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

Motivation
Need of a space-qualified platform with:
- High-throughput processing capabilities
- Versatility and reliability
- Easy configuration and use

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

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

Use cases and conclusions
- 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 command and housekeeping.

On-Board Data Handling (OBDH)
- Zynq Ultrascale+ XC7U456E-1Li (low power, industrial temperature range), High number of programmable logic resources: 192K logic cells, 18.5Mmemory, 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...).

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, Zynq), Operating System (FreeRTOS, RTEMS, Linux ) and multiprotocol (CCSDS/PU5, CSP, CPDF, ...)
- Based in micro-services approach.

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 \(\rightarrow\) high number of programmable logic resources
- Implement all changes in (isolated) software modules \(\rightarrow\) keep hardware heritage intact
Design ready, implementation well advanced, tests pending

Fully operational solution expected for 2019, first flight tests 2020

Acknowledgements
This work has been funded by the Agència de Gestió d'Ajuts Universitaris i de Recerca de la Generalitat de Catalunya through project 2016 PR000076 and co-financed by EU through FEDER funds