Enabling Mission Adaptability with New Memories and New Adaptive SoCs

Paul Chopelas, General Manager - Aerospace and Defense

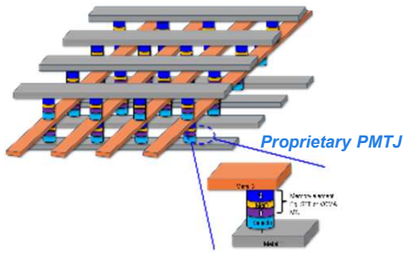
Space Computing Conference, July 18-21, 2023

Agenda

- Who is Avalanche Technology?
- Why are Avalanche MRAMs so Enabling for the Space Community?
- Space Grade MRAM Roadmap Update
- Existing Bottlenecks to Satellite Network Scalability & Resilience
- Architectural Options to Address Escalating Data Needs in Space
- Specific Partner Customer Product Platforms Rolling Out in 2023 to Support These Applications
- FPGA & SoC Boot Support for Space, Including FOTA
- Summary Impact
- Q&A

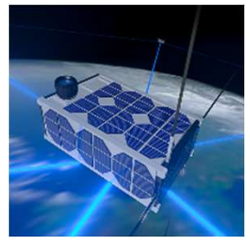
Avalanche Company Overview

Hi-Rel STT pMTJ MRAM since 2006



16+ years STT MRAM Experience

Focused on Space and Hi-Rel Industrial



Hi-Rel Industrial Heritage

Shipping volume to Industrial customers since 2019

Hi-Rel Focused

Domestic Technology

325 Granted Patents & counting

Most Next-Gen/STT MRAM Patents Stateside

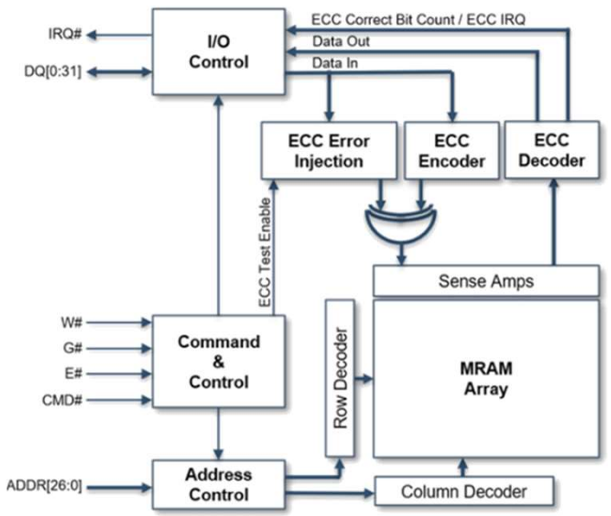
Growing Ecosystem

micross one source. one solution.
RENESAS BIG IDEAS FOR EVERY SPACE
falcon
XILINX
NanoXplore
APOGEE SEMICONDUCTOR
Protec GmbH Vertrieb elektronischer Bauteile
Lattice Semiconductor Corporation
Linear ASICs Inc.
RADIATION TEST SOLUTIONS
UMC
SONY
LA SEMICONDUCTOR

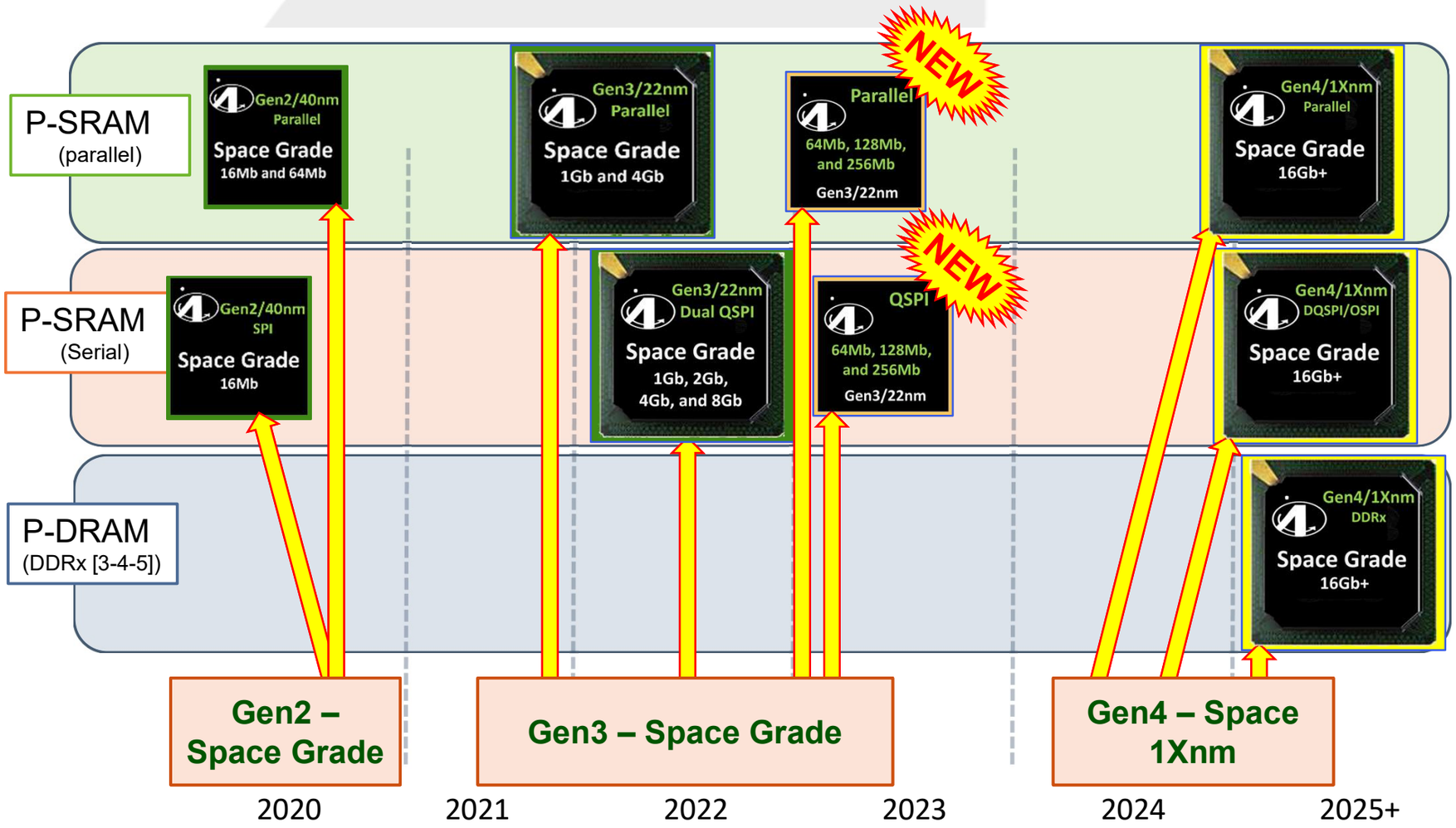
Growing Fab and Partner Ecosystem…

Avalanche MRAM Advantages – the Best SWaP for Space

- MRAM's magnetic structure provides an NVM cell **immune to radiation**
  - CMOS circuitry protected by RHBD techniques
- **Innovations in cell, circuit & device architecture** over Flash & early MRAM
  - Designed as persistent SRAM – simplifies memory design
  - Higher endurance (10^{16}) than NAND or NOR Flash - simplifies system sw
  - No Shielding Required
- Designed for the **Highest Reliability** with embedded multibit ECC
- **High Bandwidth Interface** (711Mbps parallel/1.422Gbps streaming)
- **Low Power, Unified Memory Architecture**
- **Best SWaP profile of any Space/RH NV Memory available**



Avalanche Current and Future Roadmap



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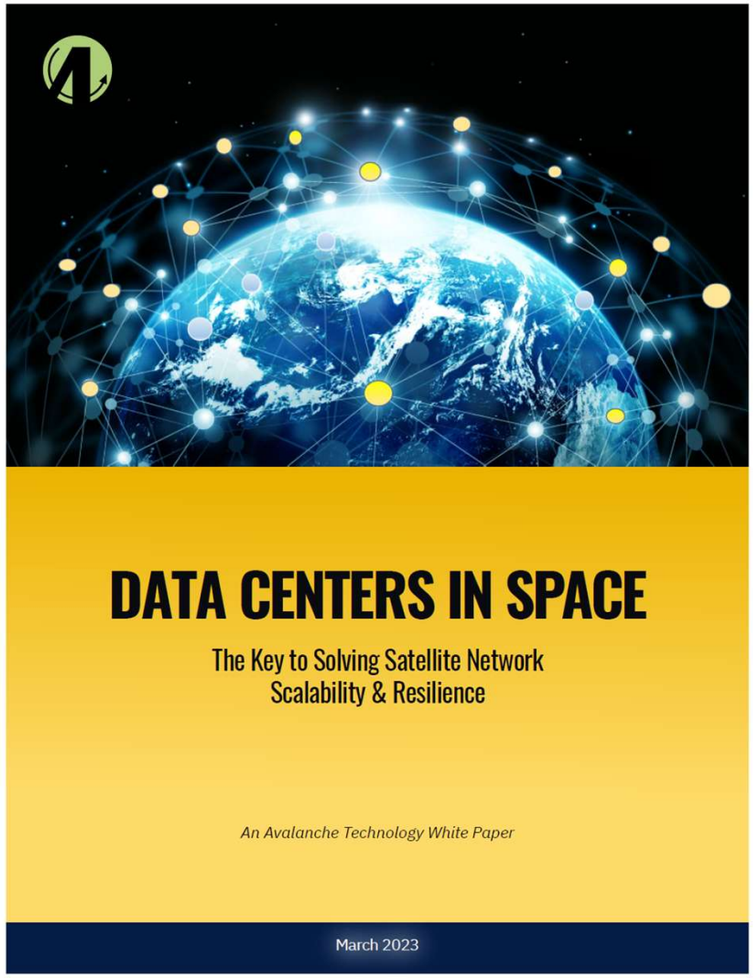
DATA CENTERS IN SPACE

Data Center in Space Campaign (White Paper)



THE EVOLUTION IN SPACE BEGINS IN EARNEST

THIS EVOLUTION OF THE NETWORK toward a more distributed mesh architecture is already beginning to happen as the next generation of Micro satellites are being launched, not just in communication topology, but also distributed intelligence. The resulting impact to the network topology is pictured below in Figure 8.

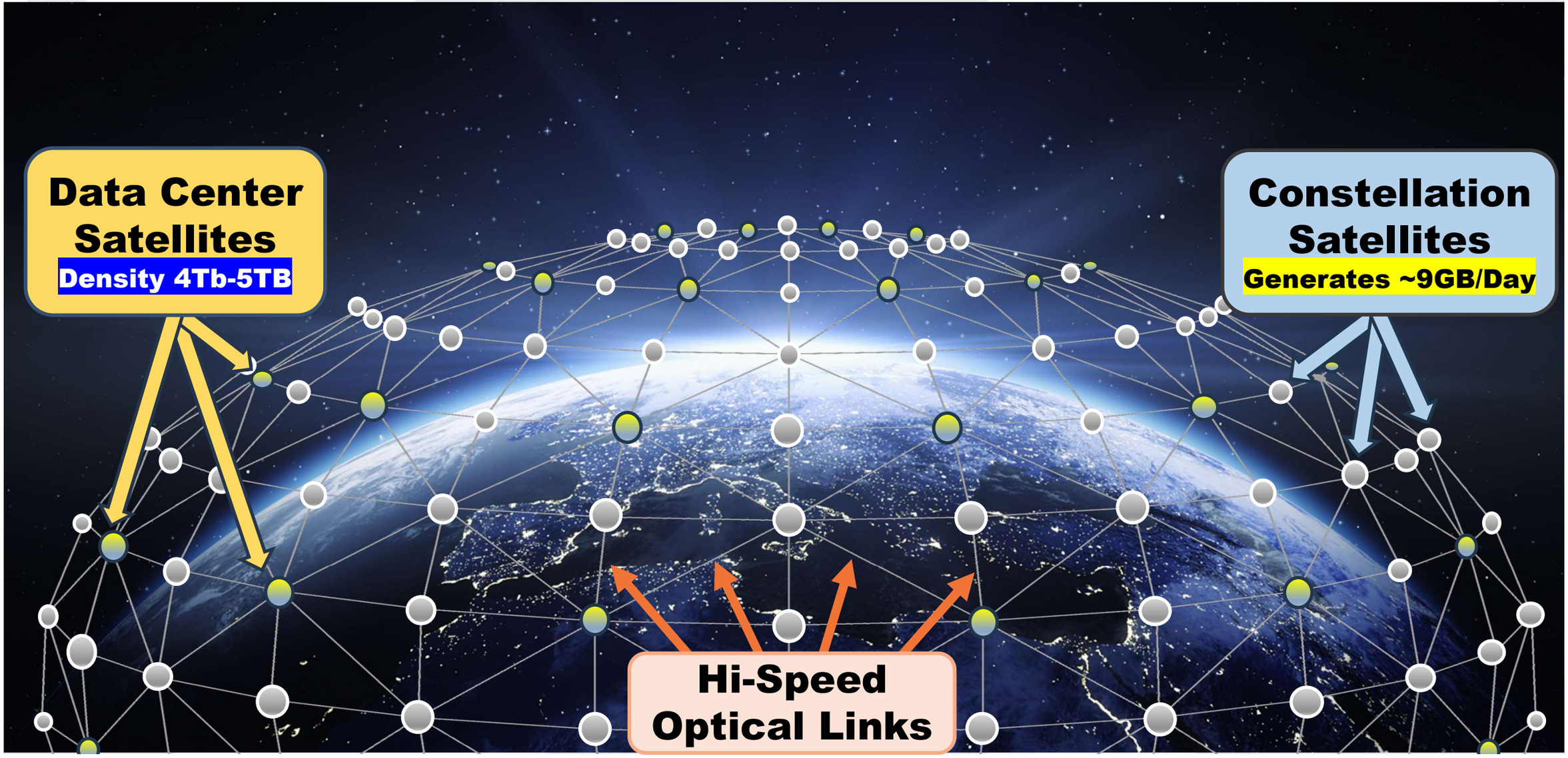
Figure 8 – Evolved Satellite Network, With Layered Comms and Distributed Data Centers

In this picture, shown as green dots, thousands of recently deployed micro satellites in Low Earth Orbit are collecting data and functioning as intelligent IoT nodes with AI engines. They communicate with one another and to the Edge (represented as red dots) using high-speed laser links, as mentioned previously. These newer Edge-based Micro Data Centers in Space can now act as temporary data buffers for the Space-IoT (micro satellites) nodes, given it is impractical to have direct links between each satellite and Earth due to the limited bandwidth RF links to Earth, number of terrestrial base stations and the line-of-sight link time to them.

For simplicity's sake, the picture above shows 6 IoT nodes for every Micro Data Center in Space, which are effectively in their own stationary position relative to one other, while orbiting Earth. Each micro satellite can now become an intelligent AI machine as shown in the block diagram depicted in **Figure 9**, with new capabilities shown in green.

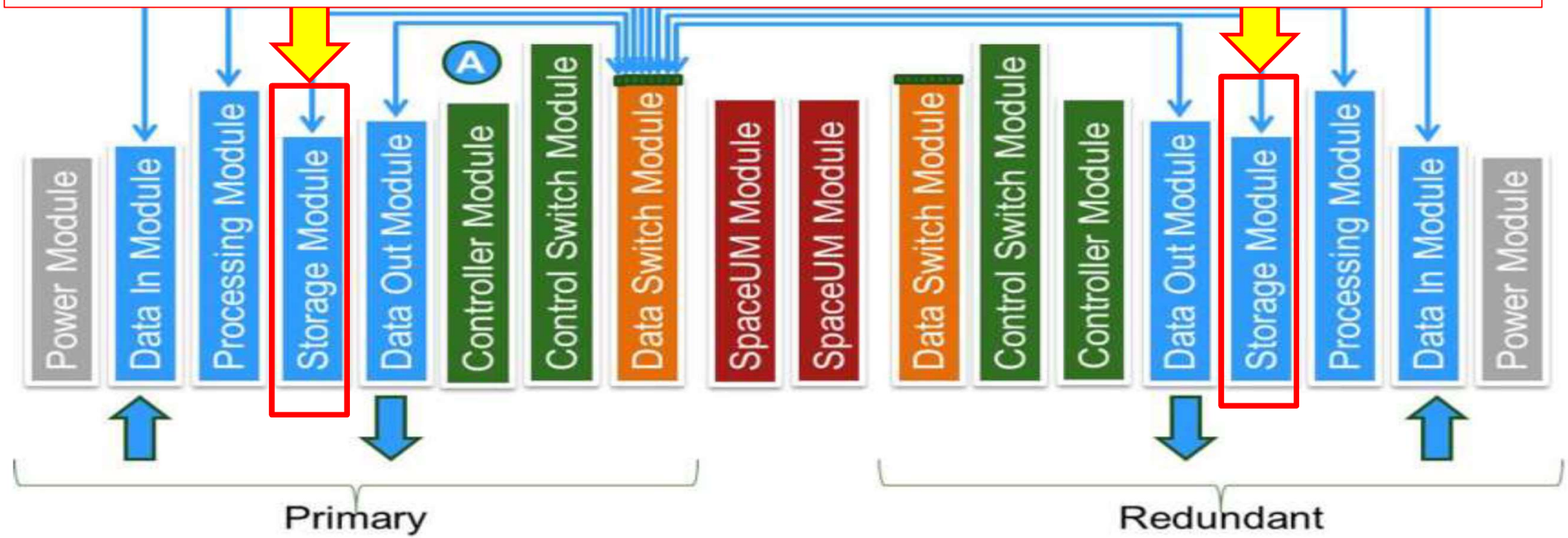
https://go.avalanche-technology.com/datacenters-in-space-whitepaper

Satellite / Constellation Challenges



Data Plane Switch Topology

For SpaceVPX Architecture – we are focusing on the Storage Class Subsystems



ADDRESSING ESCALATING DATA REQUIREMENTS

Challenges of NAND Flash Memory for Space

- Despite its many advantages in space applications, flash memory faces several severe challenges that prevent widespread adoption.[1]
  - One of the significant challenges facing flash memory in space is its inherent susceptibility to the effects of radiation.
  - NAND flash memory is particularly susceptible to single-event effects (SEE) and total ionizing dose (TID) degradation, which cause corruption and loss of stored data.
  - According to NASA, a traditional NAND flash cell, which stacks many transistors in series, making it more sensitive to gate-threshold shifts caused by TID.
- MRAM's magnetic structure provides an NVM cell **immune to radiation**
  - Avalanche MRAM traded some density for radiation hardness and very high reliability

[1] – Jake Hertz, All About Circuits, 4/25/22

Challenges of NAND Flash Memory for Space

Latest Test Results (April 2023) of 1Gb STT-MRAM Tile (Gen3/22nm)

RADIATION TEST SOLUTIONS

RTS23-J0182-01TR-1

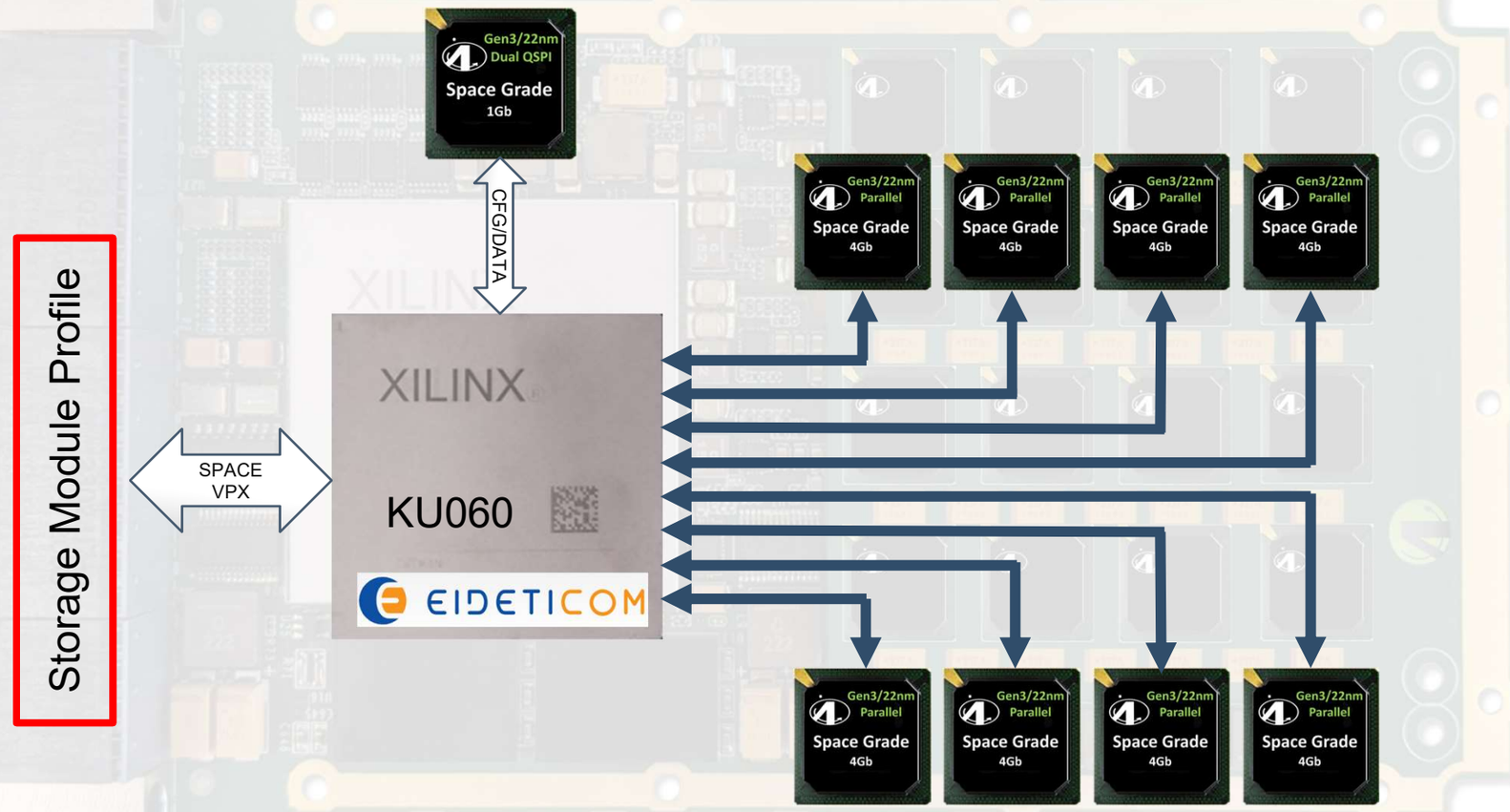
In support of Micross, the Avalanche STT-MRAM was tested for SEE (Single Event Effects) with heavy ion irradiation at the Texas A&M (TAMU) K500 Cyclotron Facility on April 12, 2023. The role of RTS in this test was to assist the customer in running the beam, suggesting ion species, and providing inputs for the successful test of the Avalanche STT-MRAM Device. Avalanche provided the control hardware, DUTs, and power supplies.

Test Result Summary:

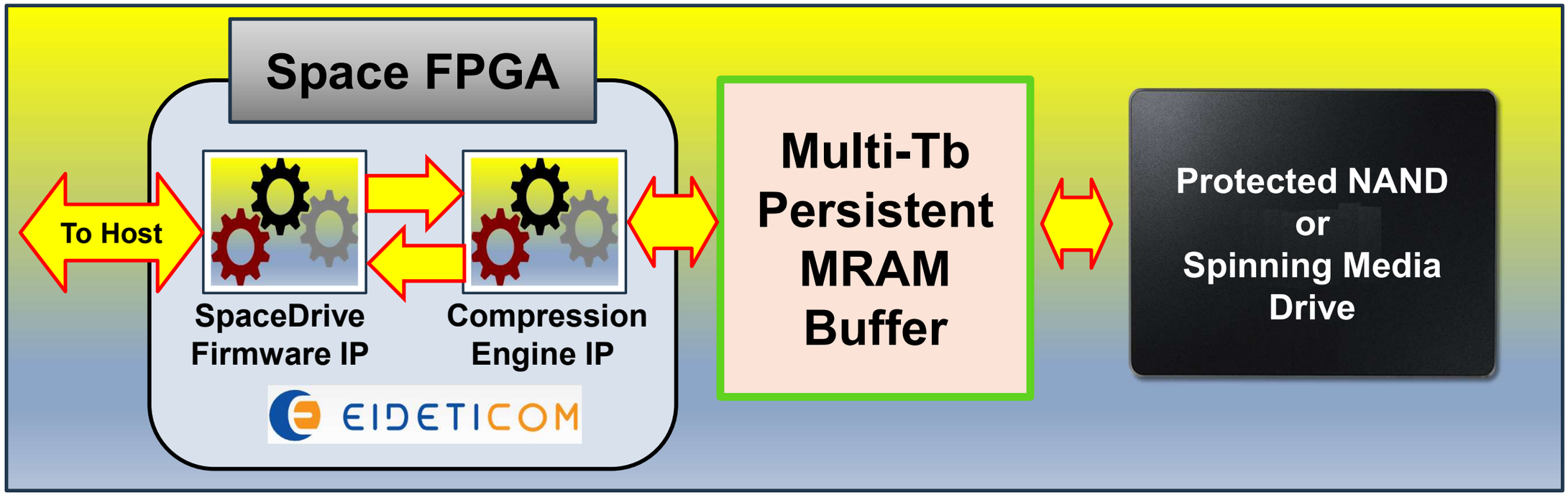
1. No high current events (HCEs) were observed on any DUT up to a LET of 58 MeV-cm²/mg, at temperatures of 120 °C or less.
2. No memory errors were observed on any DUT under any of the tested conditions.
3. No SEFIs were observed on any DUT under any of the tested conditions.
4. Since there were no HCEs and no SEFIs, it is not possible to find a LET threshold or calculate a cross-section saturation level.

MRAM-based Data Buffer Concept

8GB to 16GB Data Buffer



MRAM-based Hybrid System for Space



- MRAM used as (large) L4 Cache
- NAND/Flash Array can be powered down while cache fills

CUSTOMER/PARTNER PLATFORM EXAMPLES

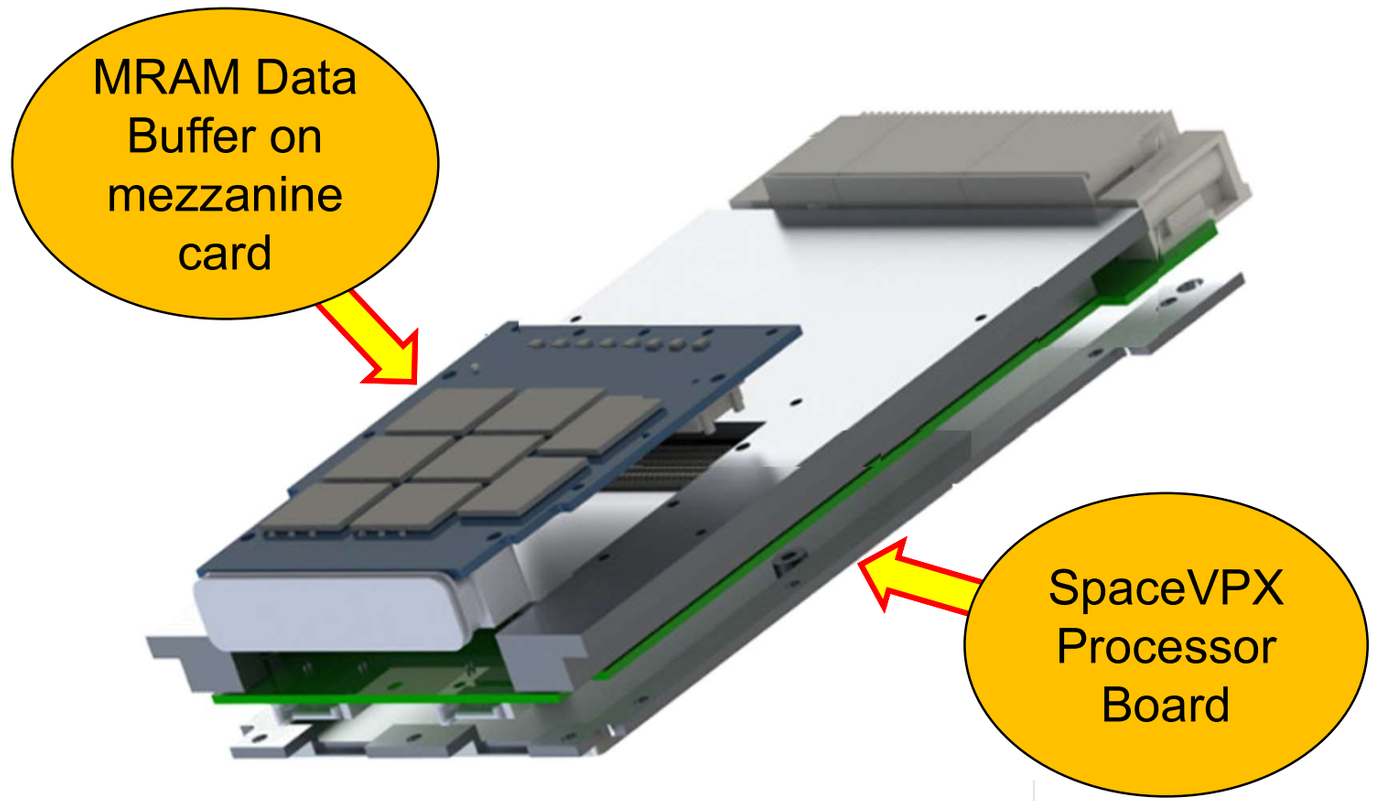
Trusted Semiconductor Solutions – 3U 64Gb Data Buffer Mezzanine

MRAM Configuration:

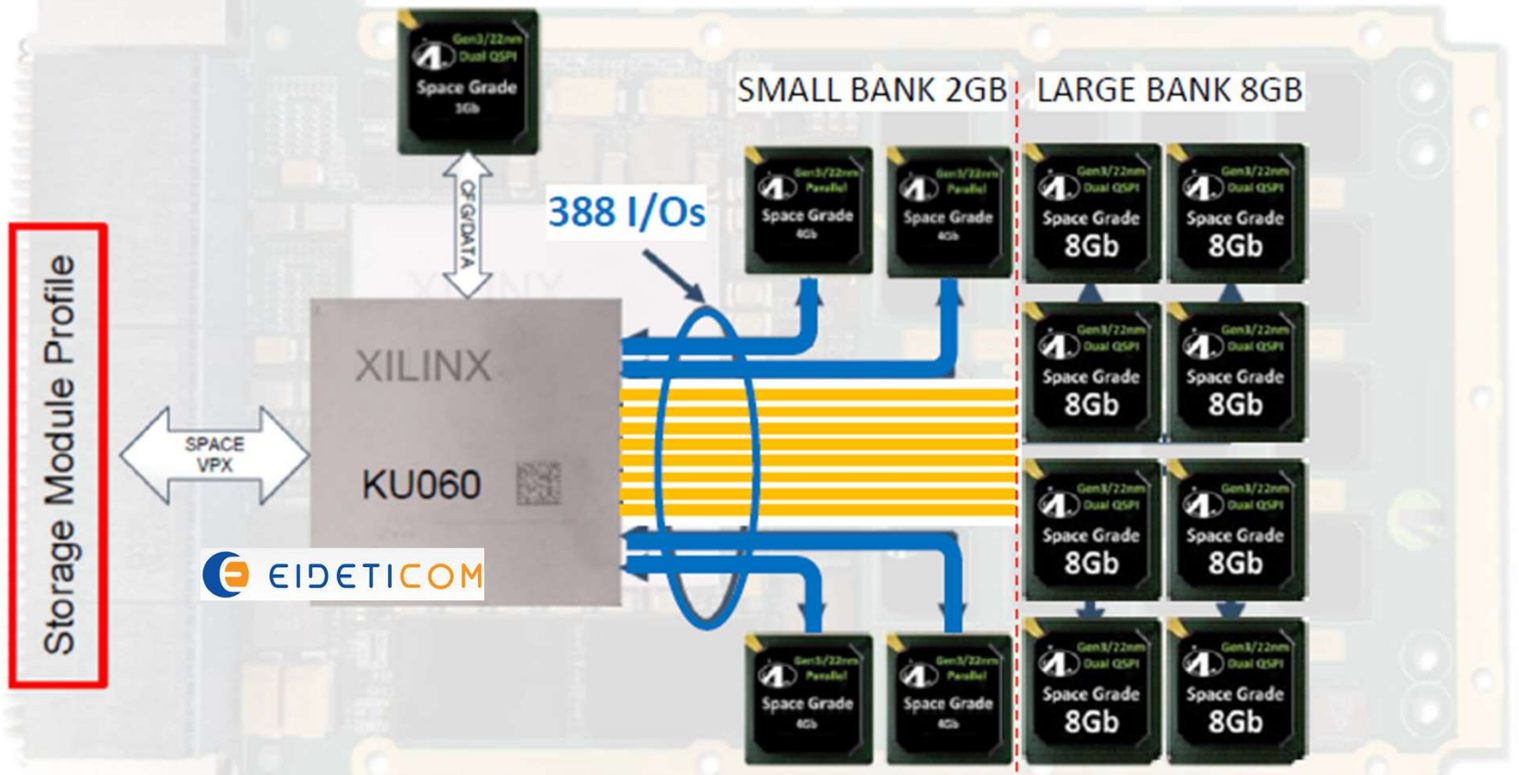
- 3U form factor
- SpaceVPX interface
- Rad Hard Single Board Computer
- MRAM daughter card
  - 4Gb devices x 16
  - Total of 64Gb / 8GB

Development Status:

- MRAM card design in process
- First hardware (Sept 2023)
- Firmware completion (Dec 2023)



Blue Halo/DDES – 3U 10GB Data Buffer Concept (1 of 2)



Design & Development Engineering Services

A BLUEHALO® Company

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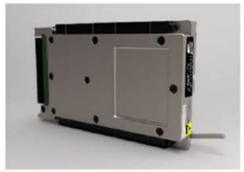
Mercury Systems Hybrid (MRAM as L4 Cache) with NAND Array

DATASHEET

In Development

mercury

Quadrium 3U VPX Rad-Tolerant, Mini-SpaceDrive Multi-Host, 350 GBytes NAND, 120 MBytes MRAM, 3.2 Gbit/s, Parallel, Octal SPI, SpaceFibre Interfaces



Models: RH3350NM6S-000I01-01

- **Rad-Tolerant non-volatile storage: 350 GBytes NAND plus 120 MBytes of MRAM**
- **Triple-Redundancy for host Data and internal ECC bytes. Four, 8-bit ECC corrections every 16 bytes of host data**
- **Lesser screened, plastic RTG4 FPGA to enable cost sensitive NewSpace applications**
- **Rad-Tolerant, by design. All components except NAND.**
- **SpaceVPX compatible, 3U VPX form-factor, single 5V supply**
- **Lower cost, lower speed, implementation of Mercury's popular SpaceDrive**
- **Multi-Host operation. Up to 6 hosts using Parallel, Octal SPI and, SpaceFibre interfaces**

The RMS350 is the first in a series of lower cost, radiation tolerant, NAND storage devices based on Mercury's popular SpaceDrive product. Using the latest generation of TLC NAND in SLC mode, the RH3350 is ideal for implementing high-reliability non-volatile storage in lower-cost applications requiring radiation tolerance.

Space grade reliability is accomplished using Rad-Tolerant, by-design components (except NAND), 3 copies of host and Reed Solomon data. To better enable lower cost NewSpace applications, lesser screened versions of true RT-by-design components are utilized. A full screened ***Premium*** version is available by special order.

The RMS350 replaces the cumbersome NAND flash command set and interface with flexible Parallel, SPI and SpaceFibre interfaces. Interfaces can be used together allowing multi-host operation. The full storage capacity is accessible by up to 6 hosts. Commands issued by interfaces are serviced based on bus ownership. Numerous status registers allow monitoring product health including PE counts, Retired Blocks, Spare Blocks, ECC errors and more. The RMS350 implements a deterministic corruption-free

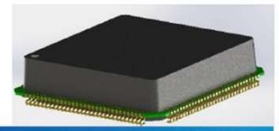
- NAND/MRAM SEE mitigations
  - Optional power cycle prior to beginning commands
  - Physical X,Y,Z placement separation of components
- Operating modes: SpaceDrive Host Addressable mode
- Data reliability:
  - Triple redundant Host and Reed Solomon ECC bytes
  - Four 8-bit corrections per 16 bytes of host data
  - Automatic retirement of worn NAND Blocks
  - PE cycle count tracking for all blocks
- Performance (up to 400 MB/s)
  - One 32-bit parallel interface (up to 400 Mbyte/s)
  - Two 16-bit parallel interfaces (up to 200 Mbyte/s each)
  - Four 8-bit parallel interfaces (up to 100 Mbyte/s each)
  - Octal SPI interface (up to 100 Mbyte/s)
- NAND endurance:
  - Minimum 60,000 drive overwrites per Block (PE cycles)
  - Total Bytes Written (TBW): 21 PBytes

DATASHEET

In Development

mercury

Quadrium Rad-Tolerant, Triple Redundant, Mini-SpaceDrive Multi-host, 350 GBytes NAND,120 MBytes MRAM 3.2 Gbit/s, 120 pin Quad Plastic Package



Models: RMS350NM6S-000I01-01

- **Rad-Tolerant non-volatile storage: 350 GBytes NAND plus 120 MBytes of MRAM**
- **Triple-Redundancy for Data and ECC bytes. Four, 8-bit, ECC corrections every 16 bytes of host data**
- **Lesser screened RTG4 FPGA to better enable cost sensitive NewSpace applications**
- **Rad-Tolerant, by design. All components except NAND.**
- **Compact solder down form-factor, single 5V supply**
- **Lower cost implementation of Mercury's popular SpaceDrive product**
- **Multi-Host operation. Up to 6 hosts using Parallel, Octal SPI, SpaceFibre interfaces**

The RMS350 is the first in a series of small form-factor radiation tolerant NAND storage devices based on Mercury's popular SpaceDrive (SSDR) product and packaged in a solder-down form-factor. Using the Micron B27C TLC NAND device in SLC mode, the RMS350 is ideal for implementing high-reliability non-volatile storage in lower-cost applications that require radiation tolerance.

Space grade reliability is accomplished using Rad-Tolerant, by-design, components (except NAND), and 3 copies of host and Reed Solomon data. To better enable lower cost NewSpace applications, lesser screened versions of true RT-by-design components are utilized. A full screened Premium version is available by special order.

The RMS350 replaces the cumbersome NAND command set and interface with flexible Parallel, Octal SPI, and SpaceFibre interfaces. Interfaces can be used together allowing multi-host operation. The full storage capacity is accessible by up to 6 hosts. Commands issued by interfaces are serviced based by bus ownership and order received. Numerous status registers allow monitoring product health including PE counts, Retired Blocks, Spare Blocks, ECC errors and more. The RMS350 implements a deterministic, corruption-free shutdown process with an optional external capacitor to supply a

- NAND/MRAM SEE mitigations
  - Optional power cycle prior to beginning commands
  - Physical X,Y placement separation of NAND components
- Data reliability:
  - Triple redundant Host and Reed Solomon ECC bytes
  - Four 8-bit corrections per 16 bytes of host data
  - Automatic retirement of worn NAND Blocks
  - PE cycle tracking for all blocks
- Performance (up to 400 MB/s total)
  - One 32-bit parallel interface (up to 400 MByte/s)
  - Two 16-bit parallel interfaces (up to 200 MByte/s each)
  - Four 8-bit parallel interfaces (up to 100 MByte/s each)
  - Octal SPI interface (up to 100 MByte/s)
  - SpaceFiber interface: (up to 290 MBytes/s)
- NAND endurance:
  - Minimum 60,000 drive overwrites per Block (PE cycles)
  - Total Bytes Written (TBW): 21 PBytes
  - Up to 32 full drive over-writes/day for 5 years
  - 1-month retention at NAND EOL (72°C)
  - Host capacity is constant across life

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Mercury Systems Hybrid (MRAM as L4 Cache) with NAND Array

DATASHEET

Concept

mercury

Indigo 3U PCIe SpaceVPX *SpaceSSD* (First product in the *SpaceSSD* Series)
10 Gbit/s PCIe Rad-Tolerant Small-Block 530 GB Solid State Drive

Models:
RH3530NM6S-000I30-01 (530 GB EDU), RH3530NM6S-000I30-02 (530 GB Flight unit)

- **Radiation-tolerant storage for space and commercial applications with potential for radiation exposure**
- **Small block sizes: 4096, 8192, 16384, or 18,432 bytes per write operation (host selectable)**
- **3D TLC NAND in SLC mode (60K PE cycles)**
- **Triple-Redundant data paths for both host data and ECC provides exceptional data reliability**
- **3U 220 mm VITA 78.00 2.0 SpaceVPX compatible form-factor**
- **Single 5V supply**

The Mercury RH3530 is the first product in the ***SpaceSSD*** series of radiation tolerant SpaceDrives. Products in the ***SpaceSSD*** series include the architectural features of the RH3440, RH3480, and RH304T SpaceDrives while operating more similarly to an industry standard hard drive by implementing small block sizes ranging from 4K to 18K bytes.

Like all Mercury SpaceDrives, the RH3530 incorporates components that are radiation tolerant ***by design***, except for the NAND flash. The NAND flash is a Micron B27C TLC device running in SLC mode. Mercury has characterized this NAND for both SEE and TID and specifies robust operation to greater than 30 krad (Si). NAND is screened to NASA EEE-INST-002 with RLAT/DPA performed on all NAND lots.

The RH3530 has new architectural features including an internal backup power supply and triple redundancy for both host data and Reed Solomon ECC check symbols.

The RH3530 is precision-engineered to thrive in the harshest commercial and space environments. These high reliability drives are perfect for storage applications with the potential for radiation exposure on the ground, in the air, and in space.

Standard Features

- Capacity vs (Page size)
  - 625 GB (18K), 530 GB (16k), 265 GB (8K), 132 GB (4K)
- Operating mode: Hard drive
  - Selectable block size: 4K, 8K, 16K, 18K
  - Constant random performance until Garbage Collection (GC) limit
  - GC limit is 2 drive OverWrites beyond initial full capacity
  - Garbage collection time: < 10 min (TBV)
- Data reliability
  - Backup power supply: Capacitor array
    - Deterministic power off control under all conditions
    - Eliminates corruption from unexpected power loss
  - Four ECC corrections in every 12 bytes of data (host + ECC bytes)
  - Triple redundant data and Reed Solomon ECC
  - Constant host capacity maintained across entire life
  - 4 Spare NAND devices can replace any failed NAND Lane
- Host Interface and performance
  - PCIe interface: 2.5 Gbits/sec per lane. 8-Lanes organized as 2x4-Lanes
  - Dual Port mode: 8-Lanes organized as 2x4-Lanes.
    - Performance: 10 Gb/s.
    - Ping/Pong of data between two 4-Lane ports
  - Dual Host mode: 4-Lanes to each host
    - Performance: 5 Gbit/s per host, 4 Lanes to each of 2 hosts
    - Serial access of the SpaceDrive. Entire memory space accessible.
- Radiation-tolerant design approach:
  - NAND: Micron B27C die, PEM. TID >30 krad (Si).
  - NAND screened to EEE-INST-002. RLAT/DPA on all lots.
  - NAND Controller: Microsemi RTG4, TID > 100 krad (Si)
    - Configuration upsets immunity to LET > 103 MeV.cm2/mg
    - Single-event latch-up (SEL) immunity to LET > 103 MeV.cm²/mg
    - Registers SEU rate < 10-12 errors/bit-day (GEO Solar Min)
    - SET upset rate < 10-8 errors/bit-day (GEO Solar Min)
  - All other devices: Radiation Tolerant, by design, to 100 krad (Si)
- VPX connectors:
  - Guide block key is adjustable and ships in the 0° position
  - WaveTherm wedgelock torque: 6-10 in-lbs
  - Smith's KVPX Series: 500 mate/unmated cycles
  - TE connectivity MultiGig RT 2-R Series: 500 mate/unmated cycles
- NAND endurance:
  - Minimum 60,000 drive overwrites (PE cycles)

.mrcy.com

DATASHEET

CONCEPT

mercury

Rad-Tolerant 6U VPX 100 Gbit/s Quad-Host SpaceDrive
Host Capacity of 22 TB NAND plus 400 MBytes MRAM
PCIe and mFAST interface options

Models:
RH622TNM6S-000I22-01 (22 TB EDU), RH622TNM6S-000I22-02 (22 TB Flight unit)

- **Radiation-tolerant storage for space and commercial applications with potential for radiation exposure**
- **22 TB using 3D TLC NAND in SLC mode (60K PE cycles)**
- **400 Mbytes of general purpose MRAM (100 MB/s)**
- **6U VITA 78, 220mm (SpaceVPX compatible) form-factor**
- **Rad-Tolerant components**
- **Single 5V supply**

The RH622T is the second product in the Mercury's ***SpaceMax*** series of radiation tolerant SpaceDrives. Designed to maximize both performance and capacity, the RH622T supports a raw data rate of 160 Gbps and a sustained host data throughput of 100 Gbits/s. This represents a 5.5X improvement in performance and a 4.8X increase in capacity compared to the Boron 4.5TB SpaceDrive.

Like all members of the ***SpaceMax*** series, the RH622T utilizes the latest generation of 3D TLC NAND running in SLC mode. Host capacity remains constant across the entire life through use of very strong error correction and more than 16% of additional capacity dedicated to spare blocks.

To keep power consumption low, the RH622T utilizes multiple low power PolarFire FPGAs operating in parallel. Each PolarFire manages 25% of the capacity using four 10-Gbps SERDES Lanes per PolarFire. A single host can control the entire capacity, or four hosts can each control 25% of the capacity independent from the other 75% of the capacity.

Designed for fault-tolerance with multiple failed NAND devices, the RH622T SpaceDrive is the world's fastest and most reliable nonvolatile VPX storage device and is ideal for applications where full-time availability and high reliability are requirements.

- Radiation-tolerant design details:
  - NAND: Micron B27C die, PEM. TID >30 krad. Screened to EEE-INST-002
  - MRAM: Avalanche Gen3. 100 krad TID, SEE > LET 45 MeV.cm2/mg
  - PolarFire NAND Controller
    - TMR of critical logic. 1.2V IOs for best SEL tolerance.
    - Total ionizing dose (TID) > 100 krad
    - Configuration upsets immunity to LET > 80 MeV.cm2/mg
    - Single-event latch-up (SEL) immunity to LET > 80 MeV.cm²/mg
    - Registers SEU rate < 10-12 errors/bit-day (GEO Solar Min)
    - SET upset rate < 10-8 errors/bit-day (GEO Solar Min)
  - All other devices: Radiation Tolerant, by design, to >100K rad
- VPX connectors:
  - Guide block key is adjustable and ships in the 0° position
  - Smith's KVPX Series: 500 mate/unmated cycles
  - TE connectivity MultiGig RT 2-R Series: 500 mate/unmated cycles
- Operating modes: Linear and Host Addressable
  - Linear Mode: Sequential data recording (Data recorder mode)
  - Host Addressable mode: operations on individual NAND blocks
  - Random SuperPage read operations: Both modes.
  - SuperPage size: 294,912 (per Port), 1,179,648 (4-Port mode)
  - SuperBlock size: 339,738,624 (per Port), 1,358,954,496 (4-Port mode)
  - UltraBlock size: 5,435,817,984 (per Port), 21,743,271,936 (4-Port mode). 1024 UltraBlocks

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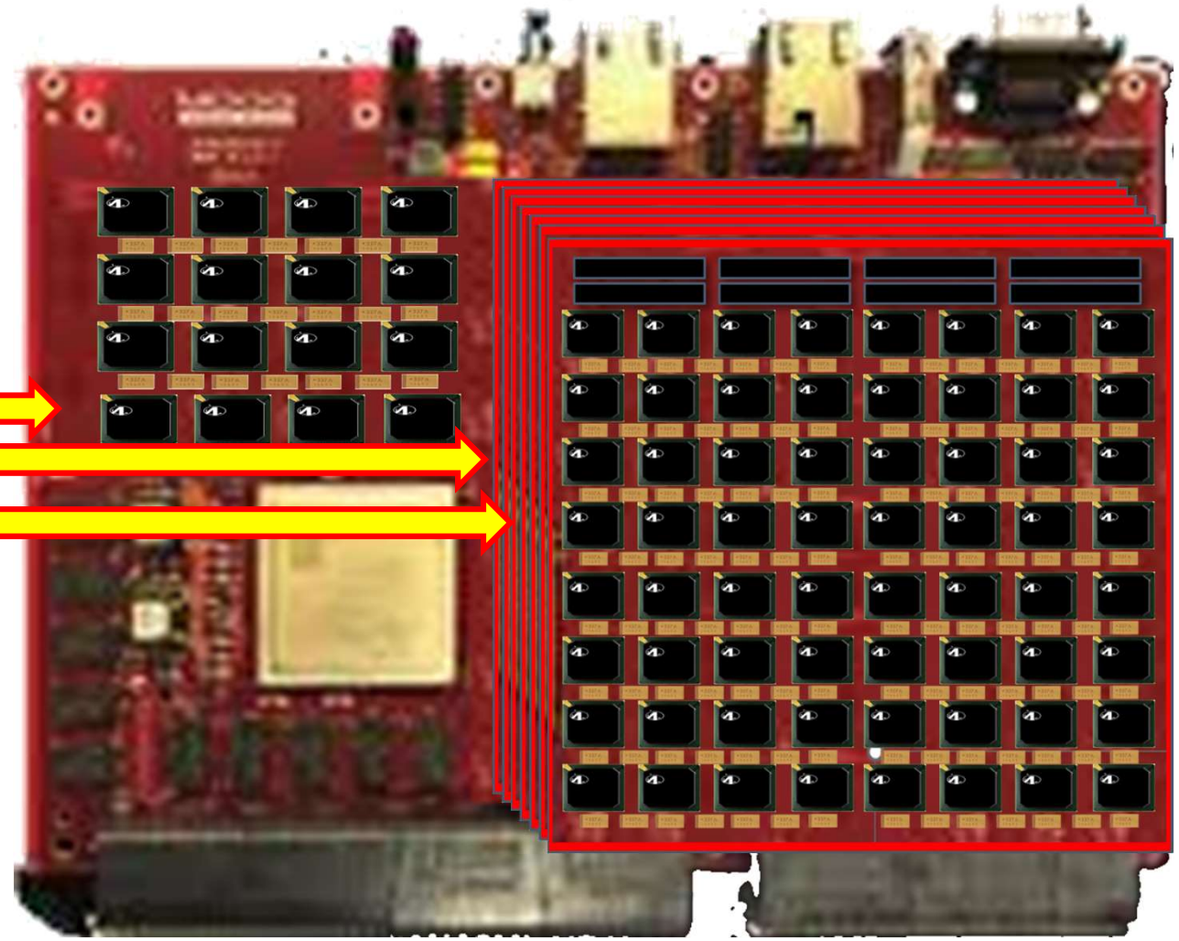
Customer Concept: 4Tb All MRAM Space SSD

4Tb All-MRAM Space SSD

- High Endurance 10^{16} - No Wear Leveling
- No Radiation Effects in Memory Array
- Uses 4Gb parallel devices as L4 Cache
- Base board has 512Gb capacity
- Each daughter card has 512Gb capacity
- System accommodates 7 daughter cards
  - Densities from 512Gb to 4096Gb
- Leverages low-power of Avalanche MRAMs



Mercury Systems' All-MRAM space SSD Concept

DATASHEET

Early Concept

mercury

Magneto 6U All-MRAM SpaceDrive (*DeepSpace* Series)
100 Gbit/s Rad-Tolerant Quad-Host 1 TB Solid State Recorder

Models: **RH601TNAMS-000I10-01** *(1 TByte EDU),* **RH601TNAMS-000I10-02** *(1 TByte FLT)*

- **TID: > 100 krad (Si), SEE: > 70 LET**
- **Multiply redundant storage for high reliability space applications**
- **All space-grade MRAM, no NAND or DRAM. Virtually wear-out proof storage**
- **6U SpaceVPX compatible form-factor**
- **Small/Adjustable block size and very high performance**
- **Single 5V supply**

Mercury's ***DeepSpace*** series of radiation-tolerant data recorders are designed for longer missions requiring higher reliability. The products utilize the highest quality RT-by-design-components available.

Unlike previous Mercury SpaceDrives, the Magneto SpaceDrive uses space-grade MRAM instead of NAND as the storage element. The use of MRAM significantly improves radiation tolerance and removes many performance limitations. With MRAM there is no ERASE time penalty. Data can be written to the same location repeatedly. Read and write latency is reduced, and temperature tolerance is improved. Applications implementing file systems can take advantage of Magneto's

Standard Features - continued

- All components RT-by-Design, 100 krad minimum
- Redundancy in both power and storage logic
- SERDES high speed Interface
  - SpaceFibre at 10 Gbps per Lane
  - Support for up to 4 hosts, 1 Fat-Pipe to each host.
  - Optical interface at 10 Gbps, copper for lower speeds
- Performance (SpaceFibre)
  - Writes/Reads: Up to 100 Gbits/sec (16-Lane mode)
  - Writes/Reads: Up to 25 Gbits/sec (Fat-Pipe per host)
  - Support for simultaneous reads/writes (different addresses)
- SPI interface: X1, X4, X8 (Control/Status/Data)
- Alternate serial control interface (planned)

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BOOTING NEW ADAPTIVE SOCS AND FPGAS

Congrats to AMD/Xilinx for Deploying the World's Highest AI Perf/Watt

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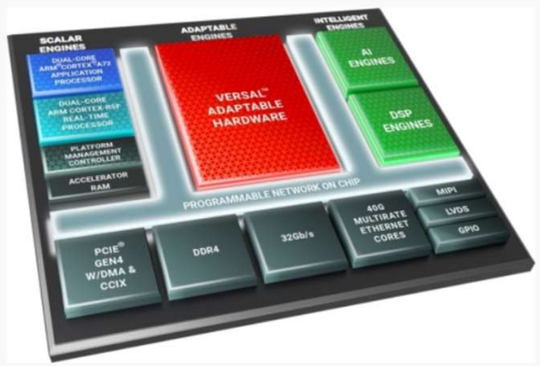
Xilinx Extends Edge Compute Leadership with World's Highest AI Performance-per-Watt

New Versal AI Edge ACAP series delivers AI-enabled intelligence for automotive, robotics, healthcare, and aerospace applications



The Versal AI Edge series is the newest member of the Versal ACAP portfolio, adaptive SoCs that are fully software-programmable, with performance and flexibility that far exceed that of conventional CPUs, GPUs, and FPGAs. (Graphic: Business Wire)

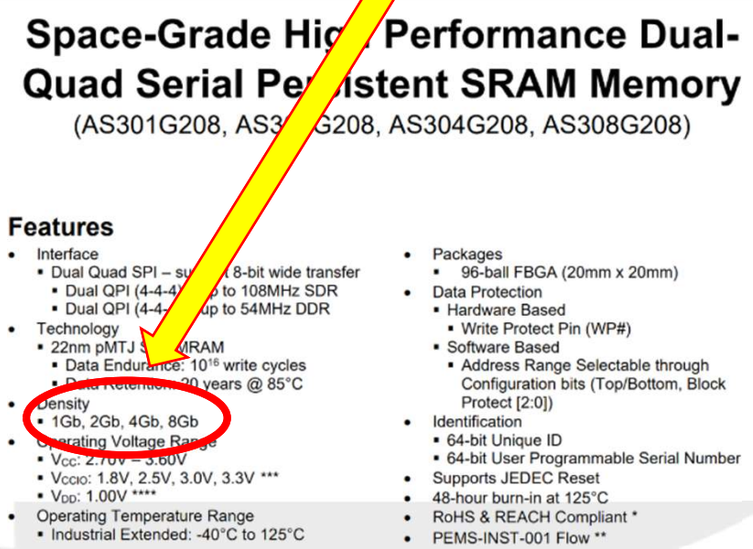
Versal Boot Memory Addressing Limits

From: Versal ACAP System Software Developers Guide (UG1304)

Table: Boot Mode Search Limit

Boot Mode	Search Offset Limit
OSPI (single, dual-stacked)	8 Gb
QSPI24 (dual-parallel)	256 Mb
QSPI24 (single, dual-stacked)	128 Mb
QSPI32 (dual-parallel)	8 Gb
QSPI32 (single, dual-stacked)	4 Gb
SD0 (3.0), SD1 (2.0), SD1 (3.0), or eMMC1	8191 FAT files (default)
eMMC1 (raw)	eMMC device size

Note: When using OSPI or QSPI dual-stacked mode, the BootROM ca…ly access the lower QSPI or OSPI addressable flash memory space for boot. After boot, the PLM can access the upper QSPI or OSPI… additional image storage.



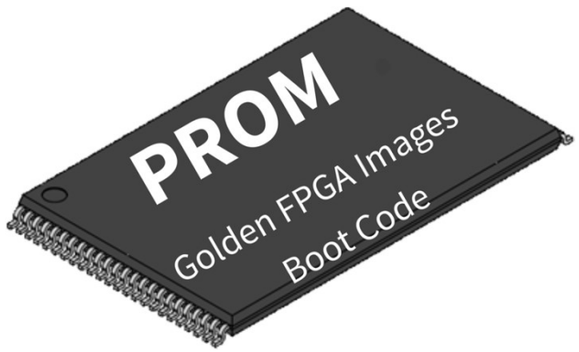
Space-Grade Hig… Performance Dual-Quad Serial Pe…istent SRAM Memory

(AS301G208, AS3…G208, AS304G208, AS308G208)

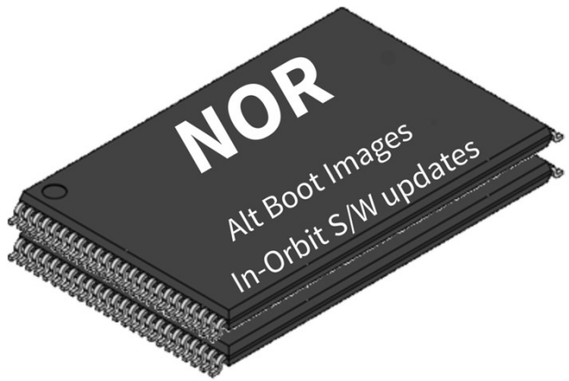
Features

- Interface
  - Dual Quad SPI – su… 8-bit wide transfer
    - Dual QPI (4-4-4) …p to 108MHz SDR
    - Dual QPI (4-4-…up to 54MHz DDR
- Technology
  - 22nm pMTJ S…MRAM
    - Data Endurance: 10^{16} write cycles
    - Data Retention: …20 years @ 85°C
- Density
  - 1Gb, 2Gb, 4Gb, 8Gb
- Operating Voltage Range
  - V_{CC}: 2.70V – 3.60V
  - V_{CCIO}: 1.8V, 2.5V, 3.0V, 3.3V ***
  - V_{DD}: 1.00V ****
- Operating Temperature Range
  - Industrial Extended: -40°C to 125°C
- Packages
  - 96-ball FBGA (20mm x 20mm)
- Data Protection
  - Hardware Based
    - Write Protect Pin (WP#)
  - Software Based
    - Address Range Selectable through Configuration bits (Top/Bottom, Block Protect [2:0])
- Identification
  - 64-bit Unique ID
  - 64-bit User Programmable Serial Number
- Supports JEDEC Reset
- 48-hour burn-in at 125°C
- RoHS & REACH Compliant *
- PEMS-INST-001 Flow **

Discrete Memory Domains with Legacy Memory Approach



ROM/PROM
No software overrides
Golden Image/Boot Loaders



Write Protected
Software override to Store
New Images up to size

[Optional] Volatile Execute Memory for Storing Transient Data

Unified Memory : Multiple Domains, Multiple Regions, Single Device

Today's Implementation:

Your Designs with Avalanche

RadHard Boot Devices Large Enough to Support FOTA

Robust Support for Golden Images (hardware pins emulate ROMs)
- Reliable fallback mechanism for an “update anomaly”

Support for Large Densities
- Storing multiple FPGA images is only part of the FOTA story…
- …updating the RTOS (Linux) and the Applications are driving today’s density requirements
- …a customer is using a Versal AI Core w/ 64Gb (8 x 8Gb) for Full Linux PLUS regular AI/ML Model Updates

Effectively Unlimited Endurance
- 10^{16} endurance means that you can write (continuously) to the same byte for ~15 years without wearing out
- Not a realistic scenario, but now you can consider our MRAMs as unlimited endurance – no “virtual” about it

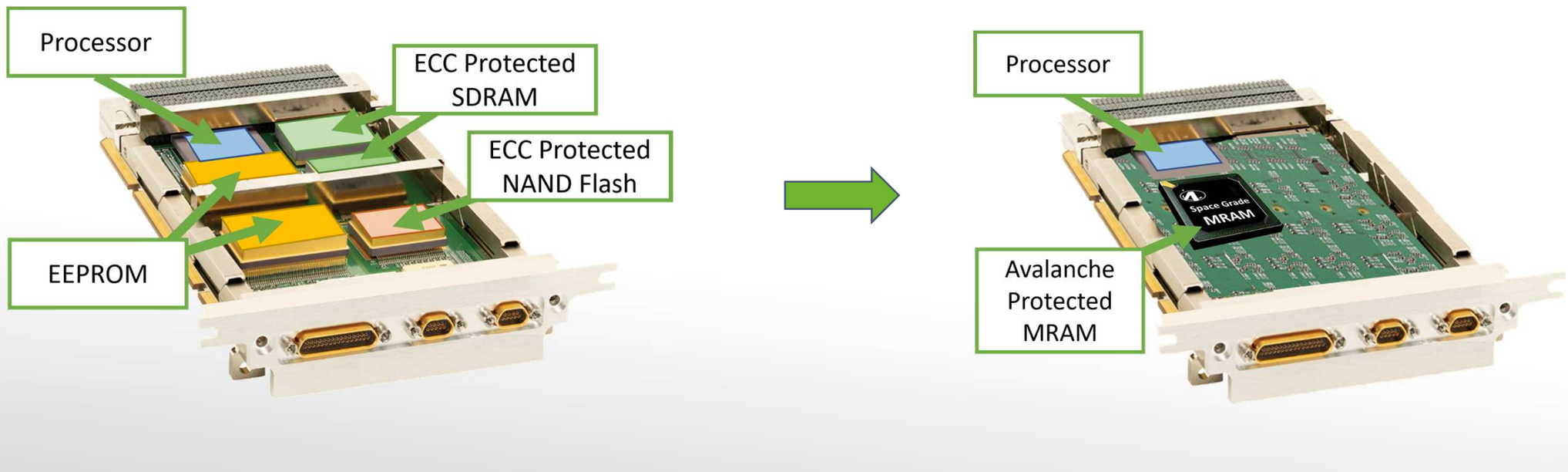
Architectural Simplification with a Unified Memory model
- Multiple domains and regions makes flight system architectures simpler than terrestrial systems

RadHard Boot Devices Large Enough to Support FOTA

Robust Support for Golden Images (hardware pins emulate ROMs)

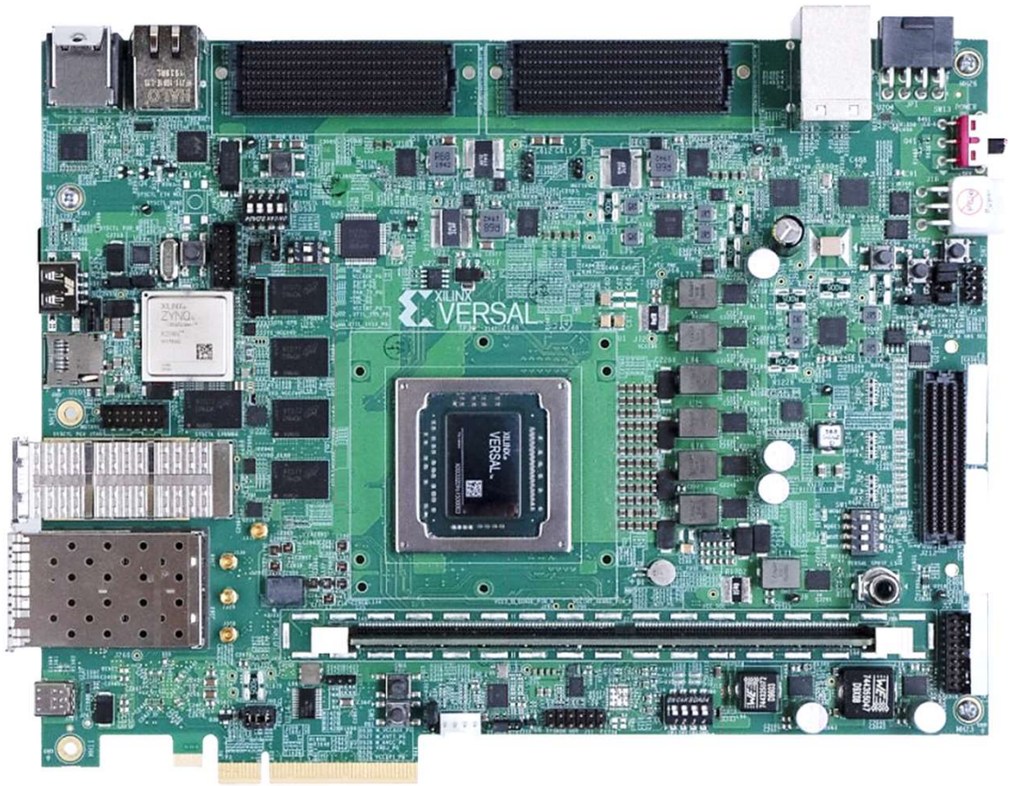
- Reliable fallback mechanism for an "update anomaly"

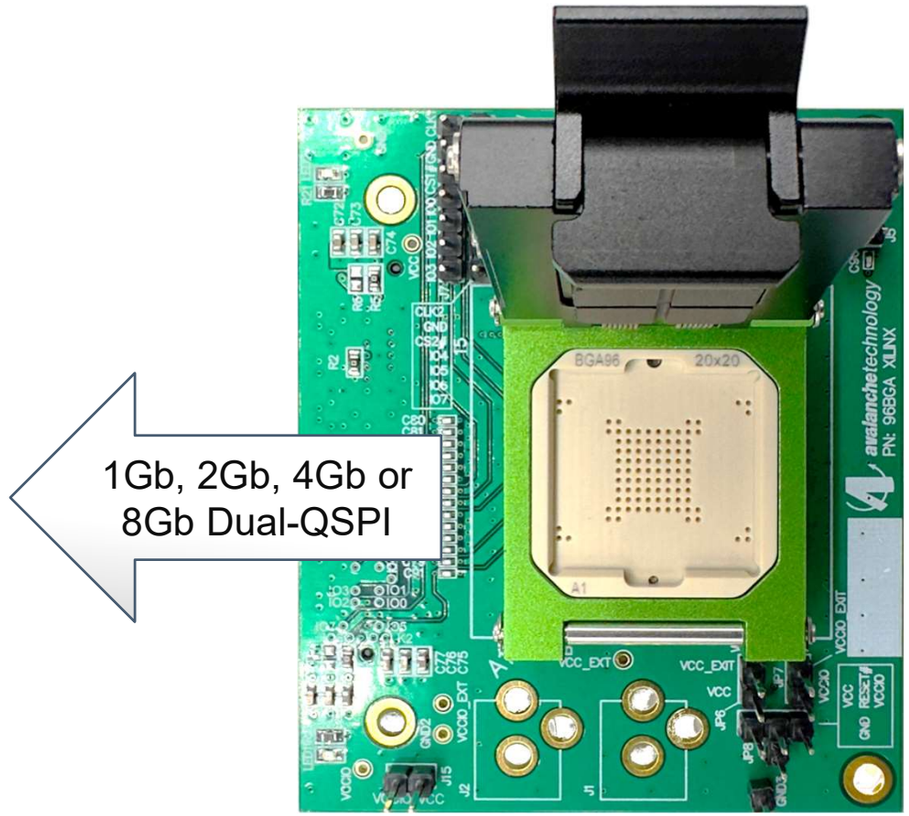
Architectural Simplification with a Unified Memory Model



Booting Versal on a VCK190 Platform

Application is “Modified GPIO Demo” from *Versal ACAP Embedded Design Tutorials using* Petalinux





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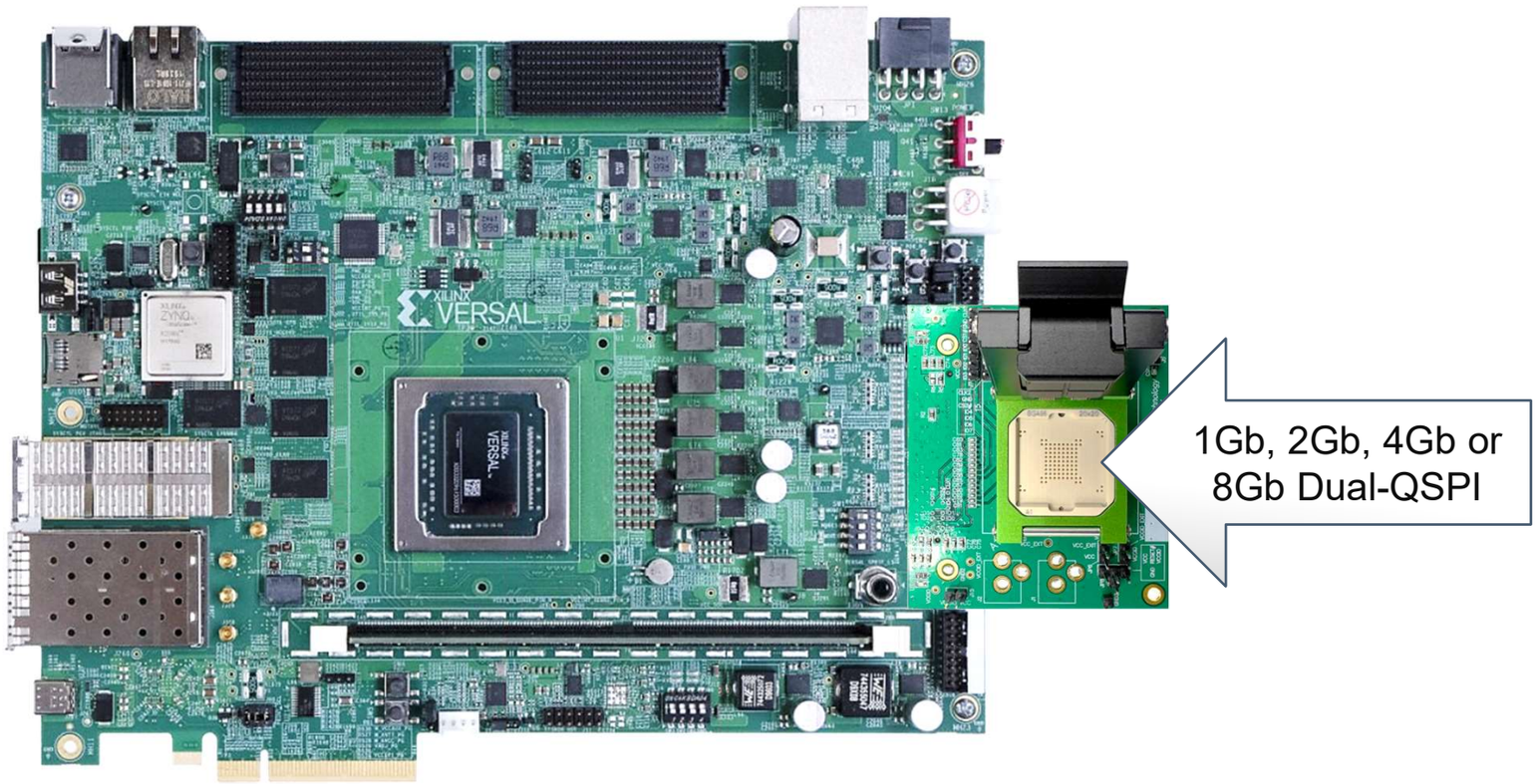


User Guides & Examples available for Versal, UltraScale+, and UltraScale

Please contact Avalanche Support to Download the Latest Version

Summary Avalanche MRAM Value Proposition for Space

Best SWaP

- **Highest Density** (up to 8Gb)
- **Lowest Power** (10mA/Gb)
- No Shielding Required
- COTS+ screening flows

Unified Memory

- Low latency, I/F like SRAM
- **Boot large images + RTOS + working mem**
- Flexible, robust write protection
- **Architectural simplification**

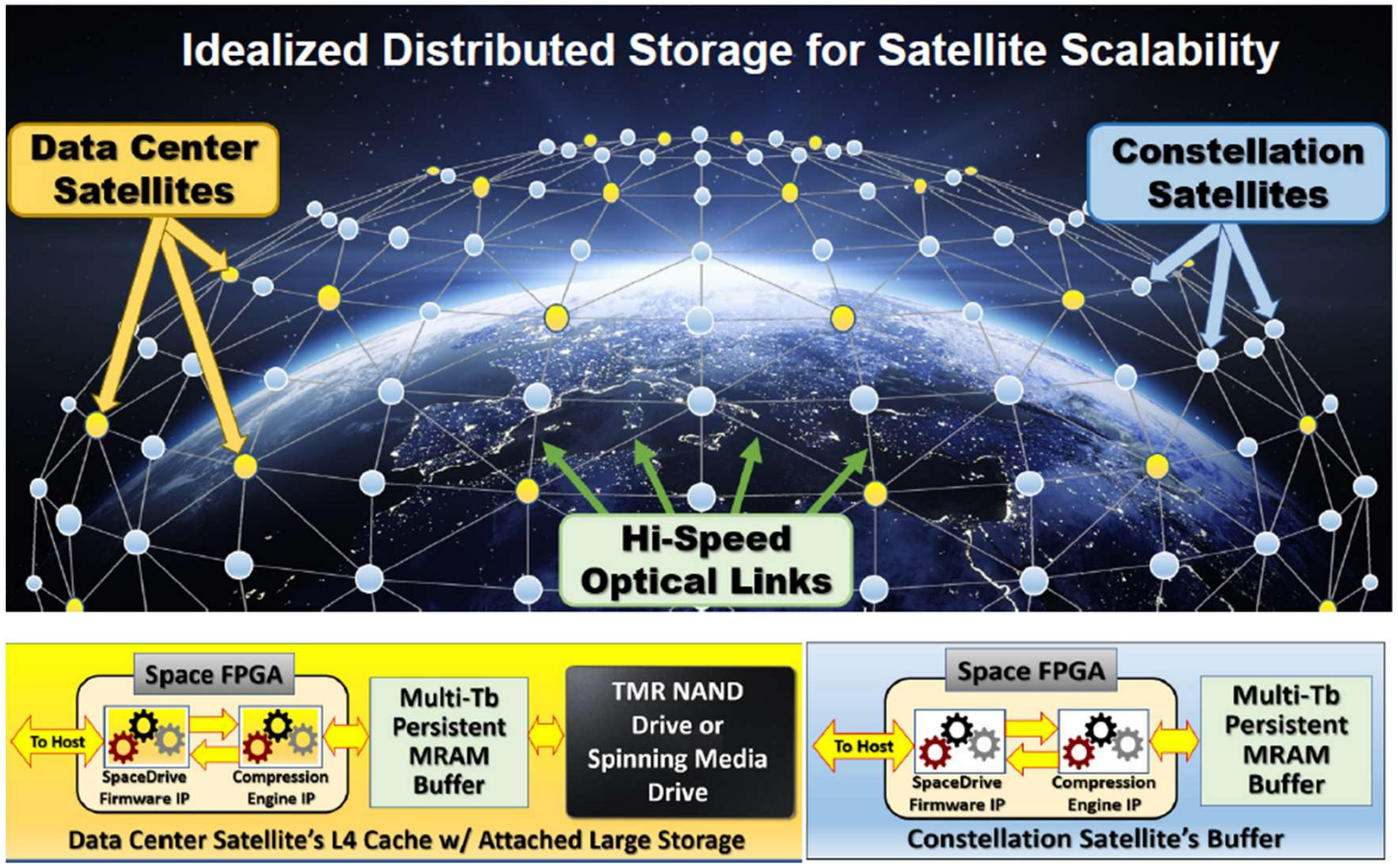
Hi-Rel by Design

- **ECC w/ Multibit Correction**
- **Highest Endurance**
- Inherently RadHard Cell
- RHBD for CMOS Protection

On-Shore / QML

- Domain Experts in RadHard & Testing
- **40+ years in PEMS & QML quals**
- US Wafer Banks for Supply Assurance
- Avalanche will use Micross Packaging

What Does All This Mean to our Satellite Network Data Problem?



- Improved Network Scalability
- Mission Adaptability in Orbit
- Distributed Intelligence & Storage
  - Improved Mission Range
  - Enhanced Network Resilience
  - Satellites More Resilient to Threats in Real Time

Thank You!

avalanchetechnology

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