EXPANDABLE HYBRID COMPUTING PLATFORM FOR SMALLSATS

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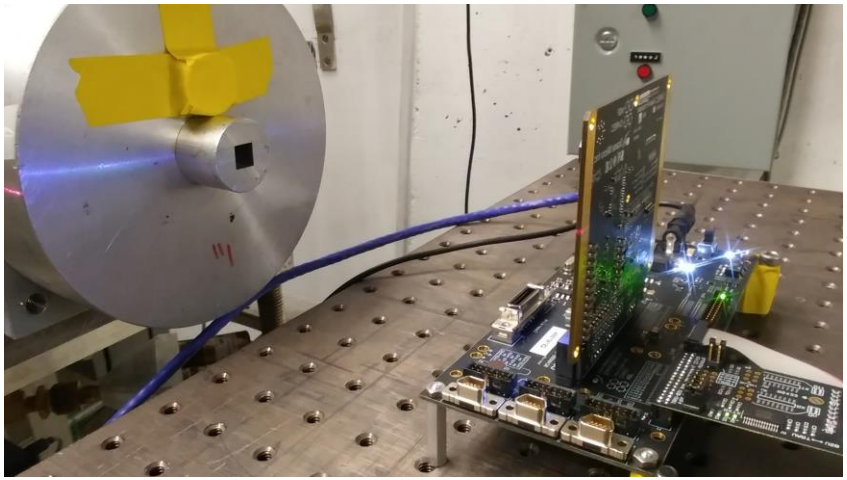
Hybrid Product Design

- Combines industrial and space grade parts
- Superior performance and reliability are achieved while staying within typical CubeSat program cost constraints
- Radiation tolerant devices monitor and manage COTS devices
- Fault tolerant computing (Hardware, software, information, networking, and time redundancy)
- Customized parts selection is applied to achieve configurations for different reliability requirements and radiation environments (up to 100 krad)



CSP Radiation Testing

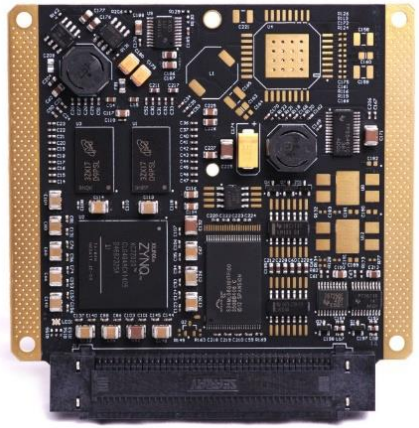
CubeSat Space Processor Overview

- **CubeSat Space Processor (CSP) single board computer**
  - **Hybrid Product Design Strategy**
  - **Designed to meet space environments**
    - Vibe, Shock, Conduction cooled
    - Parts selected for TID resilience
    - Embedded soft error mitigation
  - **Powered by Xilinx Zynq-7020**
    - Dual ARM cores
    - 7-series FPGA fabric
  - **DDR3 SDRAM**
  - **Flash Memory**
- **Extensive Software Options**
- **Modularity**
- **Radiation Resilience**
  - **Heavy-Ion Testing conducted at BNL**
- **Heritage**
  - **Currently flying on ISS**
  - **Selected for five Space Missions**

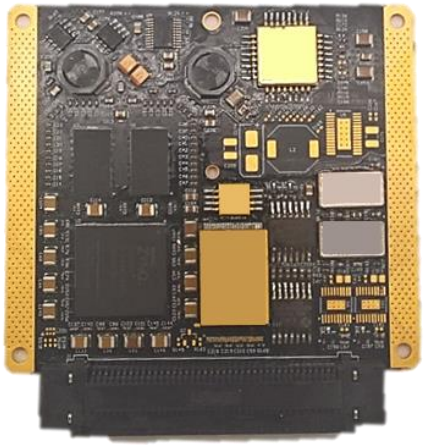
STP-H5/CSP on ISS

CSP Key Attributes

Processor	Xilinx Zynq-7020 2.5 DMIPS/MHz per CPU CPU frequency: Up to 667 MHz (-1) Up to 866 MHz (-3)	
FPGA Programmable Logic	33 MHz or 100 MHz Clock 24 differential pairs, 12 single ended 140 - 36Kb Block RAM (4.9 Mb) Programmable I/O Blocks Supports LVCMOS, LVDS, and SSTL, with 1.2~3.3 V I/O 12 bit ADCs up to One Million Samples per Second	
Total IO	24 LVDS and 38 Single-ended	
Operating Systems	Wumbo GNU/Linux, RTEMS, VxWorks, ThreadX	
Supported Interfaces	8 Channels DMA SpaceWire 10/100 Ethernet USB 2.0 OTG CAN 2.0B (1 Mb/s) SPI (3 chip selects) JTAG	I2C (external 3.3 V pull-ups required) UART (Max baudrate of 921600 bps) Hardware & Software Watchdog timer Camera Link
Memory	8 Gbit NAND Flash (EM) RadTolerant 32 Gbit NAND Flash (FM) Two 1 Gbit DDR3 SDRAM	
Connector	Samtec SEAF-RA-RA 4 x40 Designed to be Connected to a Samtec SEAM 4 x 40 Backplane	
Power Consumption	1.6 – 2.85 Watts	
Temperature Rating	CSP-EM: 70 ℃ CSP-FM: -40 ℃ to +85 ℃	
Thermal	Conduction cooled	
Mechanical Size	Designed in a 1U CubeSat form factor (8.8 cm x 8.9 cm) Thickness: 1.65 cm (tallest component)	
Mass	60 grams	



CSP EM



CSP FM

CSP Development Kit

- **Solution for Interface and Software Testing**

- **Development Kit Contents:**
  - **CSP Engineering Model**
  - **CSP Evaluation Board**
    - JTAG programming support
    - 10/100 Ethernet
    - MIO and EMIO breakout
    - 3 SpaceWire breakouts
    - Cameralink breakout
  - **USB to UART Board**
    - USB to UART Converter (1.8, 2.5, 3.3V logic supported)
  - **Software**
    - Access to CSP software and firmware repository

CSP EM on Evaluation Board

CSP Software

- **Operating Systems**
  - Custom Wumbo (Linux Environment), RTEMS, VxWorks, ThreadX

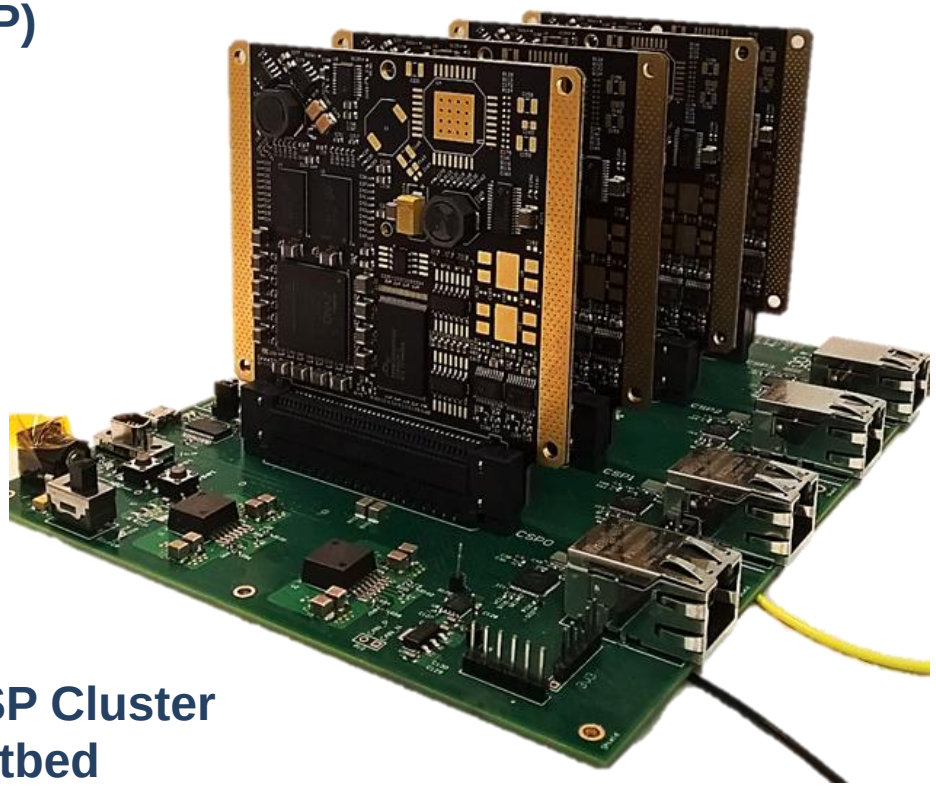
- **Interfaces**
  - 8 Channels DMA
  - SpaceWire
  - 10/100 Ethernet
  - USB 2.0 OTG
  - CAN 2.0B (1 Mb/s)
  - SPI (3 chip selects)
  - JTAG
  - I2C (external 3.3V pull-ups required)
  - UART (Max baudrate of 921600 bps)
  - Hardware & Software Watchdog timer
  - Camera Link

- **Applications**
  - Multiple open source and third party IP
  - NASA's Core Flight Executive/Core Flight System (cFE/cFS)

Modularity and Expansion

- **Backplane**
  - Dense, high-speed 160-pin backplane connector
  - 24 LVDS and 38 Single-ended IO

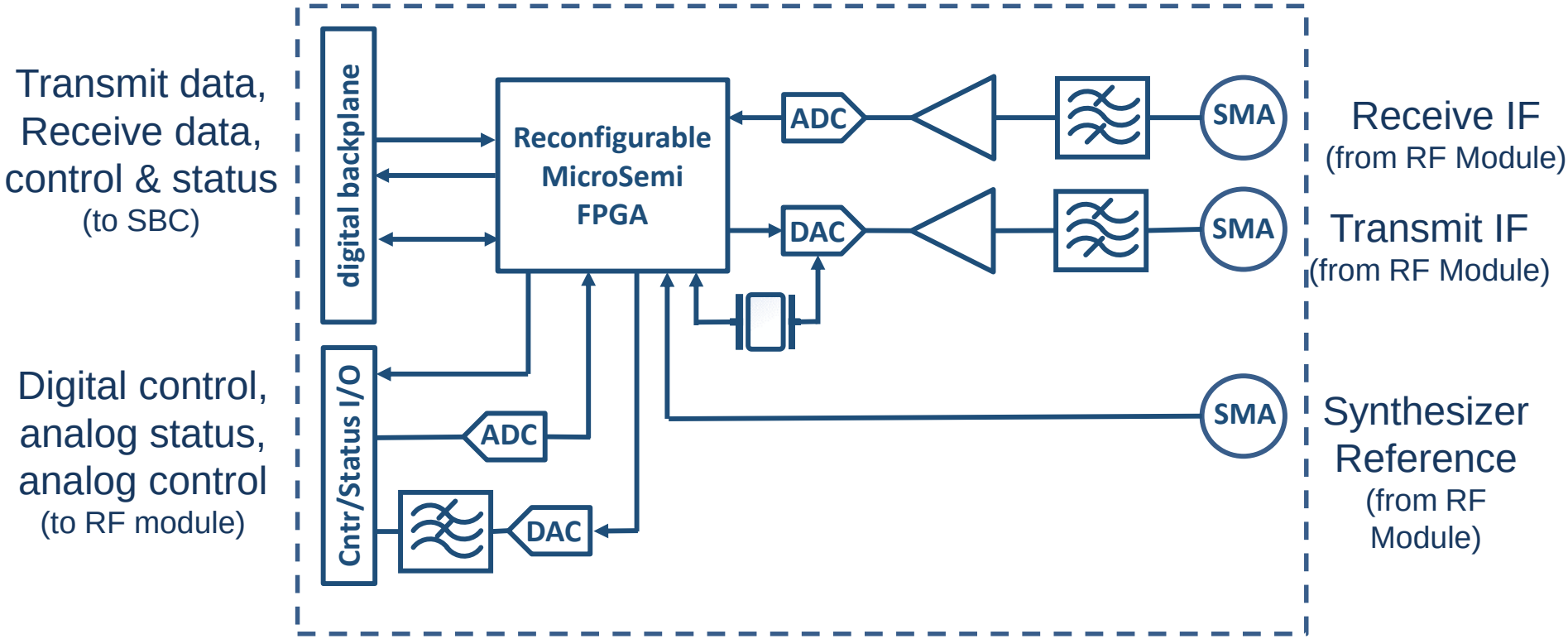
- **Examples**
  - Multiple CSPs (e.g. *Super*CSP)
  - Modem Board



***Super*CSP Cluster Testbed**

SDR Modem Expansion Card

- **Radiation tolerant Software Defined Modem in 1U form factor**
- **Supports IF frequencies up to 150 MHz**
- **Occupied bandwidth up to 25 MHz**
- **Typical configuration is 5-10 MHz occupied bandwidth at 70 MHz IF**



Industry Standard Design Practices

- **Configuration Management**

- **Design Analyses**
  - Structural, Mechanical, & Thermal analysis
  - Reliability, Part Stress, & Worst Case analysis
  - Radiation (destructive events, TID, SEE, SEU, SEFI)
    - Standard space products typically targeted to 30 or 100 krads(Si)
    - Use many parts databases
    - Routinely conduct radiation testing
    - Shielding can be provided for extra TID margin
    - Hierarchical fault tolerance

- **Parts, Materials and Processes**
  - Traceability with MRP and travelers
  - Counterfeit (CF) parts avoidance
  - No pure tin
  - Capable of working to NASA Level 1/Class “S” or TOR (Level 2 & Commercial Space are most common)
  - In-house parts screening capability
  - Regular participation in various industry groups (SPWG)

Industry Standard Manufacturing Practices

- **Parts Procurement**
  - Strong relationship with manufacturers and distributers of parts
  - Purchase from authorized distributers or OEM's
  - Quality clauses
  - Ability to purchase larger quantities of long lead parts
- **Manufacturing and Test**
  - Sub-tier Management
  - Acceptance Testing
- **Documentation**
  - End Item Data Package (EIDP)
  - Certificate of Conformance

Mission Assurance

- We are an ISO 9001 registered house since 2008
  - Undergone two re-certification audits
  - Last was October 2014
- Quality Policy
  - Space Micro Inc. is committed to customer satisfaction by producing defect-free products that conform to customer requirements and expectations, through systematic and controlled operations, on-time deliveries, and a culture of continuous process improvement.
- Quality Manual
- Standard Operating Procedures address Space Micro processes
- Workmanship Standards

bsi.

By Royal Charter

Certificate of Registration

QUALITY MANAGEMENT SYSTEM - ISO 9001:2008

This is to certify that:

Space Micro Inc.
10237 Flanders Court
San Diego
California
92121
USA

Holds Certificate No: **FM 525932**

and operates a Quality Management System which complies with the requirements of ISO 9001:2008 for the following scope:

Design and development, inspection, testing, and distribution of advanced electronics systems, microelectronics, and materials for space, military, and performance critical applications worldwide.

For and on behalf of BSI:

Gary Fenton, Global Assurance Director

Originally registered: 10/24/2008 Latest Issue: 09/07/2014 Expiry Date: 10/23/2017

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...making excellence a habit.

Quality & Supply Chain Management

Purchased Parts and Materials

- MAM reviews Purchase Requests & Inserts Appropriate Quality Clauses
  - Quality clauses also adapted from customer flow downs
  - Applicable command media (SCDs, MI's, Drawings) accompanies Purchase Order
  - Purchased Items are verified at Source and/or Receiving Inspection

Contracted Supplier Processes

- MAM reviews Purchase Requests & Inserts Appropriate Quality Clauses
  - Applicable command media (SCDs, MI's, Drawings) accompanies Purchase Order
  - Source Inspection:
    - PCB Assembly House: Placement, orientation, workmanship
    - Conformal Coat/Staking House: Workmanship

Internal Processes

- Applicable command media (Travelers, BOM's, MI's, Drawings) accompany kitted/built up assemblies
- In-Process inspection verifies command media and workmanship
- Space Micro Standard Operating Procedures (SOPs) apply
- Non-Conformance Management

Quality Assurance Participation

Perform Inspections to Ensure Compliance to Workmanship Requirements

- IPC-A-610 Acceptability of Electronic Assemblies
- J-STD-001 Requirements of Soldered Electrical and Electronic Assemblies
- J-STD-001 Space Addendum
- NASA-STD-8739 workmanship standards

Ensure Facilities Compliance

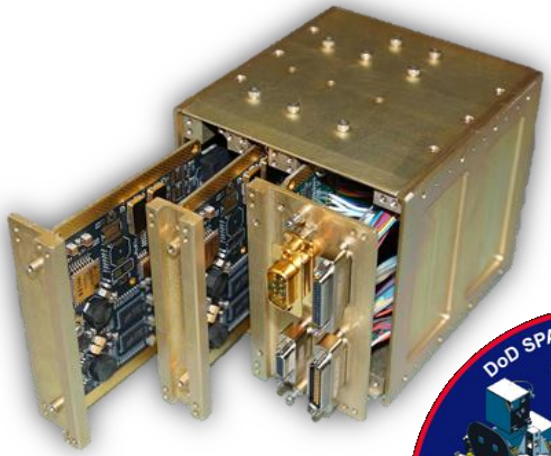
- Equipment Calibration
- Facilities Cleanliness
- ESD Safeguards

Audit Manufacturing Documentation

- Proper Revisions, Approvals, Sign-offs, Stamps
- Operations Completed Correctly and Signed-Off
- Oversight/Review Contract Manufacturing Workmanship and Documentation
- End-Item Data Package (e.g. Test Data, Travelers, Photos/X-Rays, etc.)
- Provide Certificate of Conformance

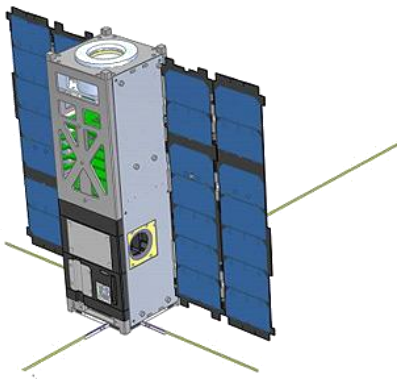
Featured Missions

- **Space Test Program – Houston 5 (STP-H5/CSP)**
  - First keystone mission for CSPv1
  - Launched February 19th 2017
  - Features twin CSPv1s with imager



- **Lockheed Martin SkyFire[1]**
  - CubeSat performing lunar flyby for surface characterization, remote sensing, and site selection
  - CSPv1 payload processor with cFS on RTEMS

- **NASA Compact Radiation Belt Explorer (CeREs)**
  - Heliophysics science mission
  - Expected 2018 launch
  - CSPv1 instrument interface



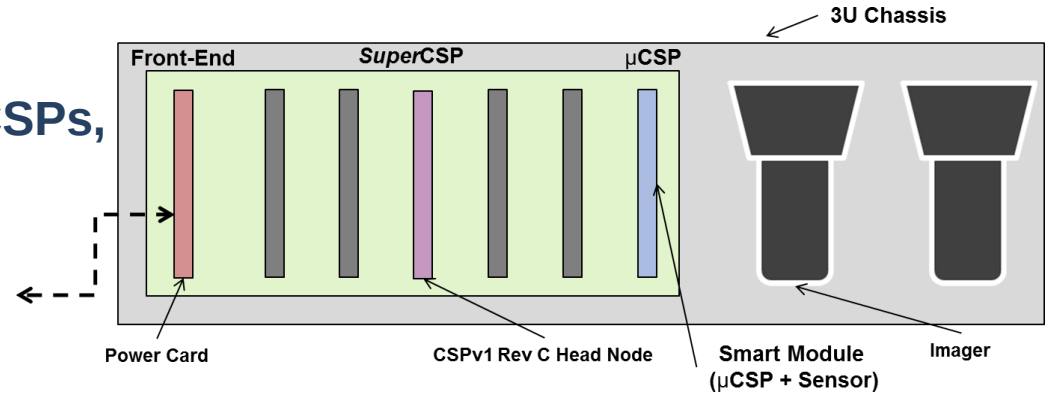
[1]Slabaugh, R., Gauvin, P., George, A. D., Holtzman, S., Phillips, M., Wilson, C., "Strength in Numbers: Core Flight System in a Real-Time Environment on a Multi-Core Space Processor," Flight Software Workshop, Pasadena, CA, Dec. 2016.

STP-H6/SSIVP

- **Space Test Program – Houston 6/Spacecraft Supercomputing for Image and Video Processing (STP-H6/SSIVP)**
  - **Proposed mission for parallel, distributed, reconfigurable, and dependable computing on multiple, networked CSPv1 payload**

- **Motivation: Develop, demo, and evaluate next-gen technologies for space supercomputing, featuring image and video processing**

- **Experiment Concept**
  - **3U computing payload (5 CSPs, 1 uCSP, Power, Backplane)**
  - **2 included image sensors for distributed computing**



Top-Down View