avalanchetechnology

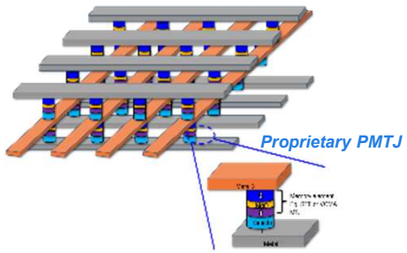
High Density MRAM update

Paul Chopelas, General Manager, Aerospace and Defense

RHET Conference
November 9th, 2023
Allen, Texas

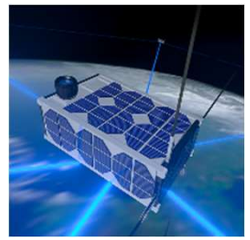
Avalanche Company Overview

Hi-Rel STT pMTJ MRAM since 2006



17+ 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

Technology funded by DARPA in 2008

Most Next-Gen/STT MRAM Patents Stateside

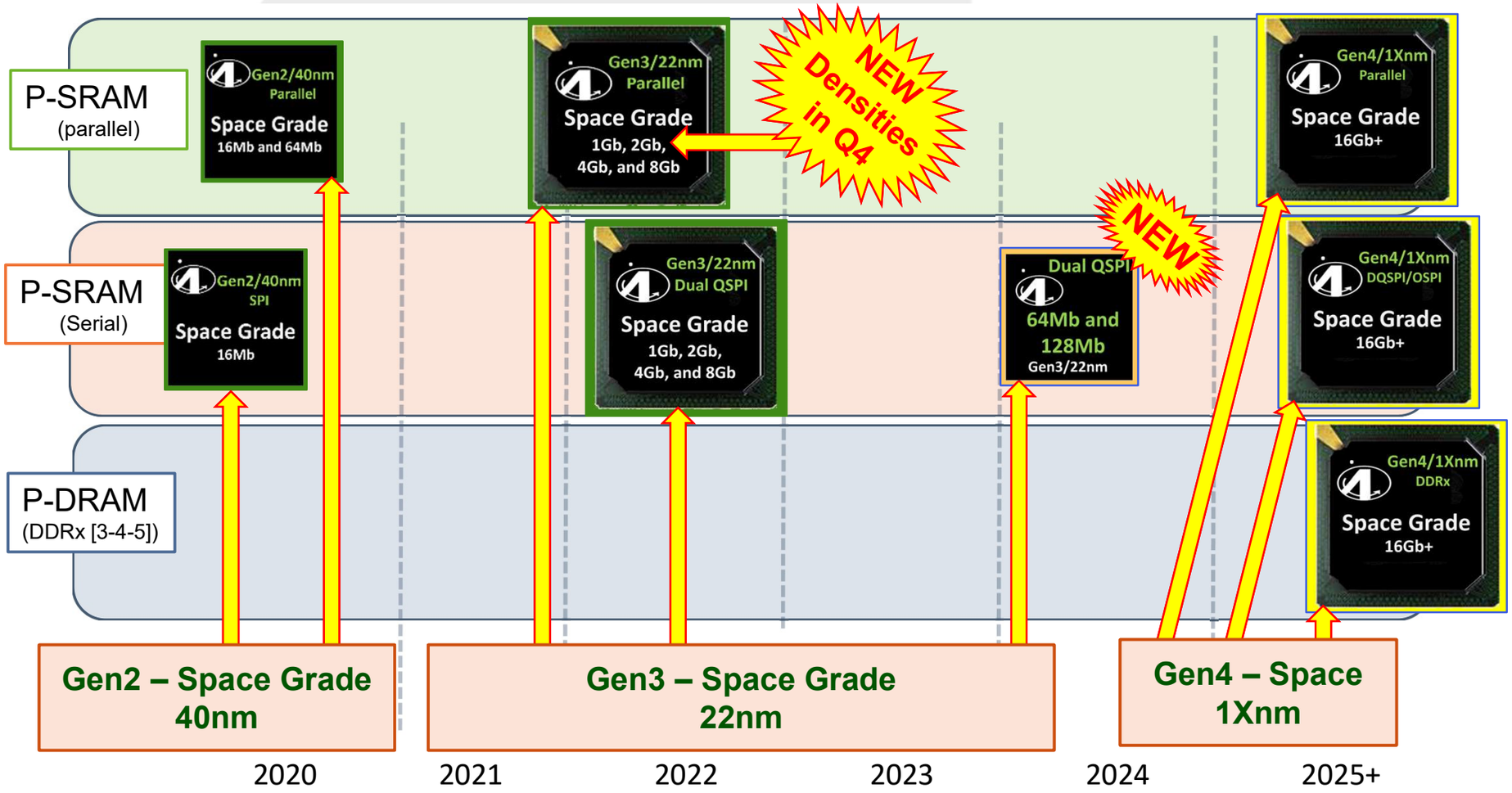
Growing Ecosystem

micross one source. one solution.
EIDETICOM
falcon electronics
XILINX
NanoXplore
APOGEE SEMICONDUCTOR™
Protec GmbH Vertrieb elektronischer Bauteile
MICROCHIP
Lattice Semiconductor Corporation
FRONTGRADE
UMC
SONY
RADIATION TEST SOLUTIONS

Growing Fab and Partner Ecosystem…

SILICON ROADMAP AND RADIATION

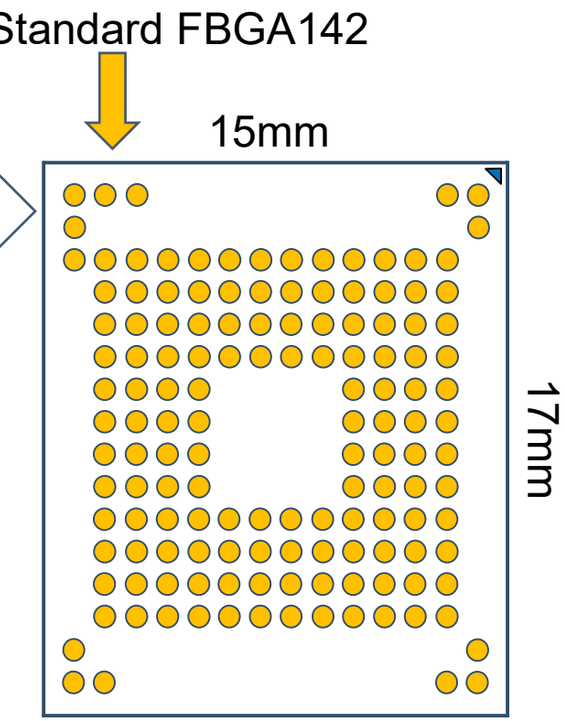
Avalanche Current Products and Future Roadmap



Preproduction
Production
Development
Planned

Parallel – 1Gb to 8Gb with one layout

1Gb, 2Gb, 4Gb and 8Gb
32Mbits/mm^2 @ 15mm x 17mm

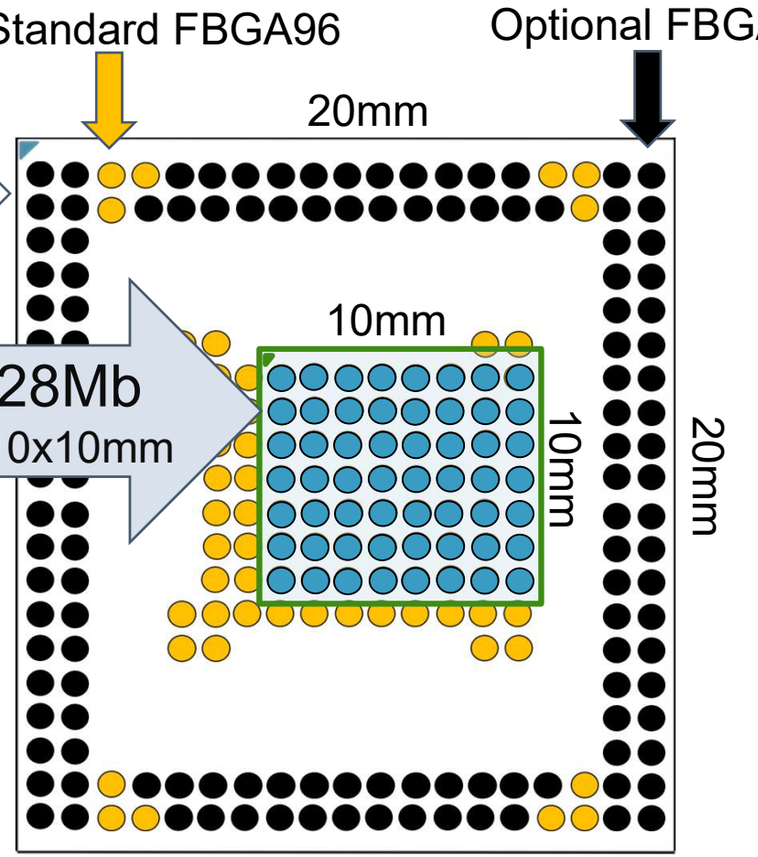


- Designed for the **Highest Reliability:**
  - Robust **On-chip ECC with multibit correction**
  - **Error-free** non-destructive **read w/ unlimited endurance**
  - **Error-free writes** with **10^{16} endurance**
- **Ultra Low Power** (as low as 50mA per Gb active)
- No Shielding Required vs legacy Toggle MRAM
- **High Bandwidth Interface (711Mbps parallel/1.422Gbps streaming)**

Serial (Dual QSPI) – 64Mb to 8Gb with one layout

1Gb, 2Gb, 4Gb and 8Gb
21Mbits/mm^2 @ 20x20mm

64Mb and 128Mb
1.3Mbits/mm^2 @ 10x10mm



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  - **Error-free writes** with **10^{16} endurance**
- **Ultra Low Power** (as low as 50mA per Gb active)
- No Shielding Required vs legacy Toggle MRAM
- **Dual QSPI Interface 108Mhz/133MHz**

Earth to Mars – Avalanche MRAM covers the spectrum

- Avalanche **MRAM technology & devices scalable** by radiation classification
- Avalanche productized **Space Grade as cost effective** COTS+ solution
- Enabling partners with **wafers & knowhow** to support extended flows

Mission Use Case	Product Family	Qual Level & Screening	TID	SEE	Write Endurance	Retention	Packaging Options	ITAR
Terrestrial	Industrial Grade	JEDEC	<10KRad	<8 LET	10^{14}	20 Years	Plastic - RoHS	No
Avionics, Missile, LEO	Space Grade	JEDEC + 48hr burnin	<75KRad	~45 LET	10^{16}	10 Years	Plastic - Leaded & RoHS	No
GEO	QED	PEMS, QML, & Custom	100KRad	~75 LET	10^{16}	10 Years	Plastic - Leaded	Yes
GEO, Missile, Strategic	RadHard	QML, Custom	>300KRad	~75 LET	10^{16}	10 Years	Plastic, Hermetic, Die, MCM	Yes

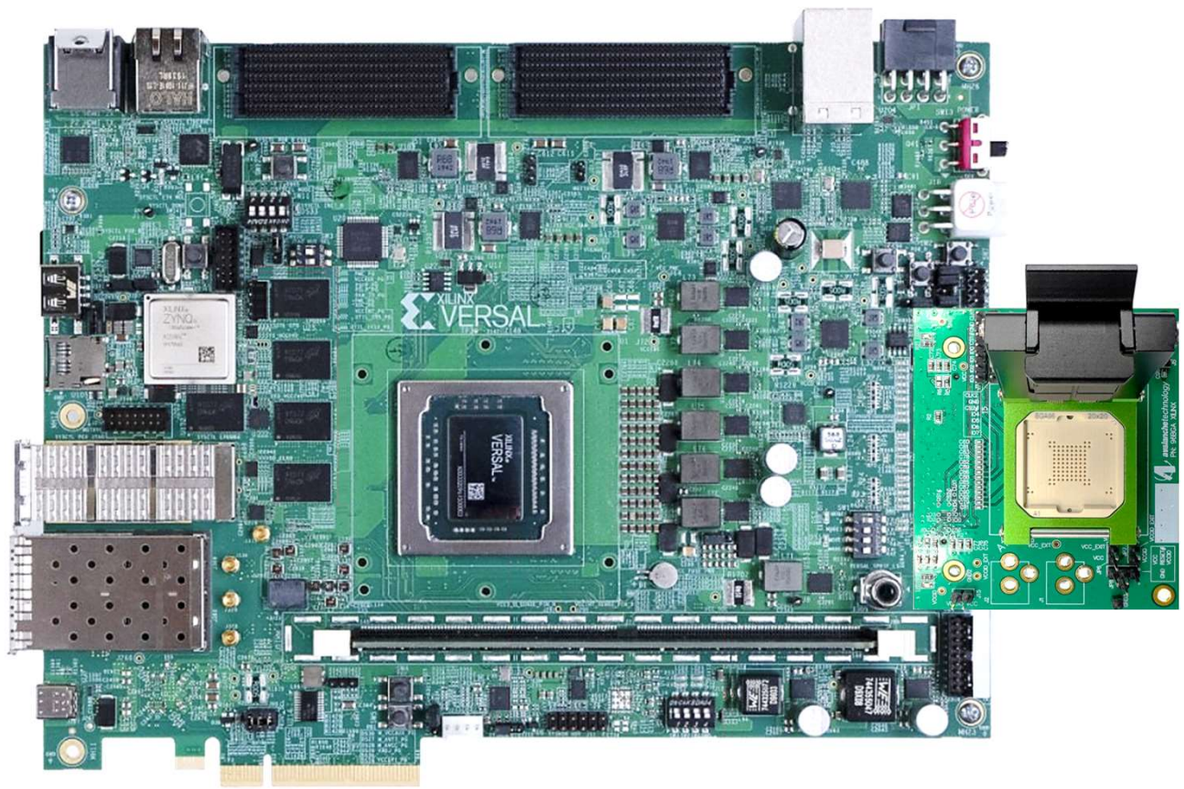
Gen3 SEE/TID Production Test Result Subset and Planning

Device Rev	Test	Test Facility	Dates	Test Participants	Test Results
Test Chip	Heavy Ions	TAMU	Aug 2 '21	Avalanche Technology Apogee, CAES	**No SEL @ Xe - 57.1**MeV*cm^2/mg @ 110°C
	Gamma	DMEA	Oct 7 '21	Micross, DMEA Avalanche Technology	Negligible change in parametric data @ **175krads**
Early Production	Heavy Ions	TAMU	Jul 29 '22*	Avalanche Technology M&A	**No SEL @ Ar – 8 & Cu – 18.9 @ >100°C** HCE @ Ag – 44.9MeV*cm2/mg @ **>110°C**
	Gamma	DMEA	Sept 6 '22	Avalanche Technology DMEA	Negligible change in parametric data @ 75k, 100krads tested to 450krads
Production	Heavy Ions	TAMU	April 2, '23	Avalanche Technology Micross	**No SEL @ Ho – LET 73.3 @ 25C or 60C** HCE @ Ho – **LET 73.3 @ > 100C** **No SEFI or Write, Read, Compare Errors During Beam**
	Gamma	DMEA	June 8 '23	Avalanche Technology	Tested **1Gb MRAM** @ 50krad and 450krads Negligible change in parametric data @ 100krad and 450krads
	Gamma	DMEA	July 19 '23	Avalanche Technology	Tested **2Gb Dual-QSPI w/Chiplet** @ 50k,100k & 150krads Negligible change in parametric data @ 50k & 100krads
	Heavy Ions	TAMU	Sept 15, '23	Customer/DoD Prime Avalanche Technology	Part 1: Tested **1Gb Parallel MRAM** and **2Gb Dual QSPI** Part 1 Test Results – Next Page
			Dec '23		**Performs additional tests after cycles of learning of part 1**

In all the testing, by us or others, not a single data error has been observed!

WE ENABLED THE PLATFORMS

Enabled Booting and nvStorage for AMD/Xilinx Devices



Family	Petalinux Support				Fabric Only
	23.2	23.1	22.2	22.1	No O/S
Versal	Dec 15TH		✓	✓	✓
Ultrascale+	Dec 15TH		✓	✓	✓
Ultrascale	Dec 15TH		Dec 1st		✓

https://www.avalanche-technology.com/support/development-kits/

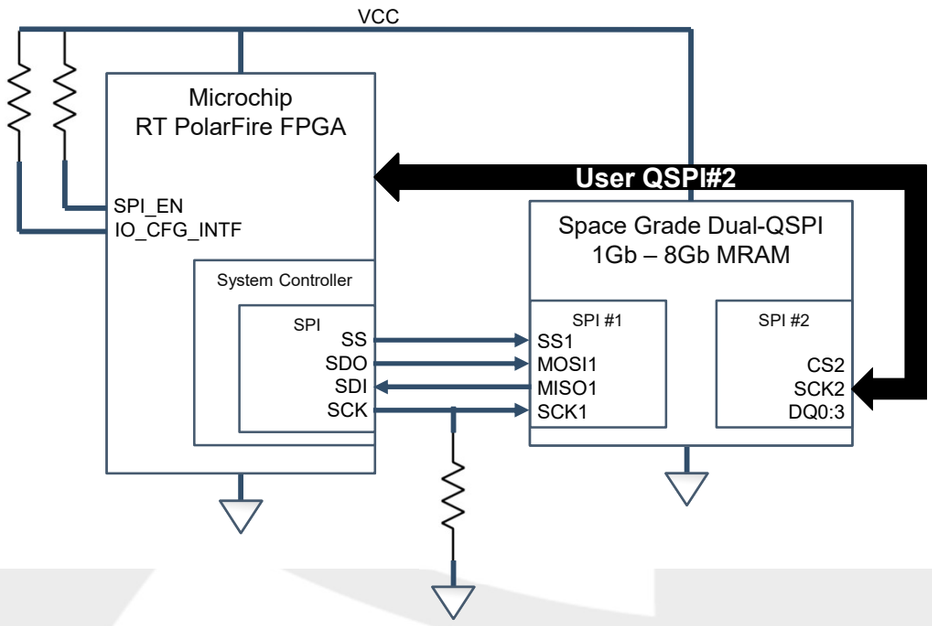
Gen 3 Space Grade Dual QSPI P-SRAM™ Kit for Xilinx

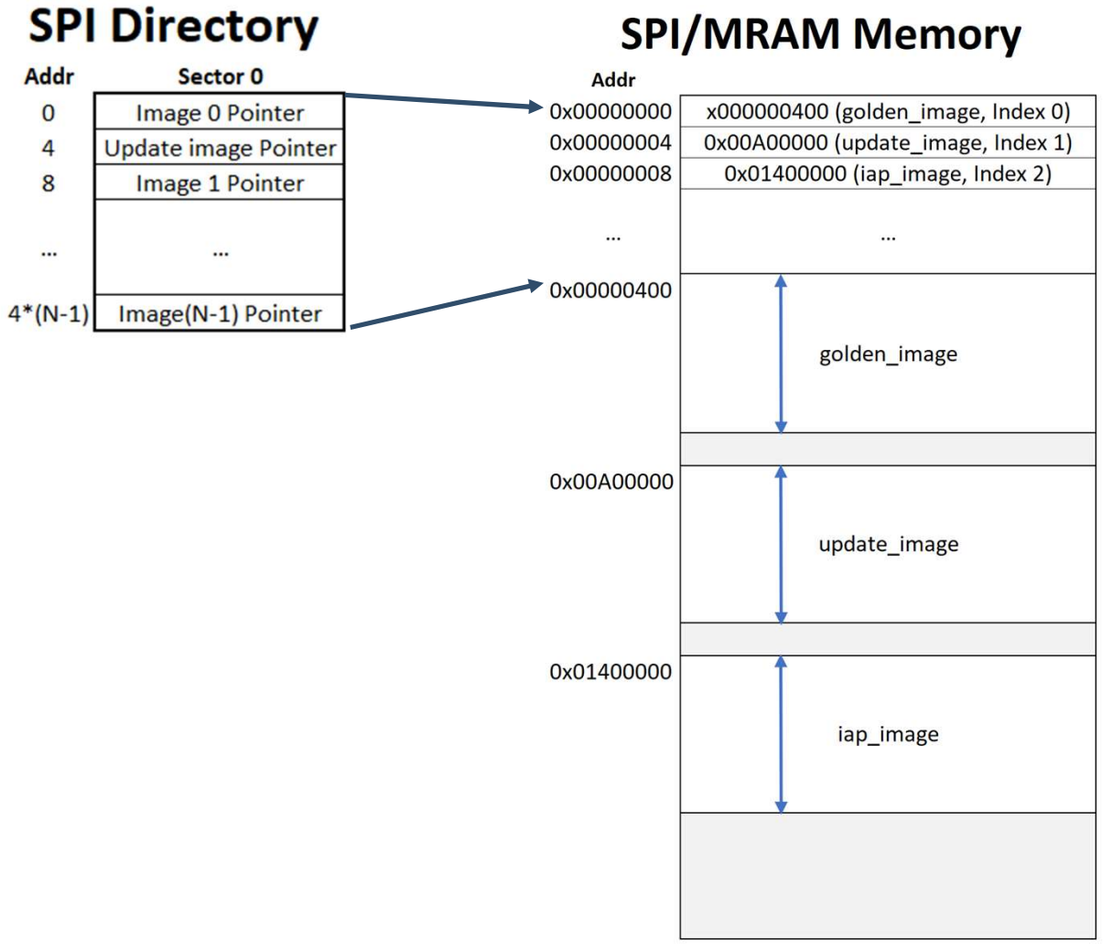
Development Kit:
Download the User Guide
Download the Sample Code
Xilinx/AMD Versal Boot Linux Drivers

Reference Design:
Download the Schematic, Board Layout, Gerber, BOMs

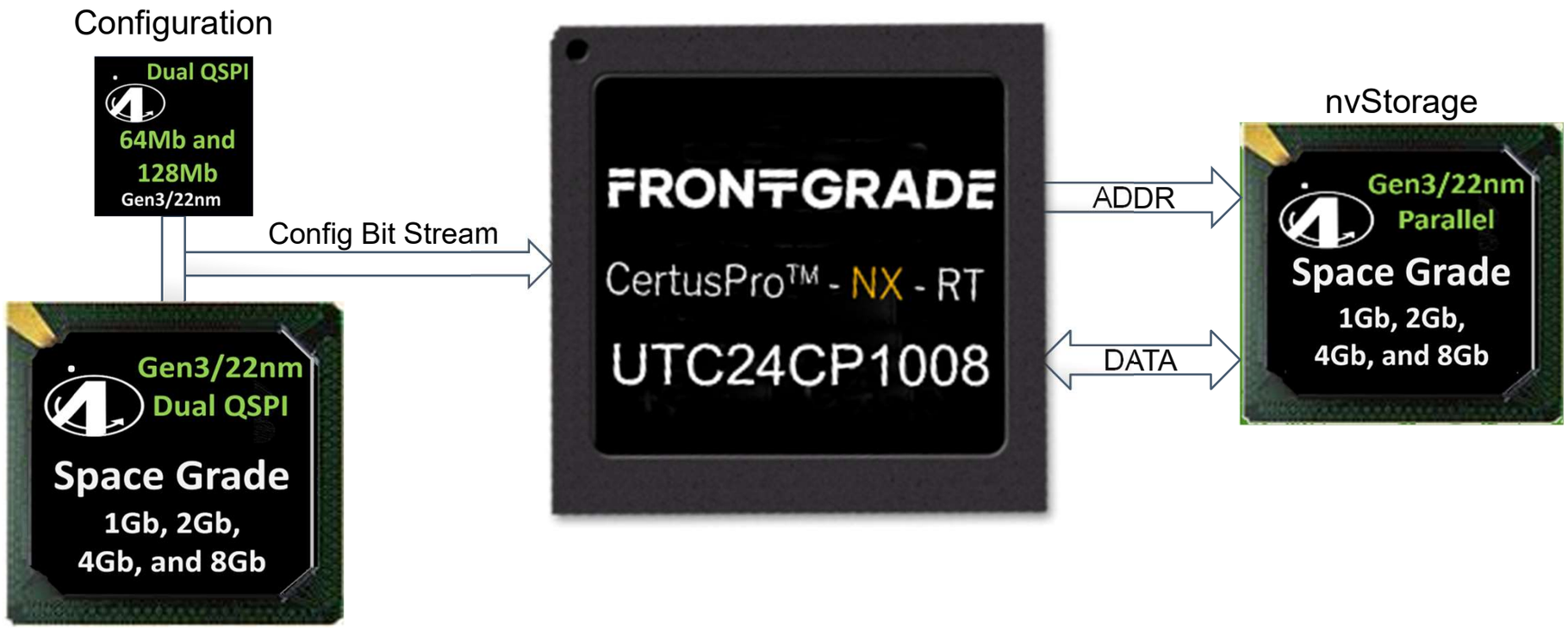
Orderable Part Numbers:
Kit: AK30X208XILCCSOC
Socket: ABGA96-1-20×20

Enabled auto-updating RT PolarFire's on-board Flash





Enabling Booting/nvStorage for Frontgrade (Lattice) CertusPro FPGAs



Enabling the driver for Storage Solutions in Space

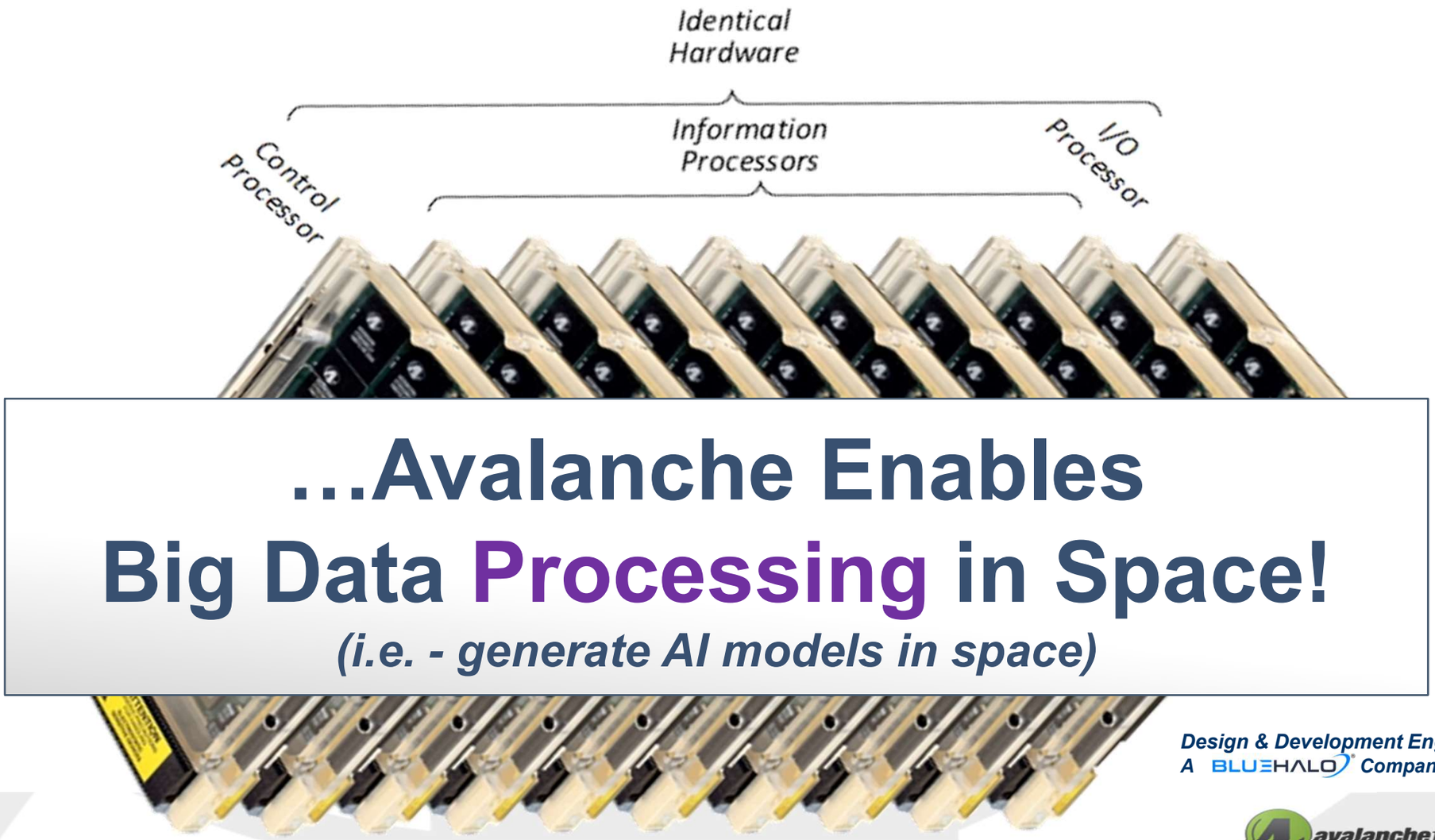
- **Avalanche provides reference design with low level drivers**
- **Partnership with EIDETICOM enabled plug and play NVMe stack**

PARTNERS DELIVERING FOR THE COMMUNITY

BLUEHALO® enabled 8Gbyte MRAM Data Buffer

- 8GByte All MRAM Data Buffer
- Licensed NMVe stack from EIDETICOM
- AI Memory: Xilinx KU060 FPGA supports data operations:
  - Compression, Cyber Security, Parameter Extraction, etc.
- High performance SSD
- 10^{16} Write Cycle Endurance
- Low power
- 3U VPX
- Affordable

From In-Memory Computing, to the use of AI…

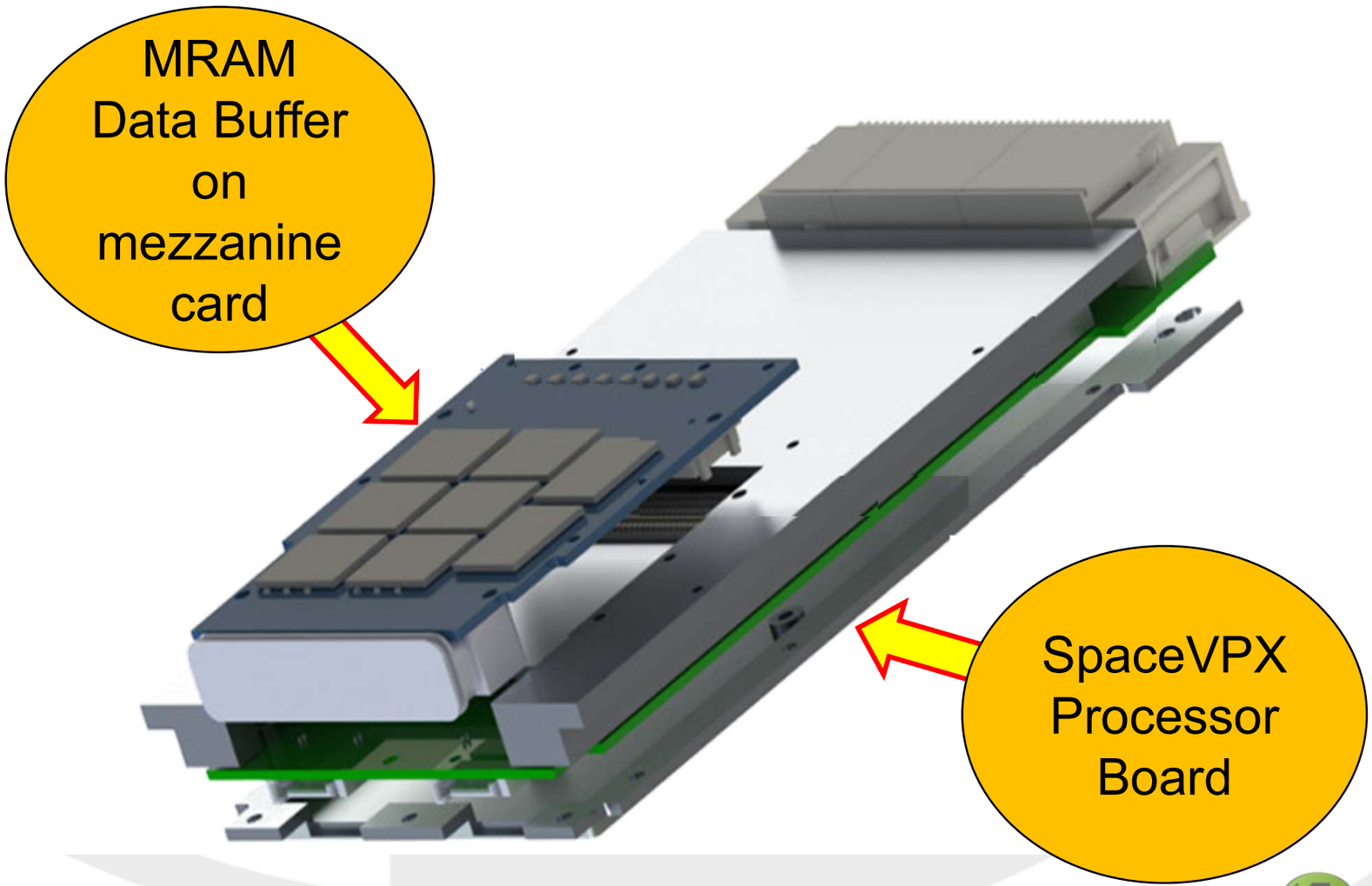


…Avalanche Enables Big Data Processing in Space!

(i.e. - generate AI models in space)

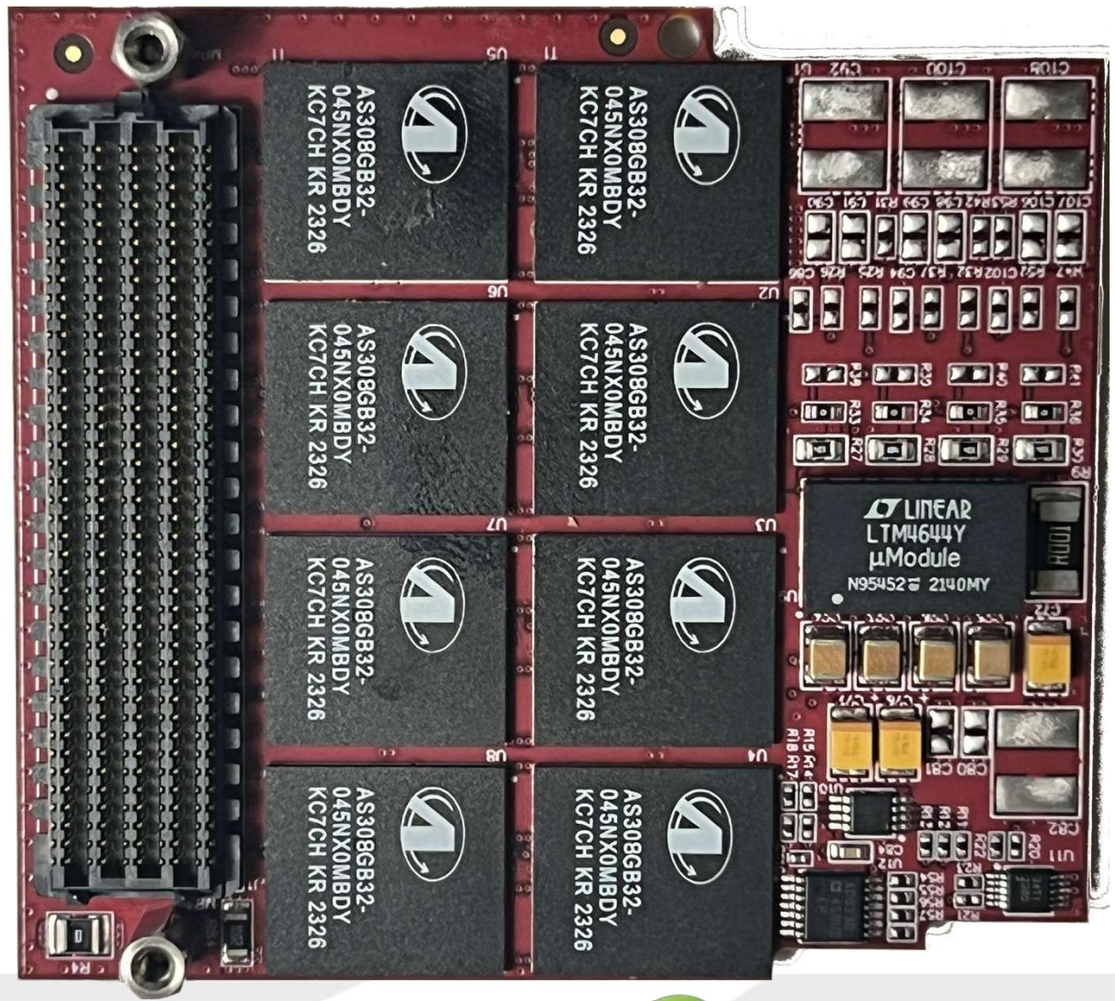
Design & Development Engineering Services
A BLUEHALO® Company

TRUSTED Semiconductor Solutions™ enabled 8Gbyte Customizable Mezzanine Card



TRUSTED Semiconductor Solutions™ enabled 8Gbyte Customizable Mezzanine Card

- Can use either 4Gbit or 8Gbit MRAM
- MRAM 8GByte Cache daughter card
  - Utilizes existing Xilinx Zynq board
- Hi-Rel 3U VPX board based on Agilex-5
  - Plan to make FMC compatible with MRAM Cache card
- Radiation Circumvented 3U VPX board
  - TSS developing PDDIC that detects, circumvents, and recovers from a radiation event
  - Will use the Agilex-5



mercury enabled Hybrid (MRAM+NAND) SpaceDrives

DATASHEET

In Development

Quadrium 3U VPX Rad-Tolerant, Mir
Multi-Host, 350 GBytes NAND, 120 N
3.2 Gbit/s, Parallel, Octal SPI, SpaceF

Models: RH3350NM6S-000I01-01

- Rad-Tolerant non-volatile storage: 350 GBytes NAND plus 12(
- Triple-Redundancy for host Data and internal ECC bytes. Four, 8
- Lesser screened, plastic RTG4 FPGA to enable cost sensitive New
- 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
- Multi-Host operation. Up to 6 hosts using Parallel, Octal SPI and

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

DATASHEET

In Development

Quadrium Rad-Tolerant, Triple Redu
Multi-host, 350 GBytes NAND 120 M
3.2 Gbit/s, 120 pin Quad Plastic Pack

Models: RMS350NM6S-000I01-01

- Rad-Tolerant non-volatile storage: 350 GBytes NAND plus 120
- Triple-Redundancy for Data and ECC bytes. Four, 8-bit, ECC corre
- Lesser screened RTG4 FPGA to better enable cost sensitive NewS
- Rad-Tolerant, by design. All components except NAND.
- Compact solder down form-factor, single 5V supply
- Lower cost implementation of Mercury's popular SpaceDrive pro
- Multi-Host operation. Up to 6 hosts using Parallel, Octal SPI, Spa

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

DATASHEET

CONCEPT

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.

- 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

Enabling mercury's DeepSpace all MRAM 1TB SpaceDrive

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-

Standard Features - continued

- All components RT-by-Design, 100 krad minimum
- Redundancy in both power and storage logic

Summary…

Architectural Simplicity

- **No wear leveling**
- No need for scrubbing, multiple copies
- **Soft errors corrected on the fly**

Best SWaP Profile

- **Highest Density** (up to 8Gb)
- **Lowest Nominal Power** (50mA/Gb)
- No Shielding Required

Footprint Scalability

- From 64Mb to 8Gb. Earth to Mars.
- JEDEC through QML Qual
- Common H/W for S/W defined systems

Enabling Platforms for TTM

- **Hardware Reference Designs**
- Base level software drivers
- **Full software stacks through partnerships**

Thank You!

avalanchetechnology

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