WORKSHOP
Applicazioni FPGA in ambito astrofisico
Osservatorio Astrofisico di Torino
18-20 maggio 2016

FPGA in elettronica di controllo per strumentazione spaziale: l'esperienza dell' IAPS

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-Progettazione e realizzazione strumentazione payload scientifici per missioni spaziali con maggiori agenzie mondiali (ASI, ESA, NASA, JAXA)

- Partecipazione alla realizzazione di strumentazione scientifica per grandi Osservatori Terrestri

- Attività osservative da Terra e dallo Spazio

- Partecipazione e responsabilità di progetti europei per l'ottimizzazione dell'utilizzo dei dati spaziali e la produzione di facilities di data archiving coordinate a livello mondiale.

Missioni spaziali in cui IAPS ha avuto un ruolo importante

Missioni Sistema Solare

Rosetta
Mars Express
Venus Express
Cassini
Dawn
Juno
Juice
Cluster
Solar Orbiter
Bepi Colombo
Thor
Plato
Ariel

Missioni Astrofisiche

Agile
Integral
XMM
Athena
ISO
Herschel
Euclid
SPICA

Principale Expertise IAPS

- Progettazione meccanica ed elettrica strumentazione spaziale

- Progettazione e sviluppo di sistemi criogenici

- Progettazione e sviluppo SW real Time per controllo strumentazione

- Progettazione e sviluppo pipelines di riduzione dati

- Esperienza nella realizzazione ed uso di SW per ground segment (sistemi telemetri/telecomandi, upload, download, archiving, quick look analysis)

-Management progetti spaziali (conoscenza standard ESA, prassi ASI, competenze PA/QA)

Il gruppo di formazione stellare e planetaria

Regioni di formazione stellare fortemente oscurate in nubi molecolari ricche di gas e polveri

→ necessità osservazioni nel Far Infrared

→Necessità osservatori spaziali

→ ISO, Herschel

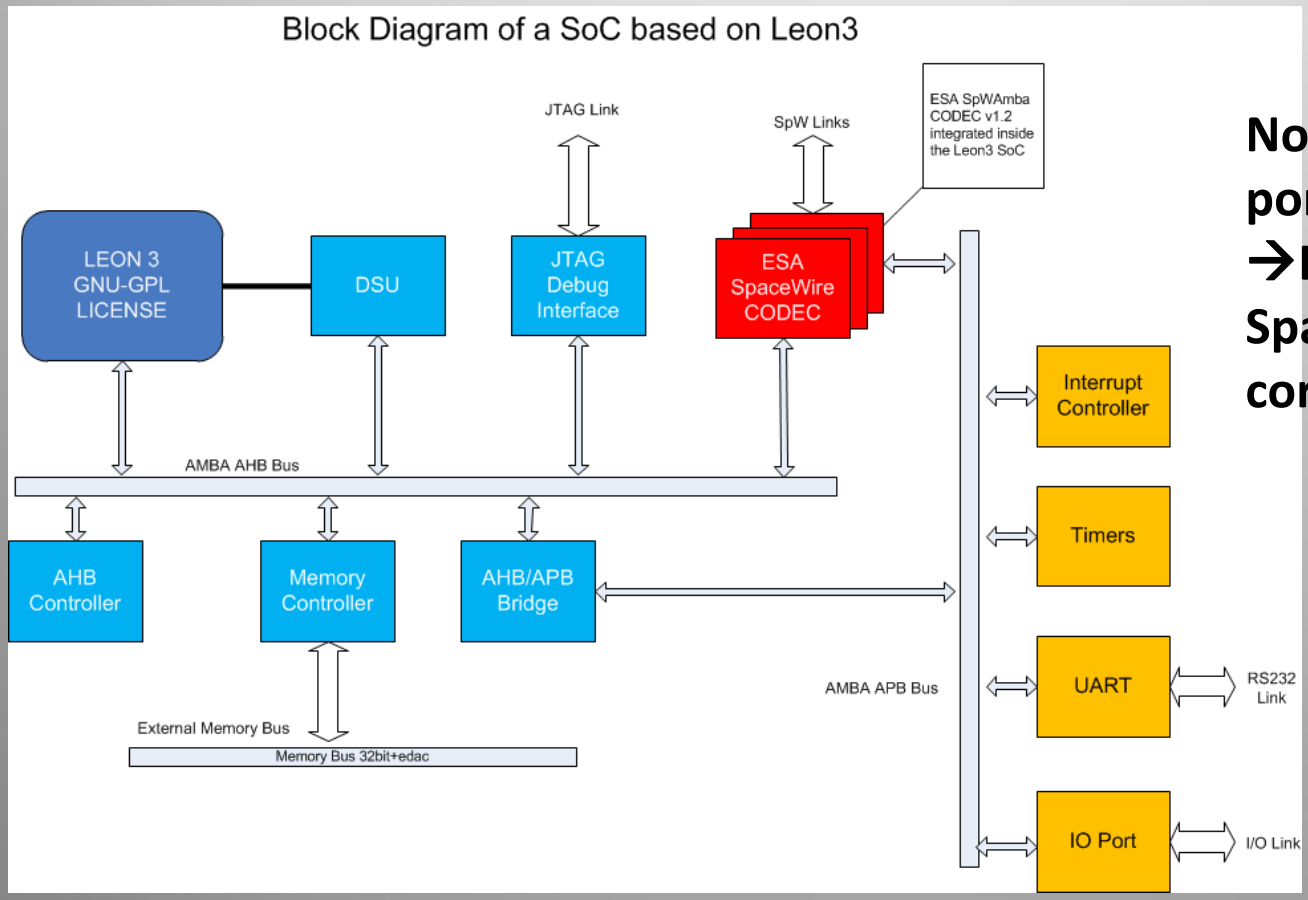
Progettazione e realizzazione in collaborazione con l'industria dei sistemi di controllo di fotometri e spettrometri di payload.

Realizzazione in house del SW di controllo e di acquisizione/pre-processing dei dati a bordo.

LEON3 Processor and SpaceWire Interface

Leon3 (GPL license) using the Xilinx Spartan3, XC3S1500 FPGA stand alone FPGA development board.

- **AMBA AHB bus transfer using DMA transfers**
- **All registers are accessed through an APB interface**



No native SpaceWire ports are present
→Integration of the ESA SpaceWire-Amba (v1.2) IP core

LEON3 Processor and SpaceWire Interface

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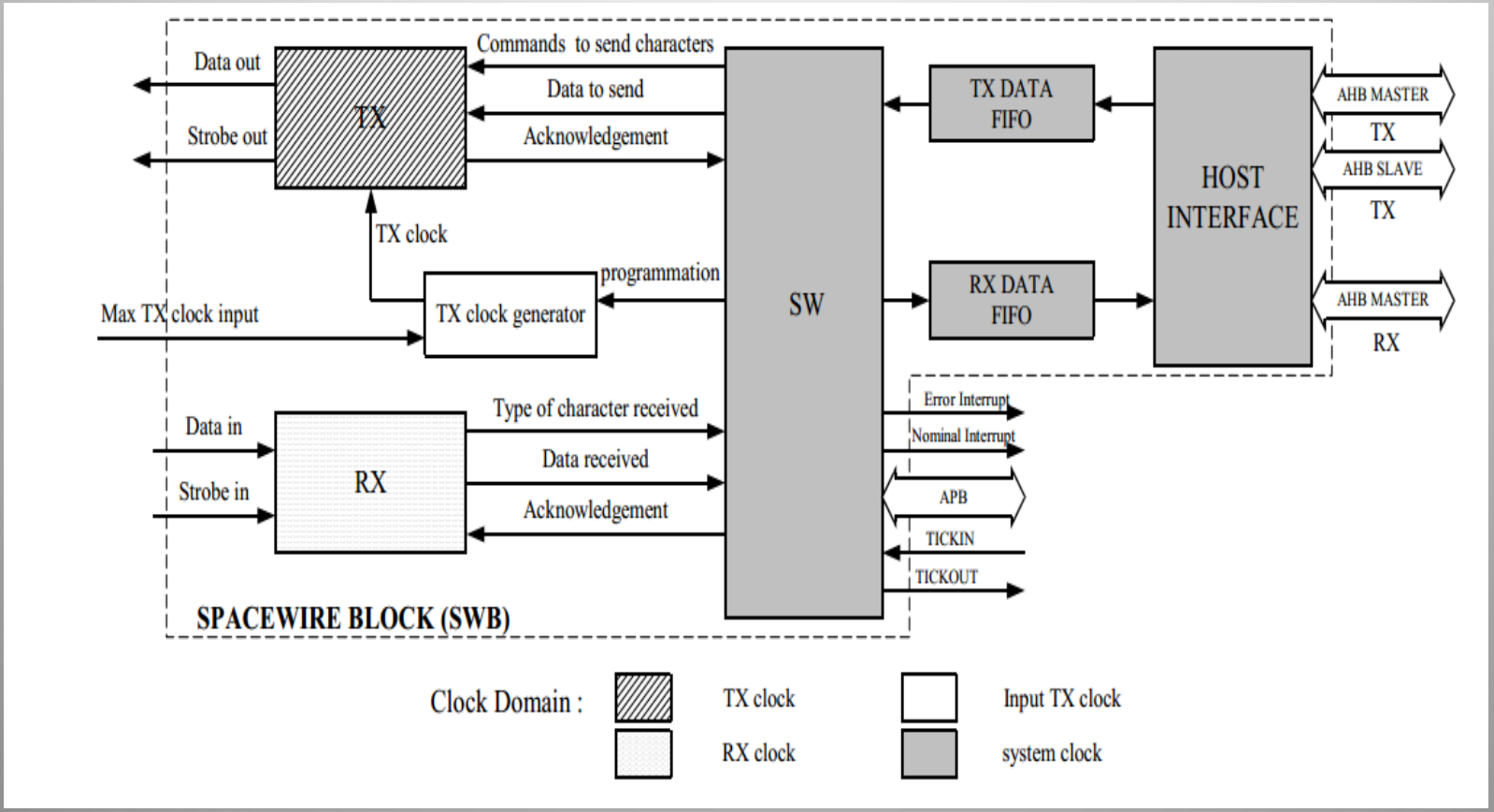
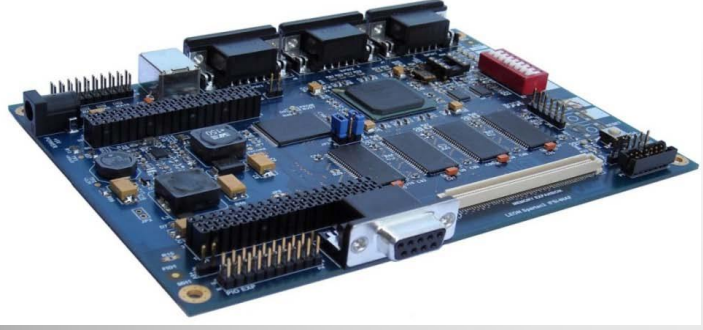
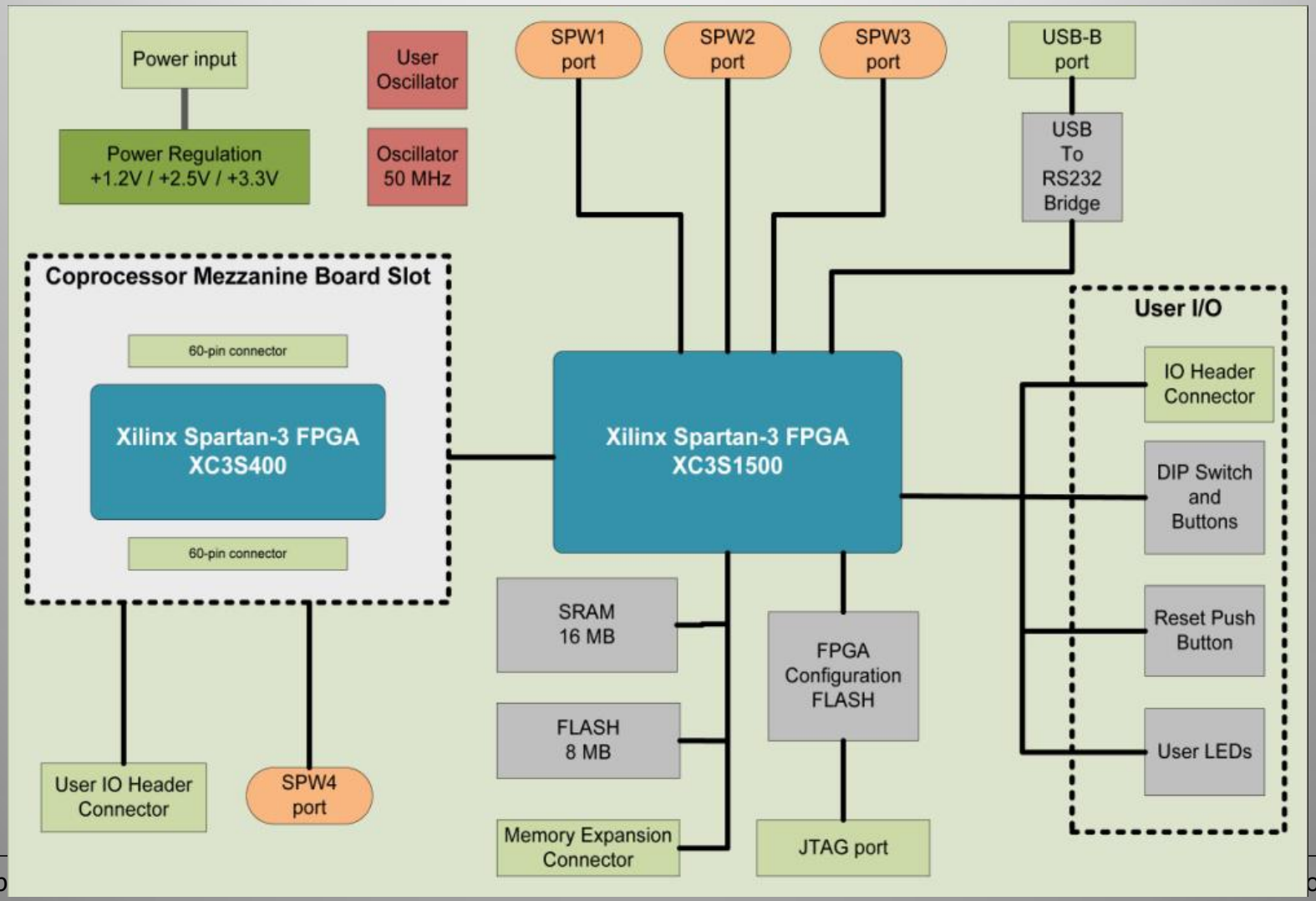
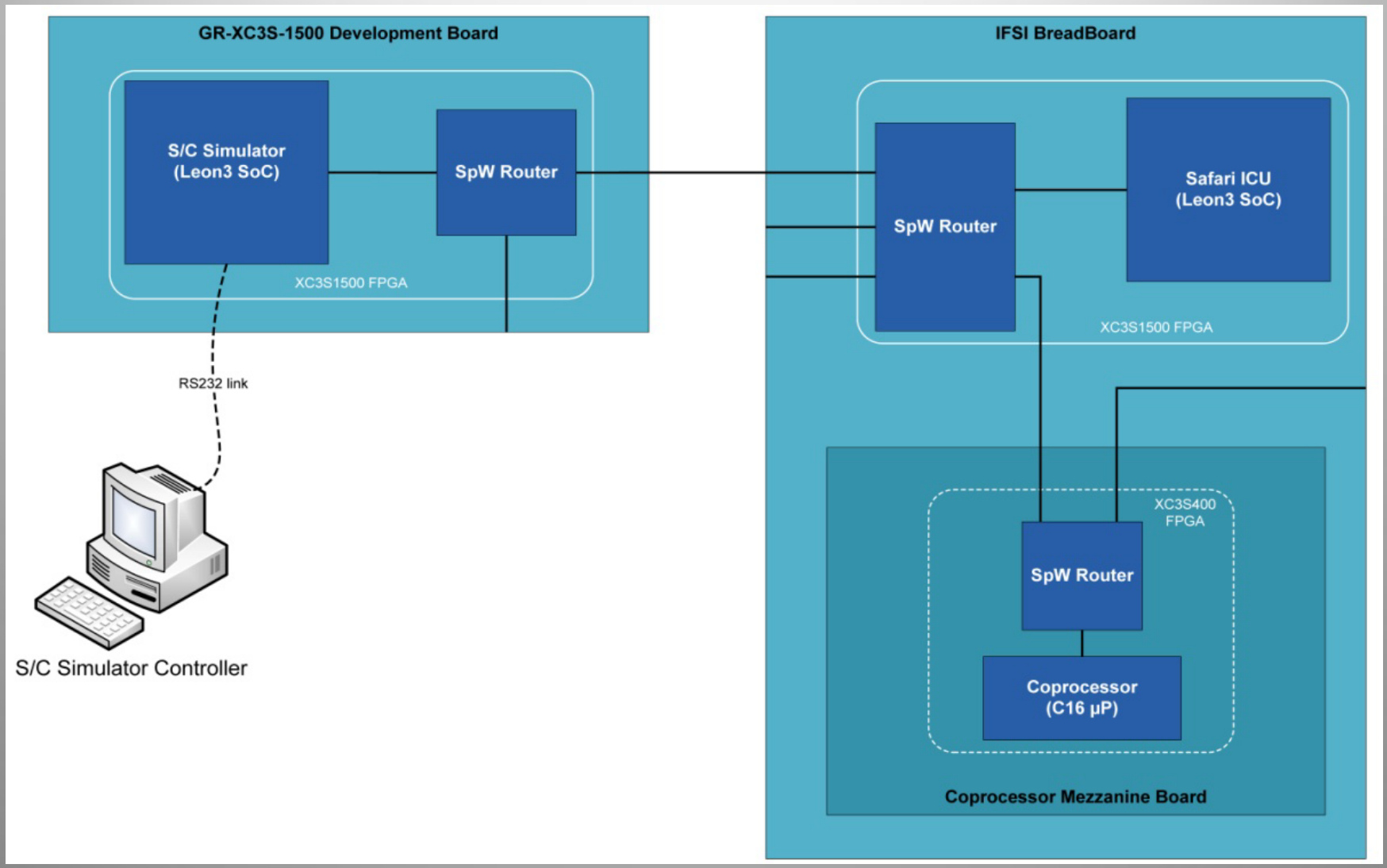




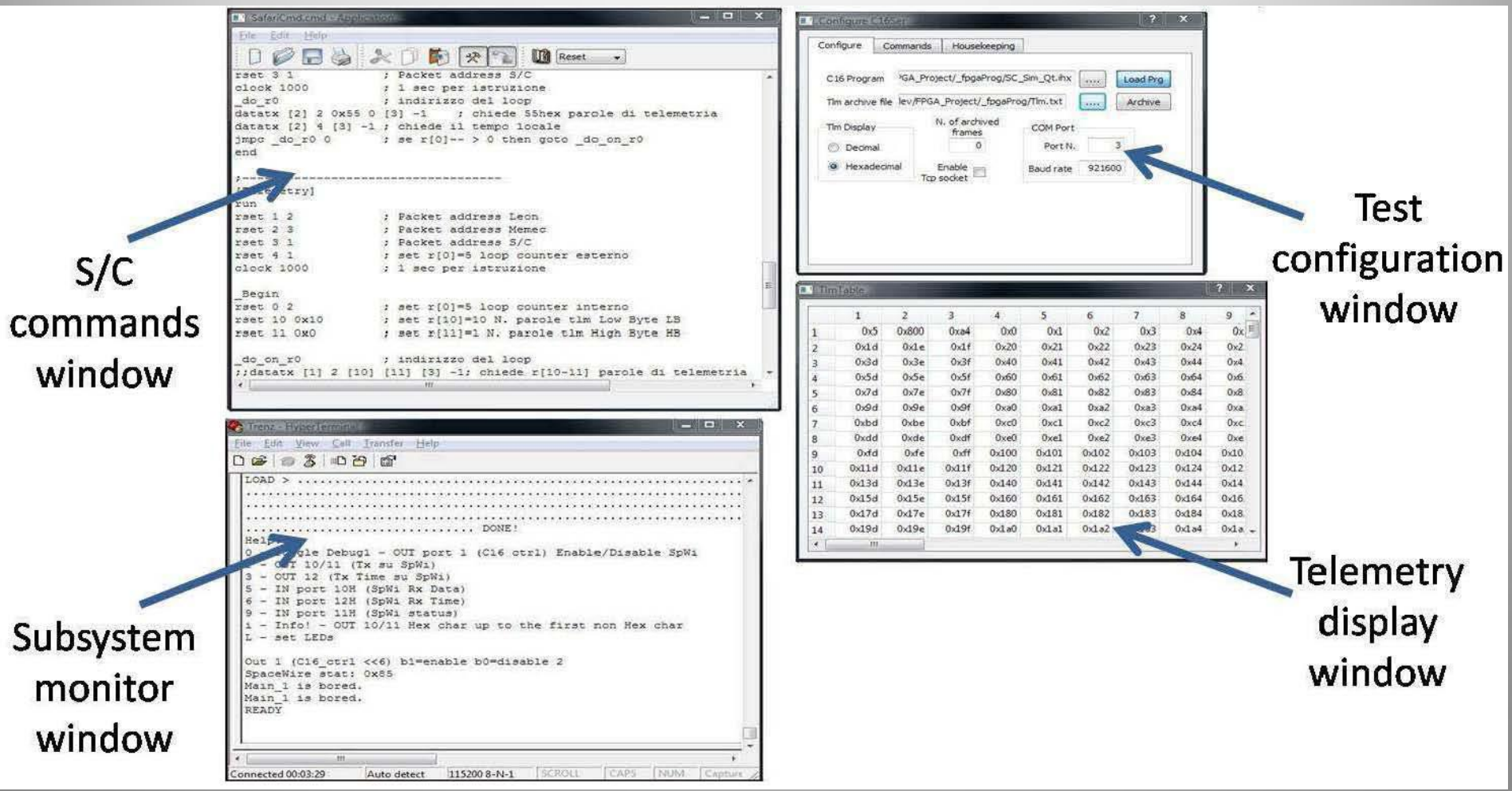
SPICA SAFARI DPU Breadboard block diagram



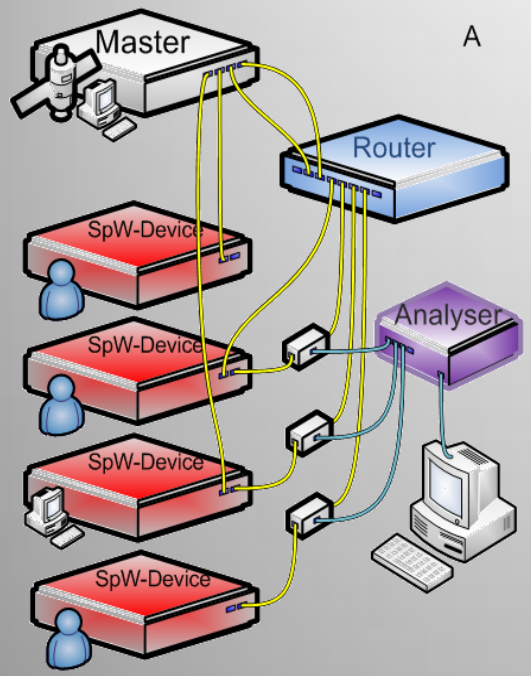
Testing Environment

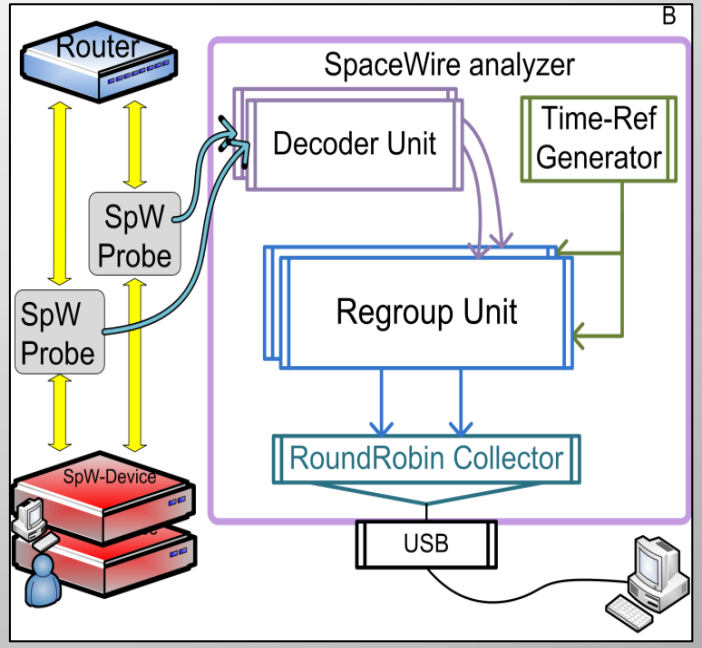


Testing Environment

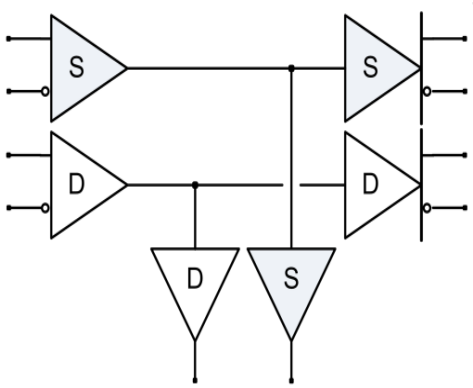


A Traffic Analyzer For Multiple SpaceWire Links





A low-level link analyser monitors bidirectional SpaceWire traffic non-intrusively with pod probes connected in-series.
Avoid the use of very long cables and the introduction of undesired delays.
The analyzer core is implemented on a Xilinx FPGA Spartan-6 LX45 FPGA, mounted on the general purpose development board Atlys, manufactured by Digilent Inc.

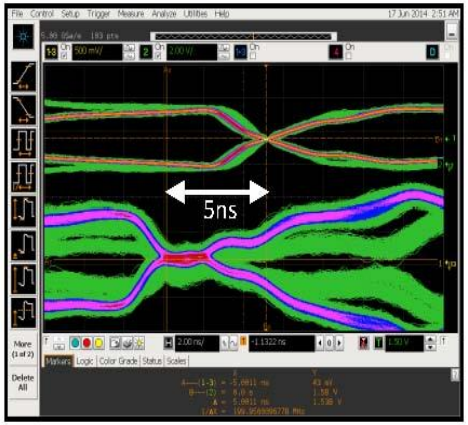


The probe is in series on the physical SpaceWire link.

LVDS → LV-TTL → LVDS

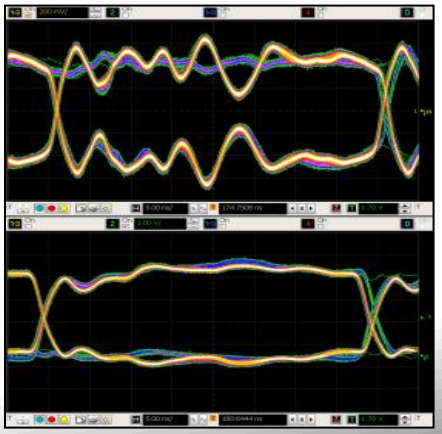
Extract and Reshape

- *Minimized delay*
- *No multi-drop side effects*
- *Transparent signals cloning*.



⇨ Before-after reshape

⇦ Reshape delay<10ns
TX-Rate → 200Mbps



Finite State Machines interpret SpaceWire chars
The Time-Ref-Generator (TRG) provides a common reference to multiple embedded decoders
~20ns granularity

Lossless Compression: SW vs HW implementations

EUCLID VIS simulations. Test environment:
- Gaisler GR-CPCI-UT699 (LEON) development board;
- ECLIPSE IDE with Bare C compiler integrated;
- GNU GDB debugger;
- Host PC: Intel Quad Core 2.66 GHZ processor, 4 Gb Ram, Win 7
- The ESA Data Compression evaluation Tool *WhiteDwarf Compression Tester V1.0 (by ESA TEC-EDP):* http://www.esa.int/TEC/OBDP/SEM069KOXDG_2.html

Lossless Compression: SW s HW implementations

LEON 3 CCSDS122		
Comp. RATIO	Comp. Time (sec)	Comp. RATE (Kpx/s)
3,2	104,5	**39,2**

LEON 3 CCSDS121		
Comp. RATIO	Comp. Time (sec)	Comp. RATE (Kpx/s)
3,23	23,8	**172,3**

LEON 3 Full frame processing time
t ≥ 15000 sec (CCSDS 122 Image compression algorithm)
t ≥ 3422 sec (CCSDS 121 Rice compression algorithm)

WD CCSDS122		
Comp. RATIO	Comp. Time (sec)	Comp. RATE (Kpx/s)
3,2	4,5	**920,4**

WD CCSDS121		
Comp. RATIO	Comp. Time (sec)	Comp. RATE (Kpx/s)
3,18	2,4	**1724,6**

The overall estimated time for the HW lossless compression of a full frame of 36 CCDs with the CWICOM ASIC is therefore of the order of 9.8 sec.

- The ESA Data Compression evaluation Tool *WhiteDwarf Compression Tester V1.0 (by ESA*

FAPEC (Fully Adaptive Prediction Error coder) algorithm: a HW prototype available in an FPGA, able to compress 16-bit samples at 32 Mbps consuming just 32 mW.

THE EXPERIMENT MICRO-MIMA ONBOARD EXOMARS

Micro- MIMA (micro-Martian Infra-red Mapper) is an Infra-Red Fourier Spectrometer (IRFS) for the ESA mission "ExoMars 2016".

-To be mounted on a descending module to Mars

- to observe the Martian atmosphere after landing.

- to study the features of atmosphere gas-composition (analysis of methane presence in particular) to make conclusions about possible biological activity and to check the meteorological conditions at the landing site.

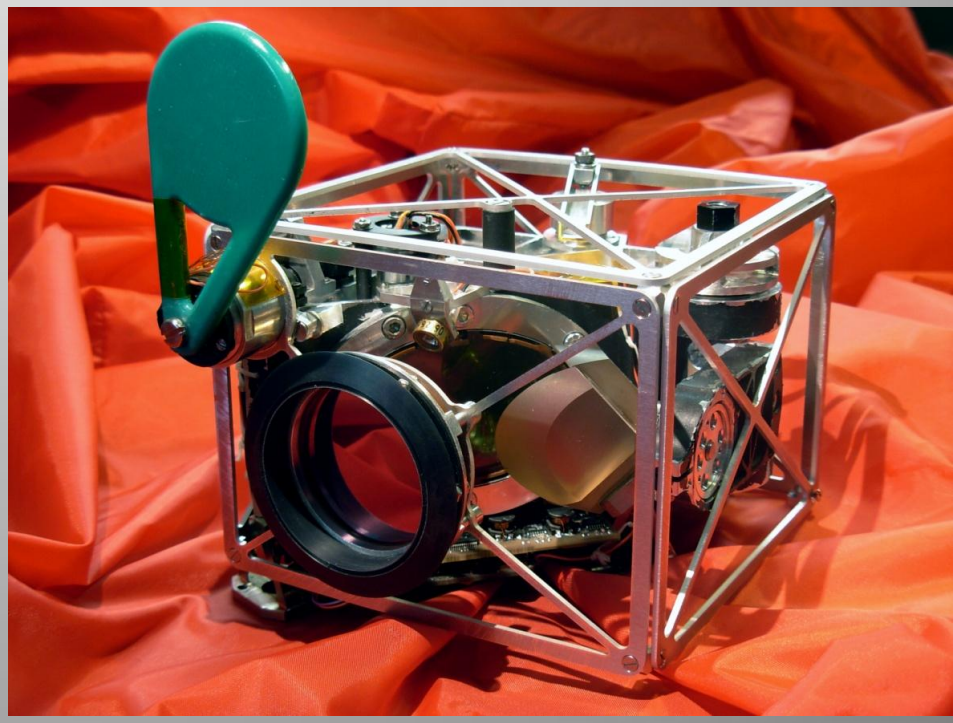
Design constraints:

- limited mass, size and power budget; ·

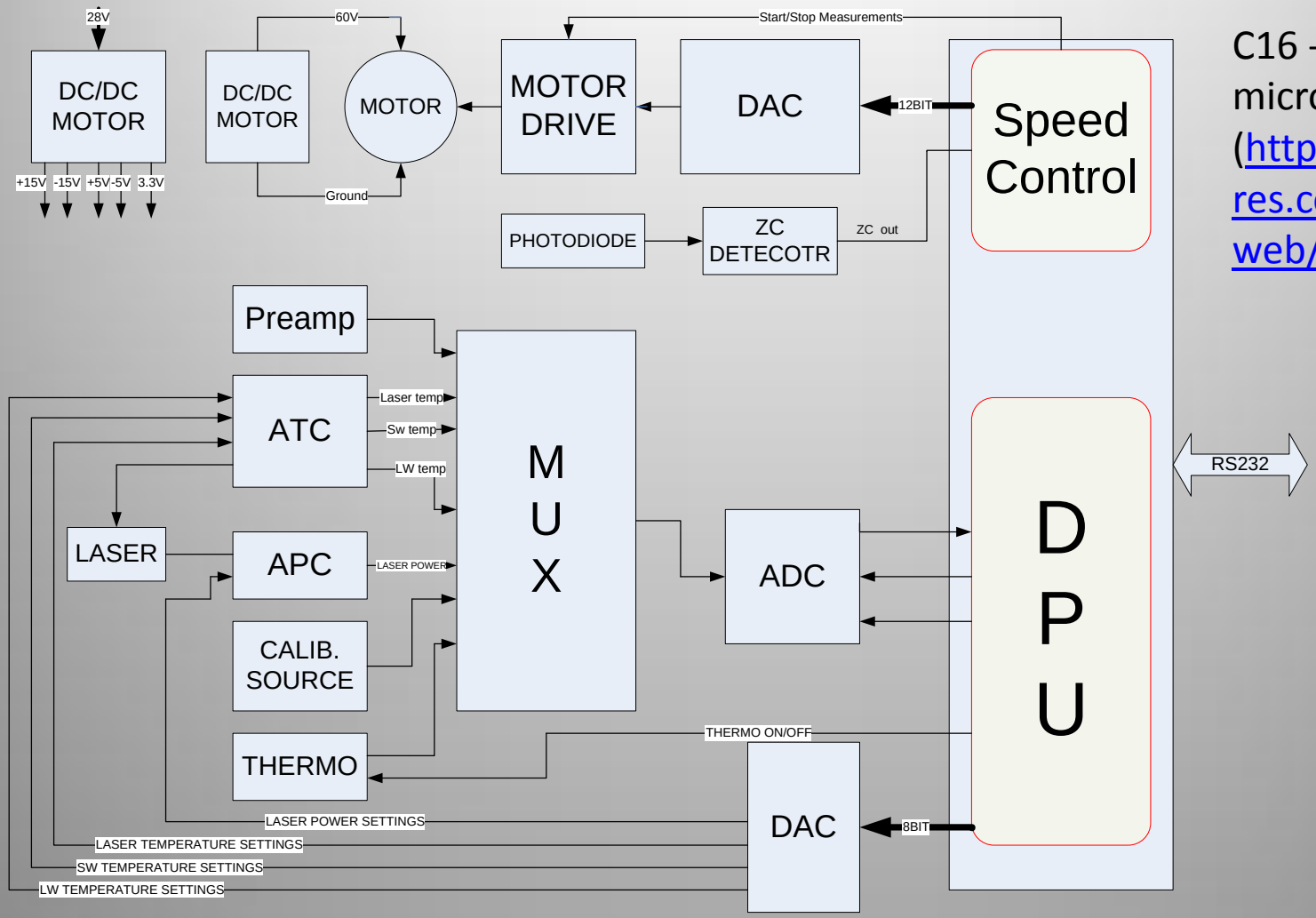
- high stress resistance for the landing shock;

-withstanding of severe environmental conditions without any power for thermal control);

- resistance for strong vibrations of the high acceleration levels in wide frequency range.



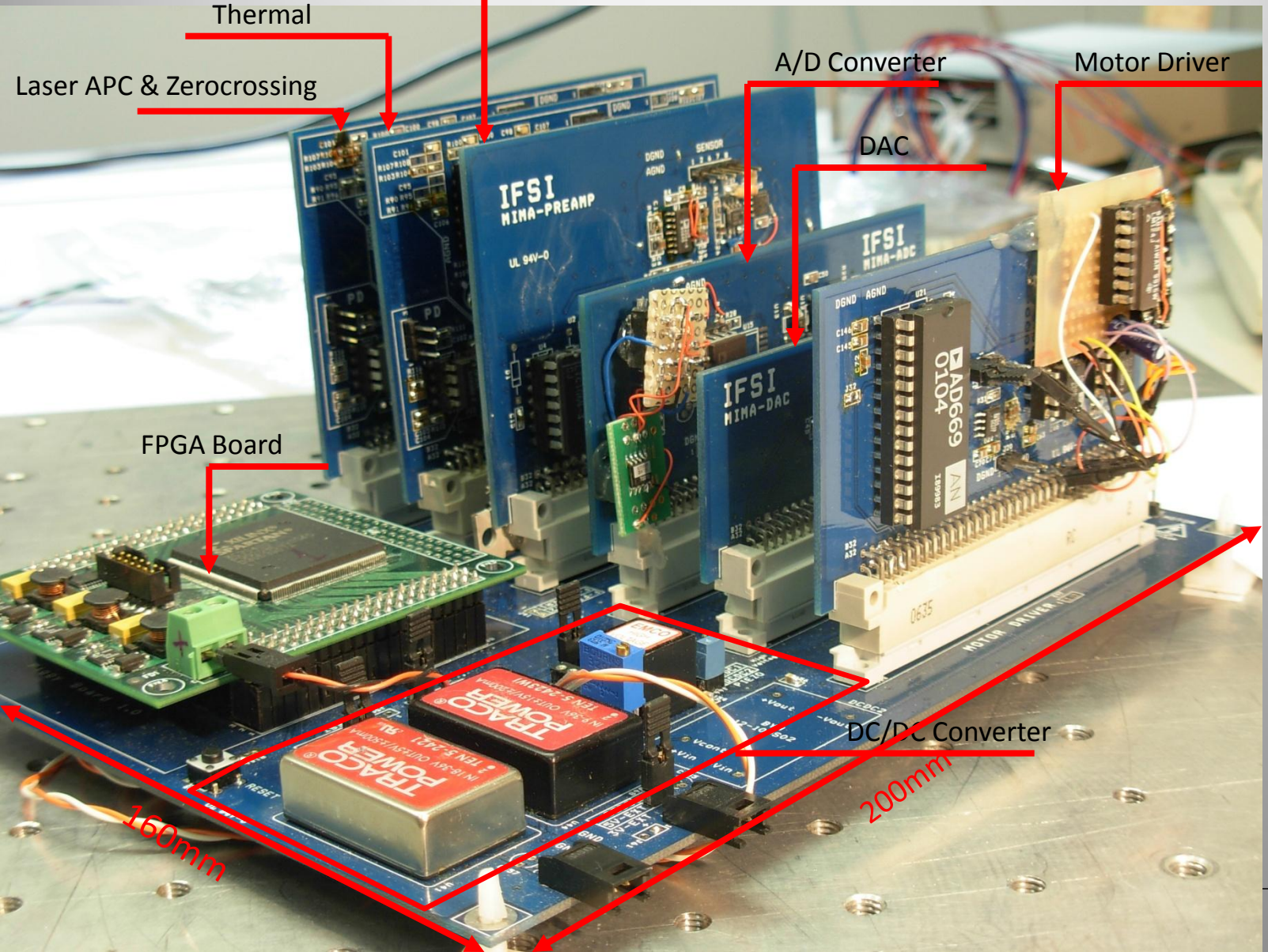
Functional diagram



C16 - 16 bit microcontroller (http://www.opencores.com/projects.cgi/web/c16/overview)

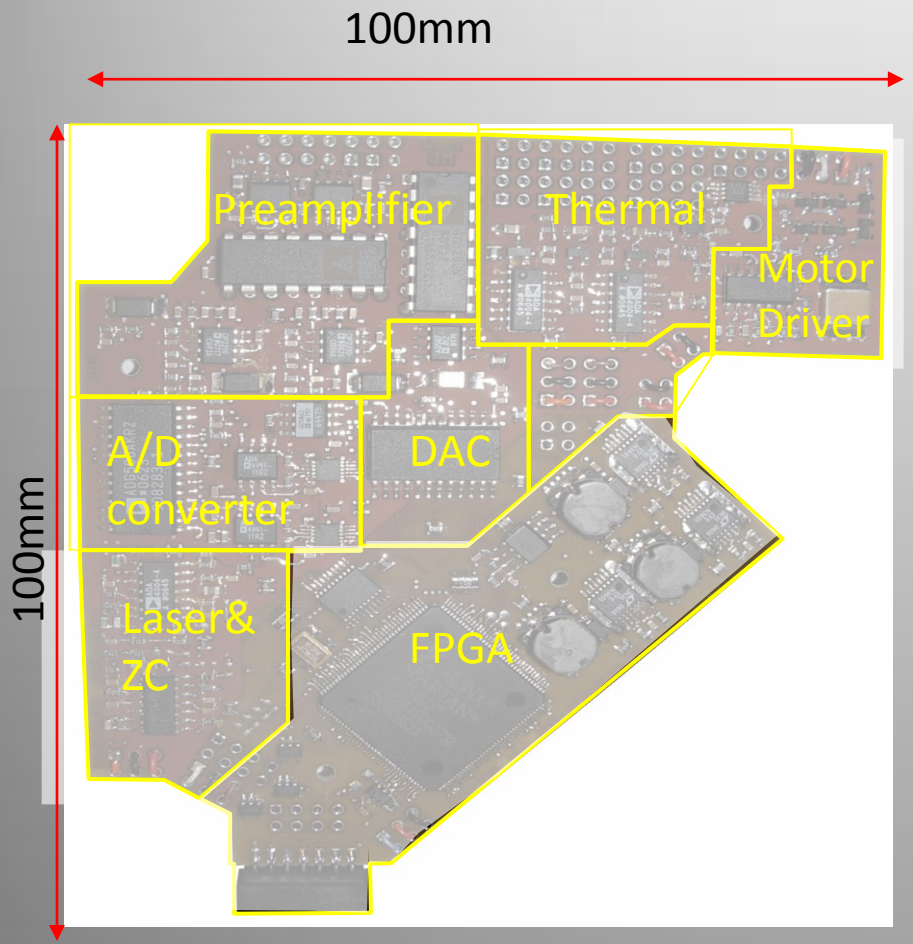
D. Biondi
M. Deluca
R. Cerulli
A. Mattana

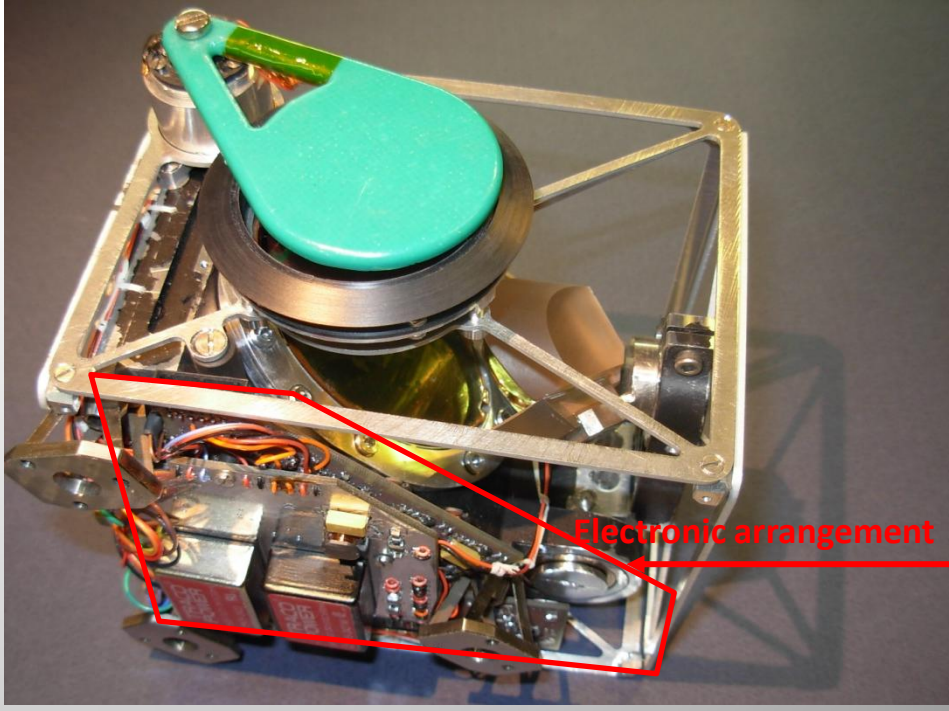
Micro-Mima Prototype

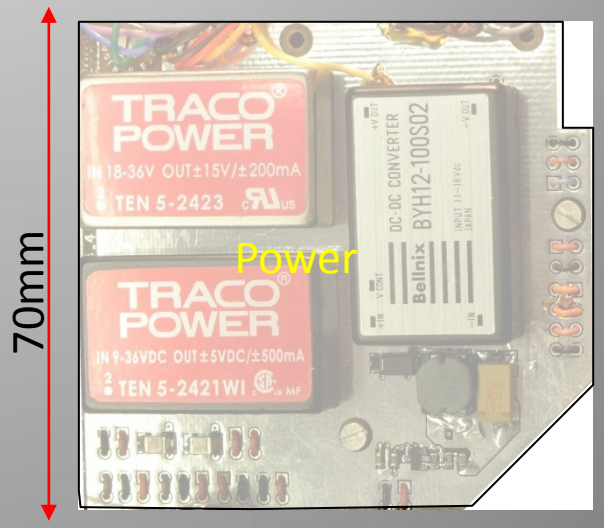


THE EXPERIMENT MICRO-MIMA ONBOARD EXOMARS

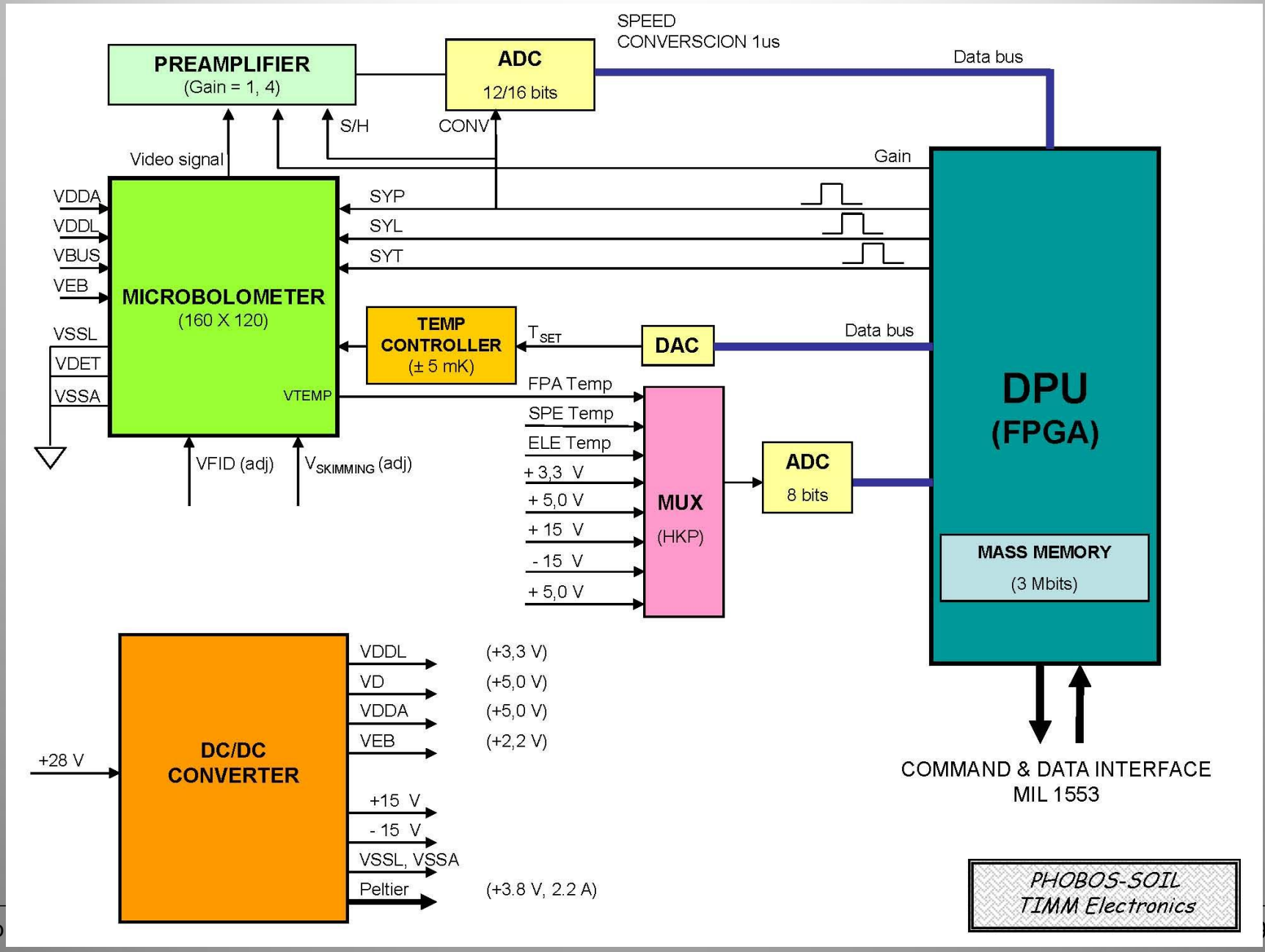
THE CONTROL BOARD

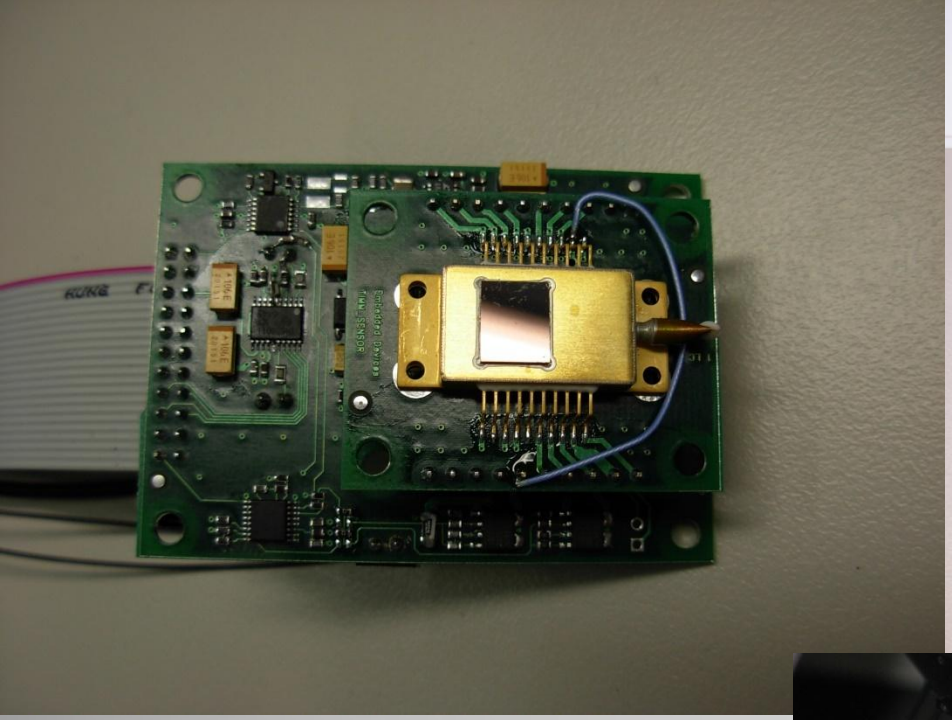


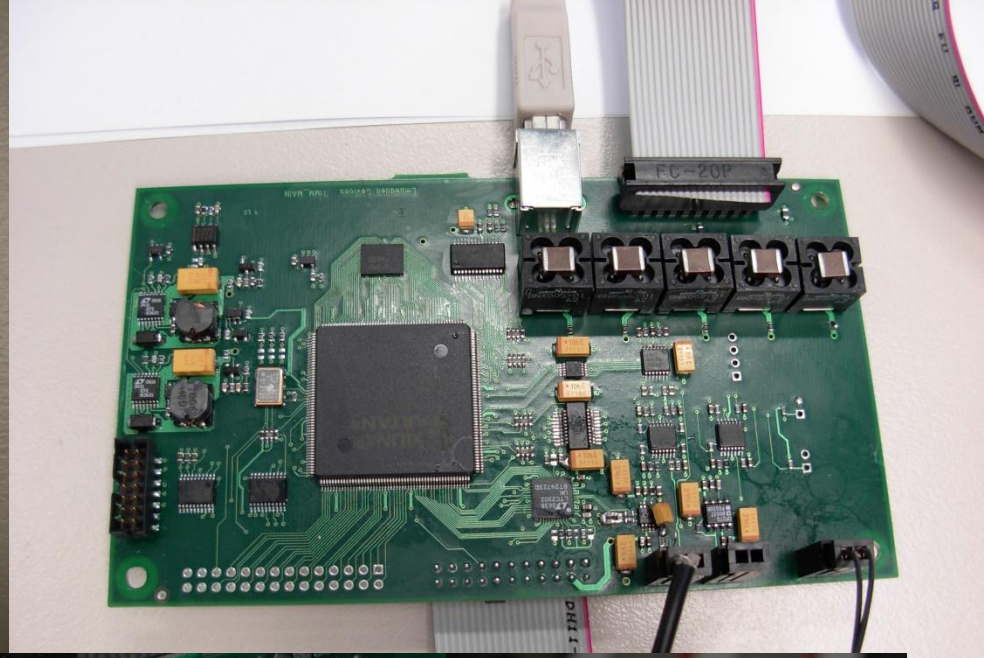


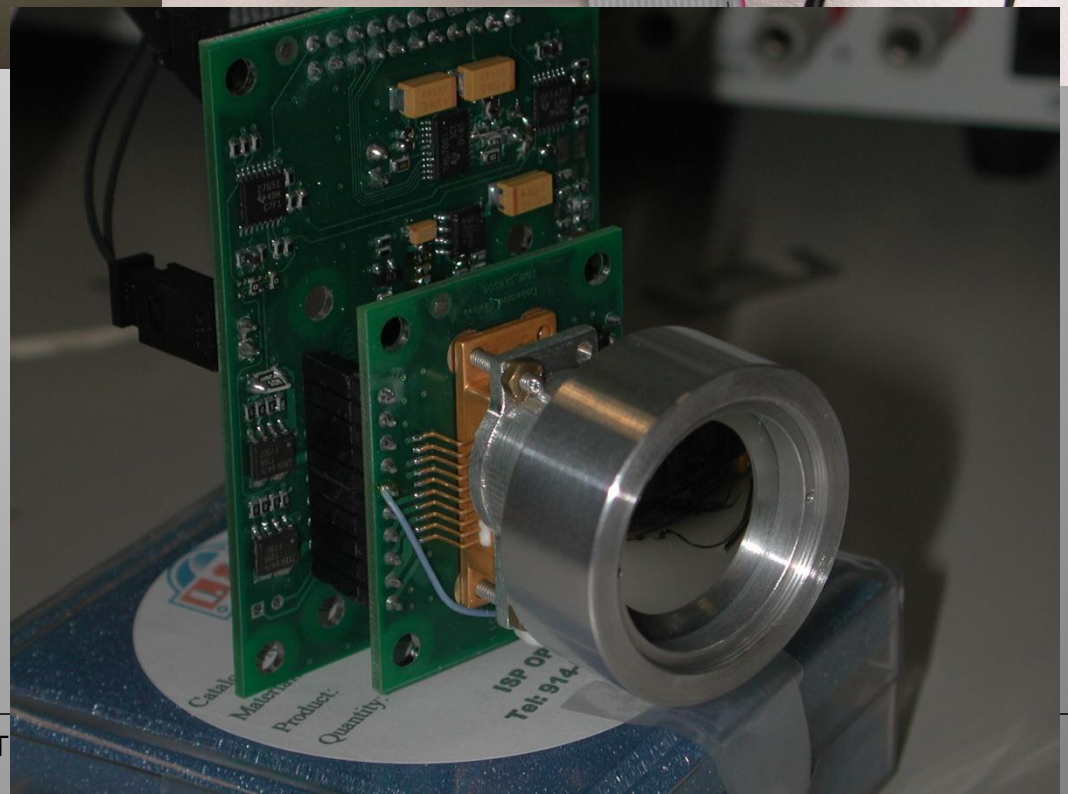


Laplace mission - Thermal mapper instrument









Microbolometer electronics

BEPI COLOMBO SERENA SCU

BepiColombo/Mercury Planetary Orbiter (MPO); it will investigate the Mercury's complex particle environment that surrounds the planet.
Environment: thermal and directional neutral atoms (exosphere) originating via surface release and charge-exchange processes, and by ionized particles originated through photo-ionization and again by surface release processes.

→ In-situ analysis of the environmental elements is necessary, and for such a purpose the SERENA instrument shall include four units: two Neutral Particle Analyzers (ELENA and STROFIO) and two Ion Spectrometers (MIPA and PICAM).

BEPI COLOMBO SERENA SCU

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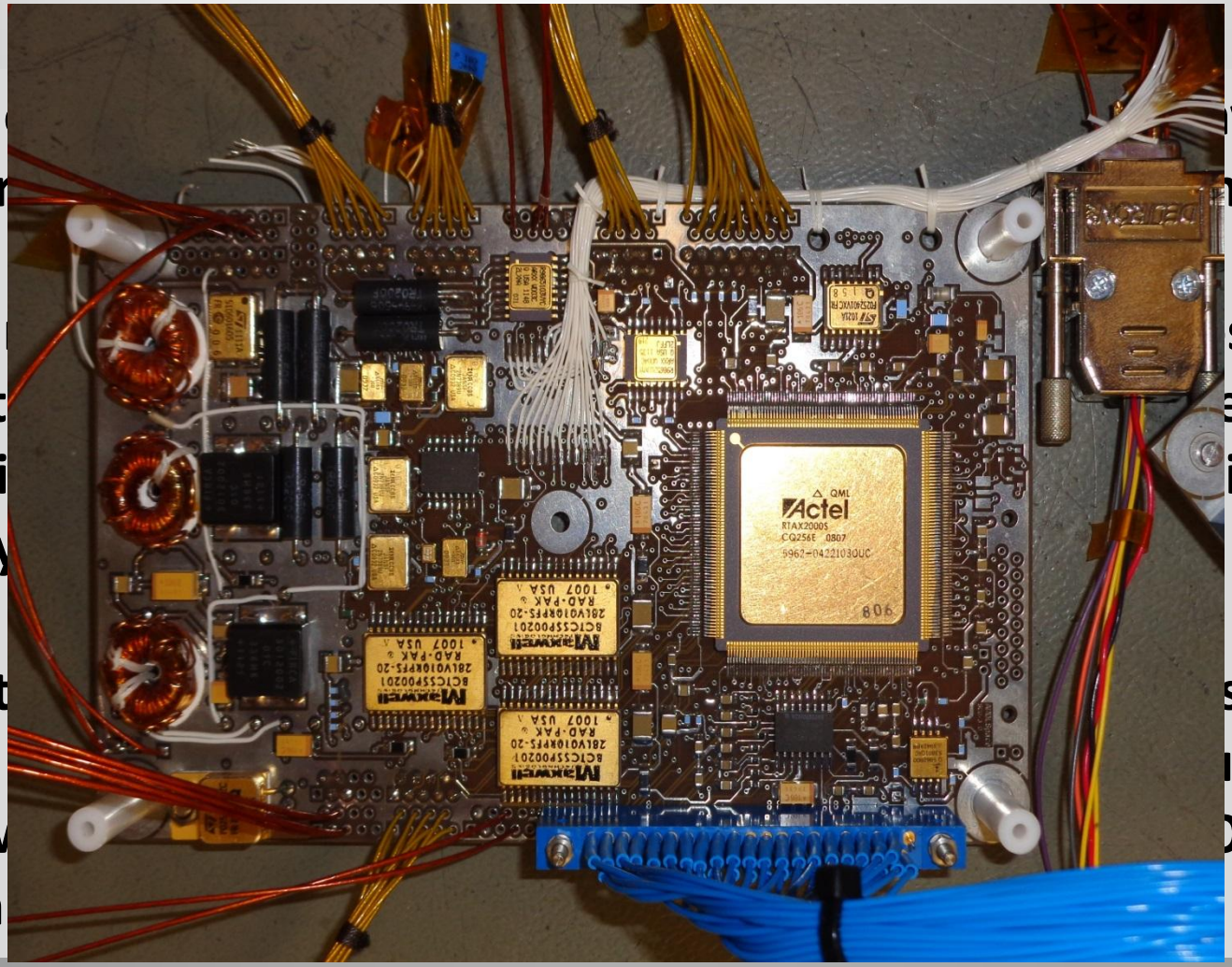

Bepicolombo/ SERENA System Control Unit: AMDL's example of 16 bit bus Sparc V8 Leon3FT synthesized core. Apart the Leon core and the S/C Main and redundant Spacewire I/F the FPGA embeds the support of fours sensors I/Fs Namely: STROFIO(NASA), PICAM (IWF-Austria), MIPA (IRF Sweeden, ELENA (IAPS –Italy)

BEPI COLOMBO FM ELENA DPU

Bepicolombo/ SERENA ELENA Main : AMDL's example of 8 bit bus Sparc V8 Leon3FT synthesized core. The FPGA embeds all the controls for the ELENA Atomic Camera.