data processing, allowing to download reduced subset of pre-processed data
  E.g.: FFT, light curves, soil/vegetation indicators, etc.

New platform with unprecedented performance capabilities in cubesat-sized missions

Extremely modular solution:

- Allows adoption by several missions with small changes
- SDR + high number of programmable logic resources
- Implement all changes in (isolated) software modules → keep hardware heritage intact

Design ready, implementation well advanced, tests pending

Fully operational solution expected for 2019, first flight tests 2020

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