HERCULES: A RELIABLE OBC SAVING SPACE ON YOUR CUBESAT

G.A.U.S.S. Srl – IAA-AAS-CU-17-09-11
ABACUS OBC vs Hercules OBC

- **ABACUS OBC**
  - MSP430 (up to 25MHz)
  - FPGA 500K Gates (up to 100MHz)
  - Flight heritage:
    - 5 satellites
    - Already gained more than 3 years of continuous operation

- **Hercules OBC**
  - ARM (up to 220MHz) for Safety & Critical applications
  - Reliable design
  - Offers compact solution for small satellites
  - Usable as Payload Computer
Hercules OBC Blocks System

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On Board Sensors

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On Board Sensors

- All sensors connected on dedicate SPI bus
- 2 x complete 9 DoF IMU
  - Redundancy
  - Noise reduction
- General features:

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<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Acc Full Scale</strong></td>
<td>±16 [g]</td>
</tr>
<tr>
<td><strong>Acc Max Resolution</strong></td>
<td>16 [bit]</td>
</tr>
<tr>
<td><strong>Mag Full Scale</strong></td>
<td>±4800 [µT]</td>
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<tr>
<td><strong>Mag Max Resolution</strong></td>
<td>16 [bit]</td>
</tr>
<tr>
<td><strong>Gyro Full Scale</strong></td>
<td>±2000 [°/s]</td>
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<tr>
<td><strong>Gyro Max Resolution</strong></td>
<td>16 [bit]</td>
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<tr>
<td><strong>Gyro Noise Spectral Density</strong></td>
<td>0.01 [°/s/√Hz]</td>
</tr>
</tbody>
</table>
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On Board Memory Mass Storage

- All memories connected to a separate SPI bus
- Ferroelectric Ram (FRAM) non volatile memory
  - Radiation and Electric Field Tolerant
  - Data retention of more than 10 years @ 85°C
  - R/W cycles greater than Flash memory ($10^{14}$ vs $10^{6}$)
  - Faster than Flash memory
  - Usable for critical data or recovery system data
  - Capacity 0.5 MB
- Flash Memory
  - On board memory mass storage
  - Capacity 125 MB
- SD Card socket connector

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Hercules CPU core

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CPU & Safety Features

- 32 bit RISC Floating Point CPU
  - 1.66 DMIPS/MHz, up to 220MHz
- Designed for Safety-Critical applications ("Hercules" family CPUs of Texas Instruments)
- Dual ARM Cortex-R4F CPUs running in lockstep:
  - CPUs perform same operation, than compare the results for each clock cycle
  - in case of fault it can enter in a defined safe mode (safe island approach)
Common mode impact protections:

- Signals of the CPUs to be compared delayed by 2 clock cycles.
CPU & Safety Features

- CPUs have a different physical placement on the chip and a dedicated guard ring for each CPU.

![Diagram showing CPU orientations]

CPU1 = "north" orientation  
CPU2 = "flip west" orientation
Other safety features:

- Integrated Flash and RAMs all with ECC
- Built-In Self-Test (BIST) for CPU and on-chip RAMs
- Cyclic Redundancy Checker module (CRC)
- Parity diagnostics on all peripheral memories
- Analog and digital loopback to test for shorts on I/O
- etc…

Currently studied by Airbus-DS and ESA
Hercules OBC (render)

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Daughter Board Connectors

- Connector for a Customer Daughter Board
  - 18 pins usable as GPIO
  - 6 ADC Input
- May be used for motors & coils control
  - 6 PWM Output
  - 6 Direction Output
  - 6 Feedback input
  - 6 ADC for current measurement
- Digital Pins are reported also on H1/H2 connector
Connector GAUSS Radio Compatible

- 1x CAN (H1/H2 conn.)
- 1x I2C (H1/H2 conn.)
- 1x SPI bus (shared)
- 3x GPIO
- Power pins (selectable source)
- Direct Radio TEST UART Connection
GAUSS OBC & Radio: 2 in 1 System

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CubeSat Connector (H1/H2)

- Digital Bus available
  - 2x CAN 2.0B
  - 2x RS232 (configurable as slave)
  - 1x RS422/485 adapter (from one RS232)
  - 1x I2C (+ a shifted voltage connector)
  - 1x SPI
- Other pins
  - 10x ADC Channels
  - Several GPIOs
  - MCU specific features (N2HET, PWM, etc.)
- Selectable Power source pins
# Reconfigurable Connector (H1/H2)

<table>
<thead>
<tr>
<th>H1 Connector</th>
<th>H2 Connector</th>
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</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>CAN1_L</td>
<td>CAN2_L</td>
</tr>
<tr>
<td>CAN1_H</td>
<td>CAN2_H</td>
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<tr>
<td>GPIO</td>
<td>GPIO</td>
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<tr>
<td>NC</td>
<td>NC</td>
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<tr>
<td>ADC</td>
<td>ADC</td>
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<tr>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>UART2_a_TX/RX</td>
<td>UART2_a_TX/RX</td>
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<tr>
<td>SPL_SD/GPIO</td>
<td>SPL_SD</td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
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<tr>
<td>GPIO</td>
<td>GPIO</td>
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<tr>
<td>NC</td>
<td>NC</td>
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<tr>
<td>UART1_a_RX/TX</td>
<td>UART1_a_RX/TX</td>
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<tr>
<td>I2C_SDA</td>
<td>I2C_SDA</td>
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<td>NC</td>
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<tr>
<td>VCC_2Power</td>
<td>VCC_2Power</td>
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<tr>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>VCC_3Power</td>
<td>VCC_3Power</td>
</tr>
</tbody>
</table>

**Mandatory** | **Selectable** | **Mandatory** | **Selectable**

**NC = Not Connected**

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Other features

- PC/104 CubeSat form factor compatible
- Powered using 3.3V or 5V and from different configurable pins
- Off the shelf industrial/automotive grades components
- Operating temperature range -40°C to +85°C
Conclusion

- **OBC Hercules**
  - Based on a Safety-Critical application designed processor
  - Radiation tolerant FRAM memory
  - Complete 9DoF redundant IMU
  - Versatile CubeSat connector & Daughter connectors
  - Possibility to create a compact system for small satellites including the GAUSS Radio on the same board
Thank you

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