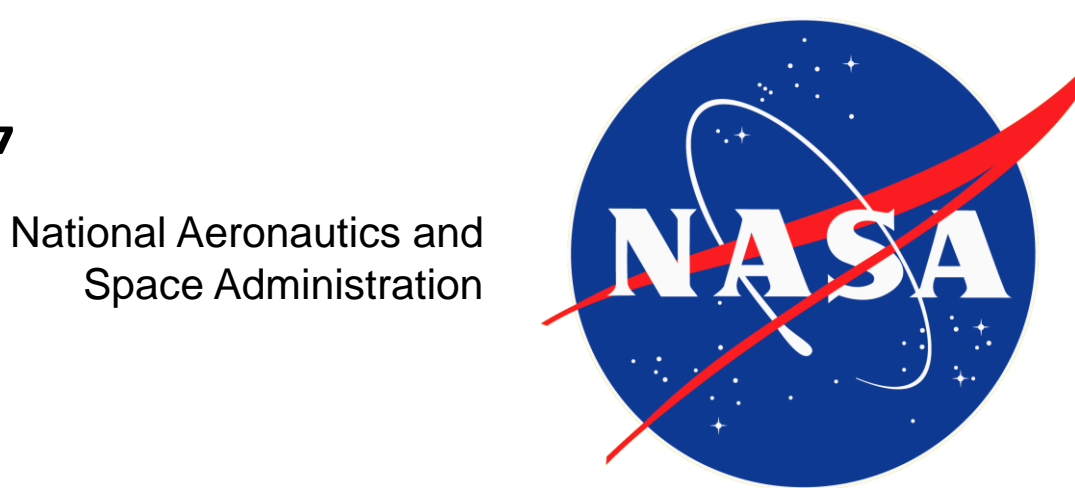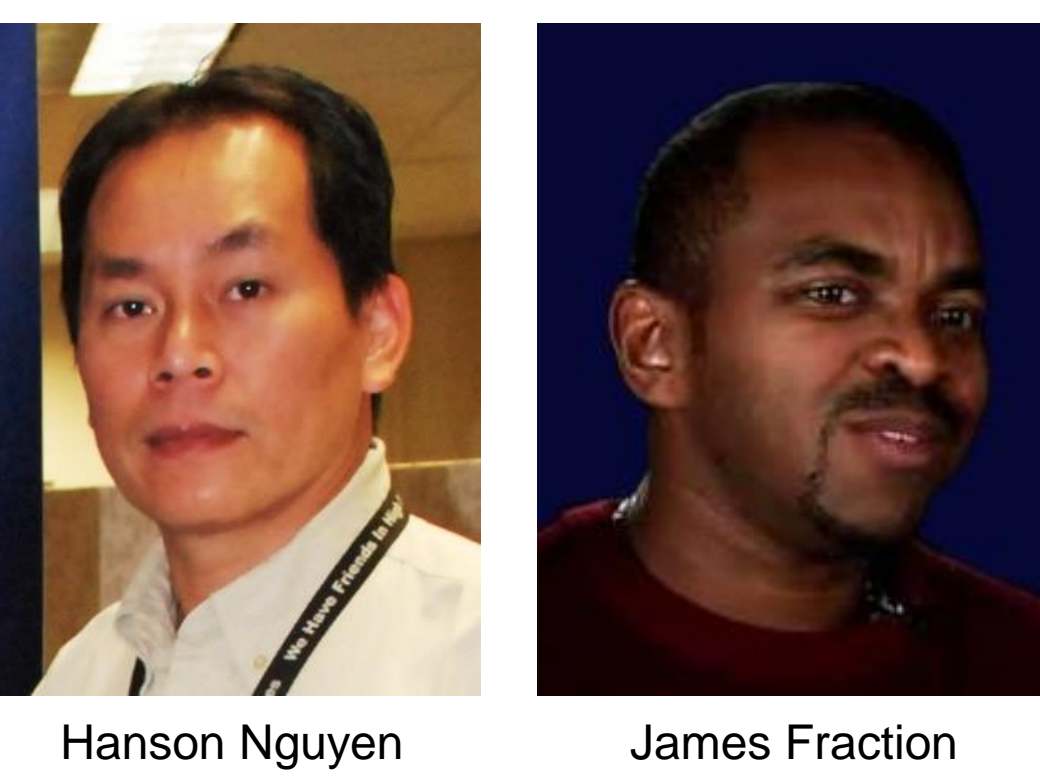# Robust, Radiation Tolerant Command and Data Handling and Power System Electronics from NASA Goddard Space Flight Center

Hanson C. Nguyen[1], James Fraction[2], Melyane Ortiz-Acosta[1], Dr. George Dakermanji[3], Bradford P. Kercheval[3], Amri Hernandez-Pellerano[1], Leonine S. Lee[1], David S. Kim[1], David S. Jung[1], Steven E. Meyer[4], Udayan Mallik[4], Kurt D. Rush[4], Faramarz Farid[5], James C. Olsen[6], Pietro A. Sparacino[7]
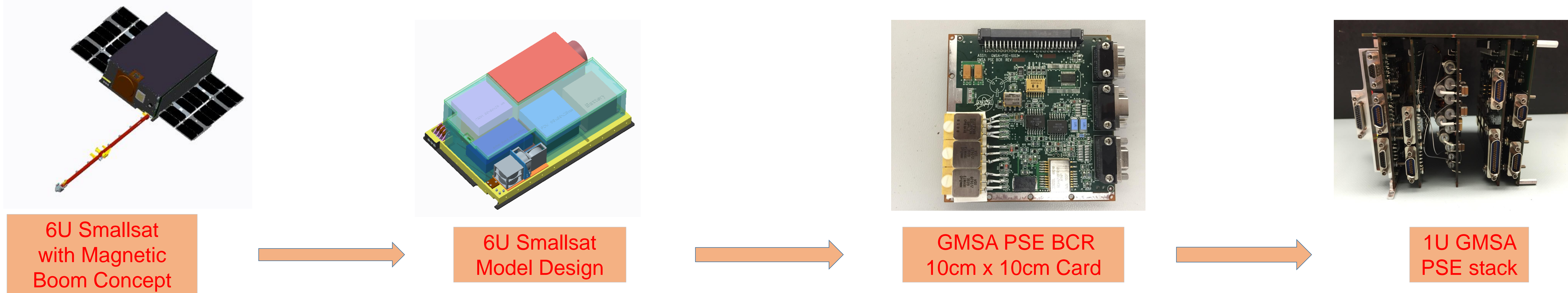
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Abstract: The Goddard Modular Smallsat Architecture (GMSA) is developed at NASA Goddard Space Flight Center (GSFC) to address future reliability along with minimizing cost and schedule challenges for NASA Cubesat and Smallsat missions.

6U Smallsat with Magnetic Boom Concept

6U Smallsat Model Design

GMSA PSE BCR 10cm x 10cm Card


1U GMSA PSE stack

Background

Within the National Aeronautics and Space Administration (NASA), interest is shifting from large-scale science missions such as the Lunar Reconnaissance Orbiter (LRO) or the Magnetospheric Multiscale (MMS) to faster and cheaper missions. Within industry and academia, many small missions have to date employed commercial-off-the-shelf (COTS) components in lieu of mostly radiation-tolerant or radiation-hardened parts. To enable higher reliability science missions that can operate at least one year in potentially harsh radiation environments, avionics which include command and data handling (C&DH) system and Power System Electronics (PSE) must have predictable reliability that goes beyond the capabilities of currently available COTS components. While there are a number of COTS components that can withstand a total ionizing dose (TID) of tens or hundreds of kilorads, this is not universal. Furthermore, there remains concern regarding tolerance to and mitigation of single-event effects (SEE).

The Goddard Modular Smallsat Architecture (GMSA)

To meet this need for higher reliability small missions, NASA Goddard Space Flight Center (GSFC) is developing the Goddard Modular Smallsat Architecture (GMSA). Addressing improved reliability along with minimizing power, mass, volume, cost, and schedule constraints, GMSA is a modular, flexible, and extensible small satellite implementation approach that can accommodate spacecraft subsystems designed both internally within NASA and externally by industry and academia. Initially targeted for 6U (10cm x 20cm x 30cm) satellites, GSFC is developing GMSA Power System Electronics (PSE) and Command and Data Handling (C&DH) subsystems.

Acronym list

1U = 10cm x 10cm x10 cm (HxWxL)
AB: Actuator Board
BCR: Battery Charge Regulator
BP: Backplane Board
C&DH: Command and Data Handling
cFS: Core Flight System
COTS: Commercial-off-the-shelf
DET: Direct Energy Transfer
FW: Flight software
GMSA: Goddard Modular Smallsat Architecture
GPIO: General purpose input/output

GSFC: Goddard Space Flight Center
I2C: "Inter IC" or I²C bus (or IIC bus)
LRO: Lunar Reconnaissance Orbiter
MMS: Magnetospheric Multiscale
NASA: National Aeronautics and Space Administration
PDU: Power Distribution Unit
PSB: Power Switches Board
PSE: Power System Electronics
SEE: Single-event effects
TID: Total ionizing dose

GMSA PSE

The GMSA PSE is a Direct Energy Transfer (DET) system with the battery connected directly to the bus. The shunt control technique is a linear sequential full shunt which provides a simple solar array interface. This topology can support both 3-axis stabilized and spinner satellites. The GMSA PSE includes all the circuits needed to perform telemetry and command function using I2C interface with the C&DH. Additionally, the EPS is designed, and will be tested and verified, to meet launcher vehicle safety requirements.

The GMSA PSE consists of five cards:

- Battery Charge Regulator (BCR): The BCR board provides battery charge control to selected voltage and current levels. Any excess power that is not used by the spacecraft or to recharge the battery is dissipated in linear sequentially operated shunts.
- Power Distribution Unit (PDU): The PDU converts and distributes all load secondary voltages which include: +12V, +5V, +3.3V.
- Power Switches Board (PSB): The PSB distributes secondary voltages to the un-switched essential and switched non-essential loads.
- Actuator Board (AB): The AB distributes Battery (Bus) voltage to deploy solar array, magnetic boom, transmitter, and propulsion.
- Backplane Board (BP): The BP is used to connect all PSE cards together to share Bus power, secondary power, and I2C lines.

The GMSA PSE is compatible with Goddard Smallsat Battery Pack. The battery pack consists of 9 Li-Ion rechargeable type 18650 cells, it is configured with 3 strings in parallel and each string has 3 cells in series. This battery has capacity of 73Wh (or 6.6Ah at nominal voltage of 11.1V).
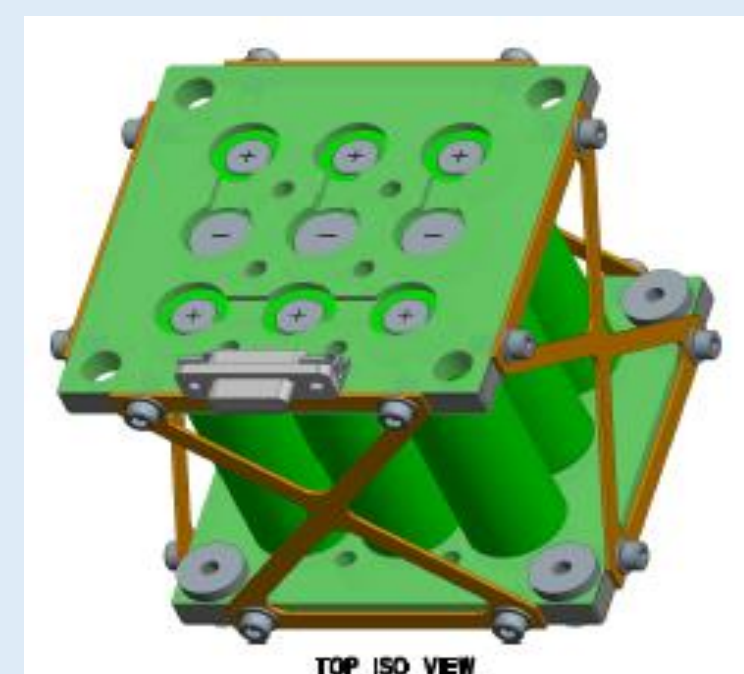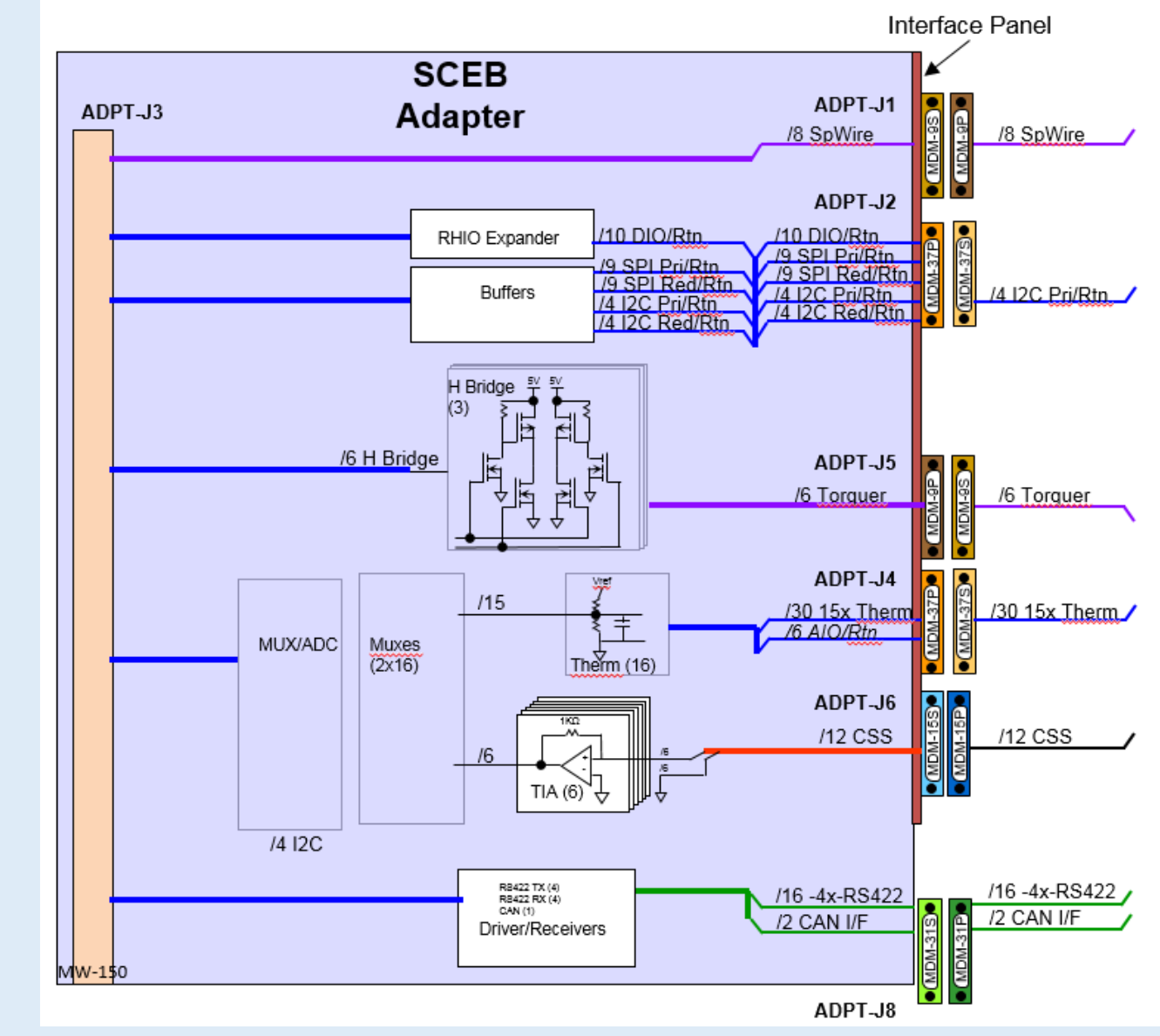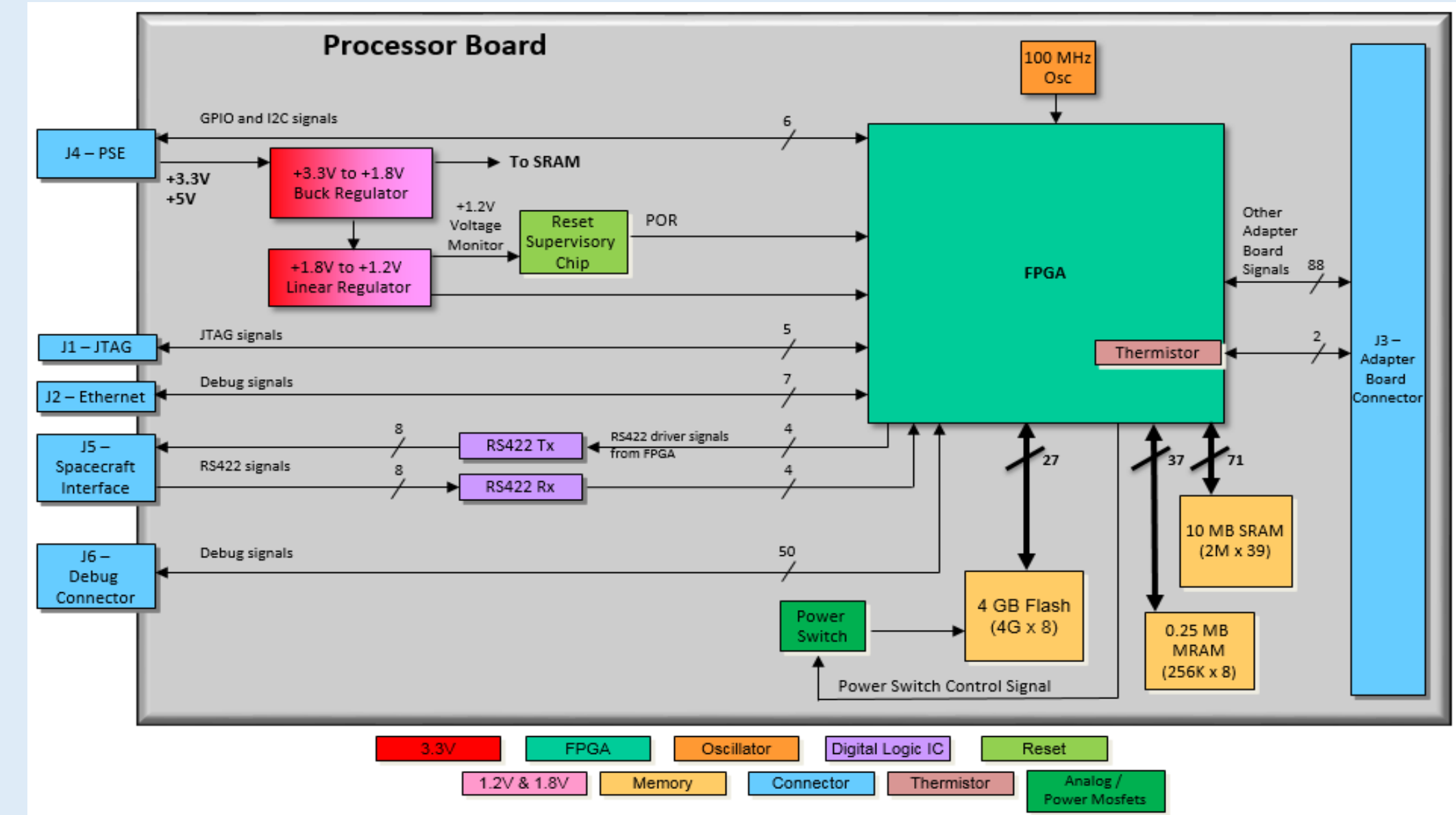

GMSA Battery Pack
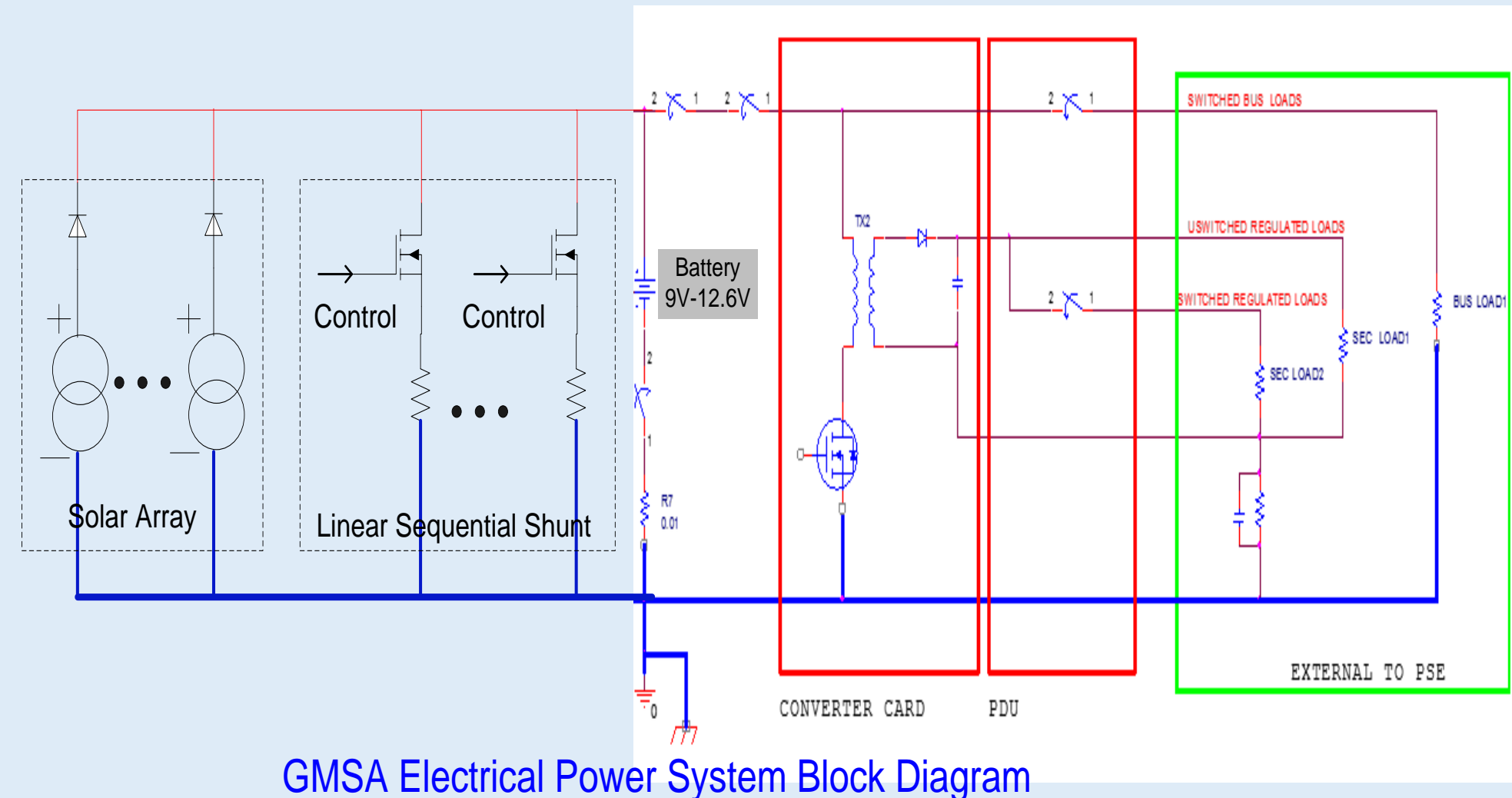
GMSA Electrical Power System Block Diagram

GMSA C&DH

The GMSA C&DH is implemented as a two board solution based on a MicroSemi RTG4 Field Programmable Gate Array (FPGA) implementing a soft core processor. The C&DH can be configured to implement a variety of serial communication interfaces including:

- RS-422
- I2C
- SPI
- SpaceWire
- General purpose input/output (GPIO)

In addition to providing these interfaces, the C&DH contains the analog circuitry that converts temperature, voltage, and current data collected from multiple points within 6U satellite to a digital format that can be processed, stored, and downlinked using the front end communication interface. The C&DH includes sufficient volatile and non-volatile memory to operate GSFC's Core Flight System (cFS) as well as providing.

GMSA Processor and Adaptor Board Block Diagram

Conclusion

The PSE and C&DH subsystems that are currently under development will provide the miniaturization, flexibility, and reliability required for GMSA. Once completed, these developments will position GSFC to develop cubesat and smallsat science missions that can operate reliably in harsh radiation environments for durations exceeding one year.