LIGHTNING TALK

RADIATION-HARD AI PROCESSOR TO ADDRESS SECURITY CHALLENGES IN SPACE

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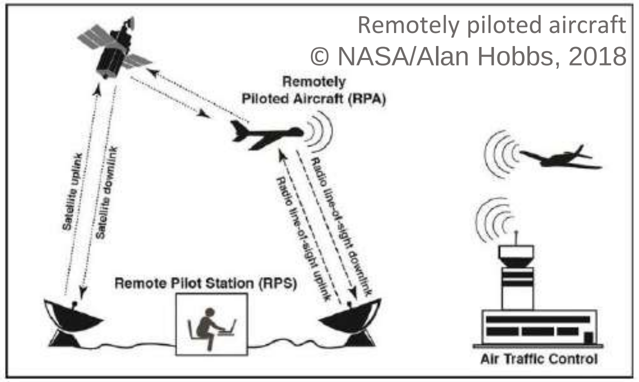
MAGICS

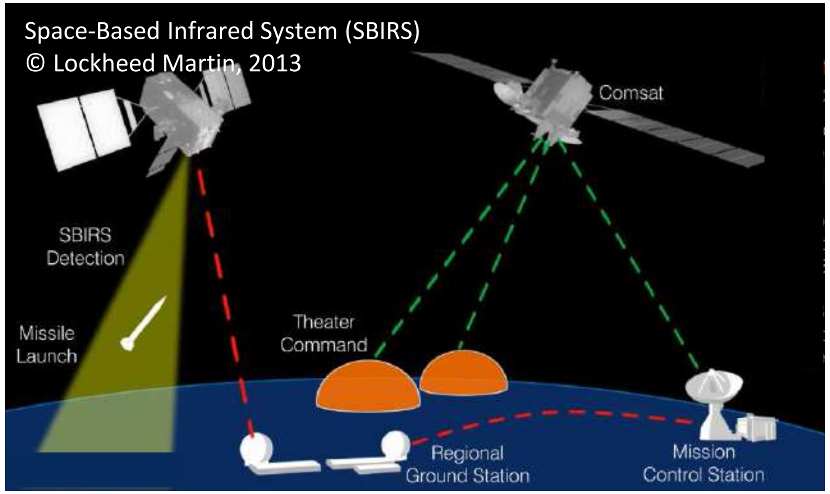
Space-based services are underpinning terrestrial operations

- Military examples
  - ISR
  - Military communication
  - Operational navigation
  - Missile launch detection
  - Guidance for precision weapons
- Civil examples
  - Navigation
  - Internet
  - Banking
  - Weather forecasting
  - Emergency response


Composante Spatiale Optique (CSO)
© CNES/Mira Productions/PAROT Rémy, 2018



Remotely piloted aircraft
© NASA/Alan Hobbs, 2018



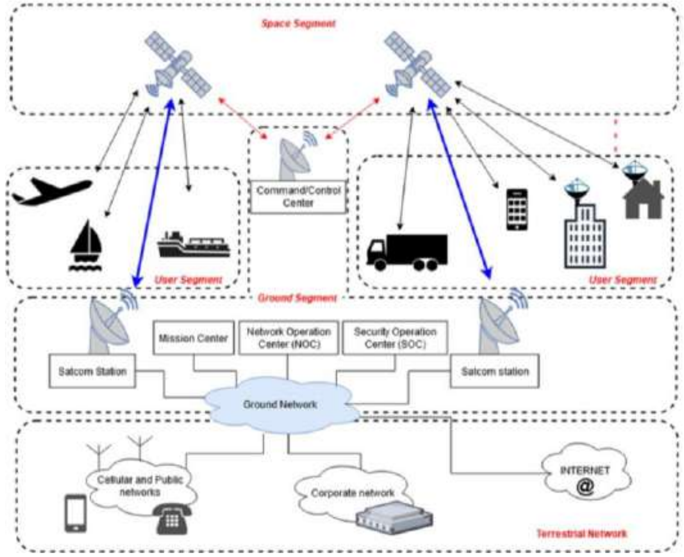
Space-Based Infrared System (SBIRS)
© Lockheed Martin, 2013

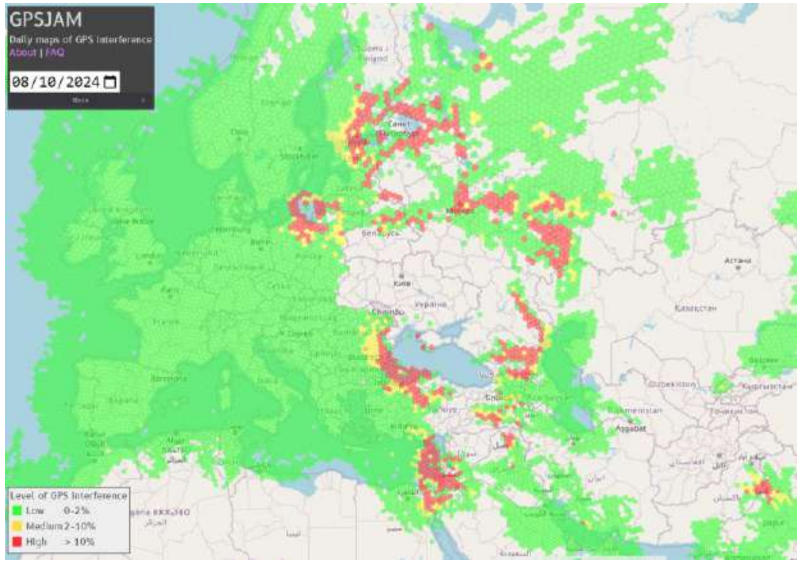

Four Galileo Satellites
© ESA/P. Carril, 2012

- Space is recognized as an important strategic domain

Counter-space capabilities are being pursued globally

- Non-kinetic approaches (degrade/disrupt)
  - Jamming
  - Spoofing
  - Cyberattack
- Kinetic ASATs (destroy)
  - Direct-ascent ASATs
  - Co-orbital ASATs
  - Destructive indiscriminate effects
    - Debris
    - Radiation / EMPs (Starfish Prime)
  - Close-proximity capabilities
  - *Directed-energy (non-kinetic physical)*



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GOP warning of 'national security threat' is about Russia wanting nuclear weapon in space: Sources

It would not be to drop a weapon on Earth but to possibly use on satellites.

By John Parkinson, Luke Barr, Anne Flaherty, Luis Martinez, and Adam Carlson
February 14, 2024, 11:27 PM


BBC

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US says Russia likely launched anti-satellite weapon

22 May 2024

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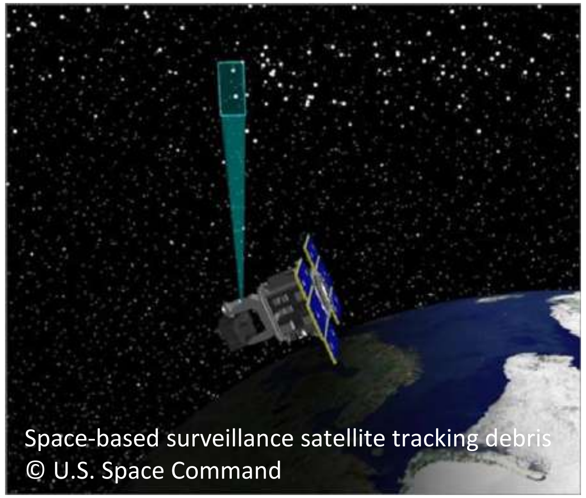
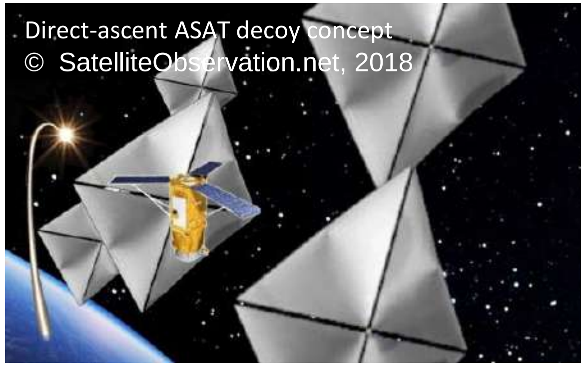
Jaroslav Lukiv
BBC News

On-board autonomy is key in coping with adversarial denial

- *Scenario*
  - *- Ground segment has lost (temporarily) control over a space asset*
  - *- Space asset is being targeted by a kinetic ASAT*
- Need for real-time space-domain awareness
  - Sensor data acquisition and processing
  - Analyzing and extracting information from the processed data → AI/ML
- Need for autonomously responding to imminent threats
  - Further integrating data into an autopilot/world/operational model → AI/ML
  - Lower-level controller to be fed with model output reference data
- AI/ML is an important TBB to implement advanced capabilities
- **Applying AI/ML on board requires robust processing hardware**



Space-based surveillance satellite tracking debris
© U.S. Space Command



Direct-ascent ASAT decoy concept
© SatelliteObservation.net, 2018

https://satelliteobservation.net/2018/03/08/contested-space-ii-countermeasures/

Magics Technologies

Fabless Semiconductor Company

Space and Defence Market
Nuclear Energy Market

Geel, Belgium
Spin-off from KU Leuven and SCK-CEN

Rad-hard-by-design
Methodology and Library

5 Product Series
Autonomy in harsh environments

40 FTEs

Rad-hard product series

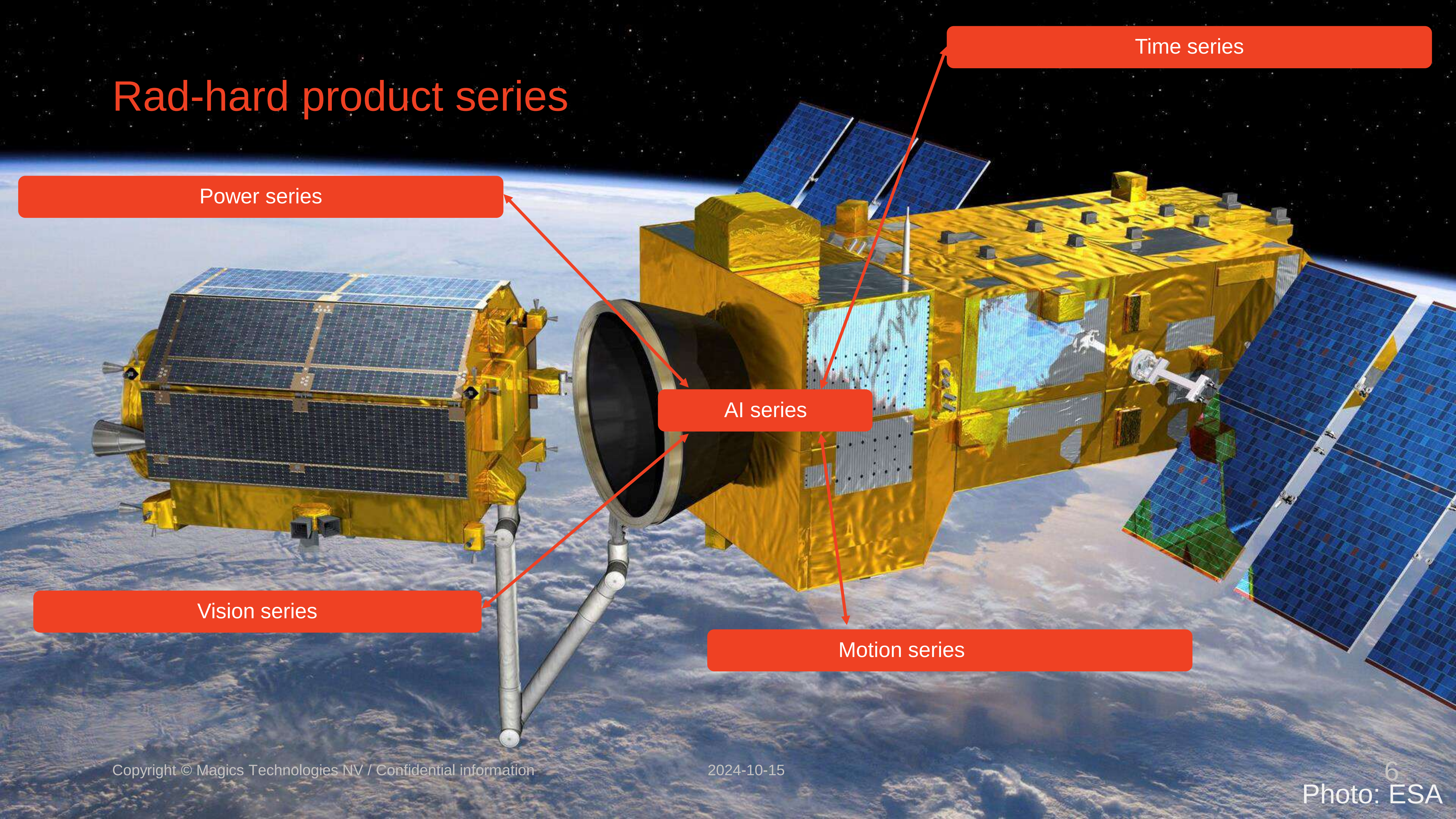
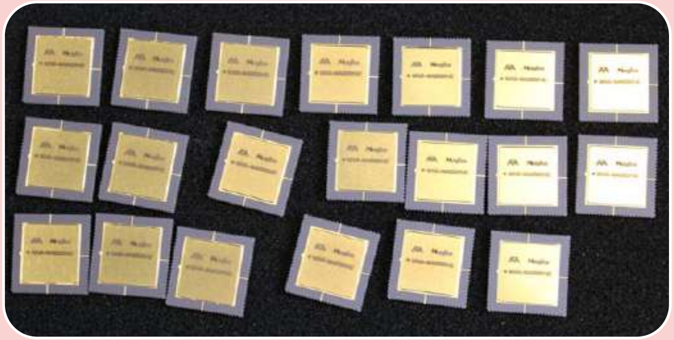
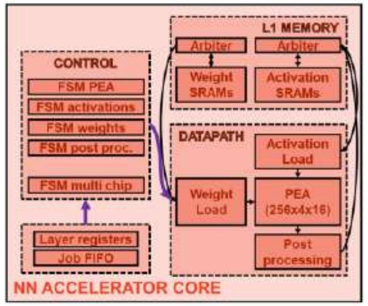


Photo: ESA

AI series – overview





Tesla (Internal R&D)

- **15 mW peak power consumption**
- Dynamic freq. scaling up to 100 MHz
- **Up to 5.85 GMACs/s**
- 3 MB L1 weights and activation cache
- PULPissimo-based SoC
- Power management with deep sleep
- Demonstrator taped out
- Industrial-grade component

Versa (R&D collaboration with KUL*)

- **20 mW peak power consumption**
- Dynamic freq. scaling up to 150 MHz
- **Up to 8.8 GMACs/s**
- 128 kB L1 weights and activation cache
- PULPissimo-based SoC
- Power management with deep sleep
- Optimized for duty-cycled operation with eMRAM
- Demonstrator taped out
- **TID > 100 krad, SEL immune, eMRAM SEU immune**

Moviq (Product)

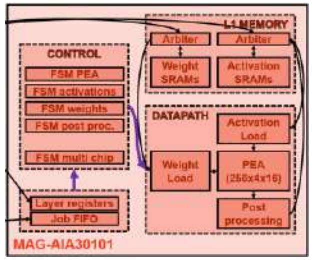
- High computational performance
- **Up to 10 TMACs/s**
- *Dynamic freq. scaling up to 1 GHz*
- *1 W typical active power consumption*
- 4 MB L1 weights and activation cache
- RISC-V-based SoC
- First-class depth-first execution
- **Radiation-hard by design**
- Status: development ongoing
- Accelerator softcore IP: MAG-AIA30101

*Jain et al., "TinyVers: A Tiny Versatile System-on-Chip With State-Retentive eMRAM for ML Inference at the Extreme Edge," in IEEE Journal of Solid-State Circuits, vol. 58, no. 8, pp. 2360-2371, Aug. 2023

AI series – roadmap

AI processor soft IP

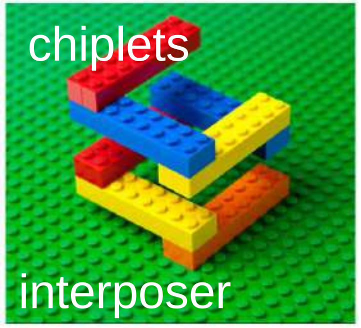
- Size scalable AI processor IP
- Optimized for CNNs
- Loosely-coupled architecture
- Compatible with SPARC, ARM, RISC-V
- AXI-based integration
- Open-source software tools
- SEU-mitigation in logic



AI processor chip(let)

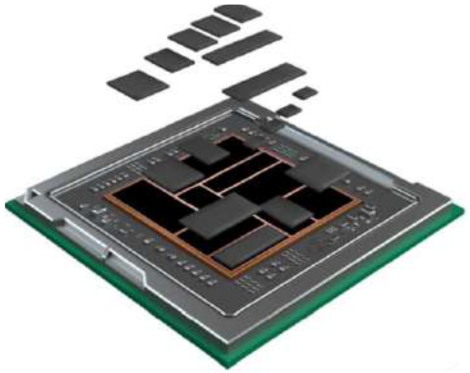
- Silicon realization of IP
- 10 TOPS/W compute fabric
- > 120 – 300 krad TID
- SEL immune
- Designed for *natural* space environment

monolithic



UDSM AI processor chip(let)

- UDSM realization of IP
- Additional pre-processing acceleration
- 40 TOPS/W compute fabric
- Designed for *natural* space environment
- Radiation effects on SoTA nodes under investigation



Concept – weapons-grade AI processor

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List of Artificial Radiation Belts

Explosion	Location	Date	Yield (approximate)	Altitude (km)	Nation of Origin
Hardtack Teak	Johnston Island (Pacific)	1958-08-01	3.8 megatons	76.8	United States
Hardtack Orange	Johnston Island (Pacific)	1958-08-12	3.8 megatons	43	United States
Argus I	South Atlantic	1958-08-27	1-2 kilotons	200	United States
Argus II	South Atlantic	1958-08-30	1-2 kilotons	256	United States
Argus III	South Atlantic	1958-09-06	1-2 kilotons	539	United States
Starfish Prime	Johnston Island (Pacific)	1962-07-09	1.4 megatons	400	United States
K-3	Kazakhstan	1962-10-22	300 kilotons	290	USSR
K-4	Kazakhstan	1962-10-28	300 kilotons	150	USSR
K-5	Kazakhstan	1962-11-01	300 kilotons	59	USSR

https://en.wikipedia.org/wiki/List_of_artificial_radiation_belts

MIL-STD-3053

Satellite Systems Natural and Nuclear Environment Standard

Online Access to your Standards Collection - Automatic Updates and Multi-user Licensing!

Information FSC-Areas Citations Responsibilities History Preview

General Information

Status:	Active
Last Modified:	2020-11-10
Distribution Statement:	[A] Approved for public release.

MIL-STD-3065

Satellite Systems Nuclear Survivability Protection (SSNS-P)

Online Access to your Standards Collection - Automatic Updates and Multi-user Licensing!

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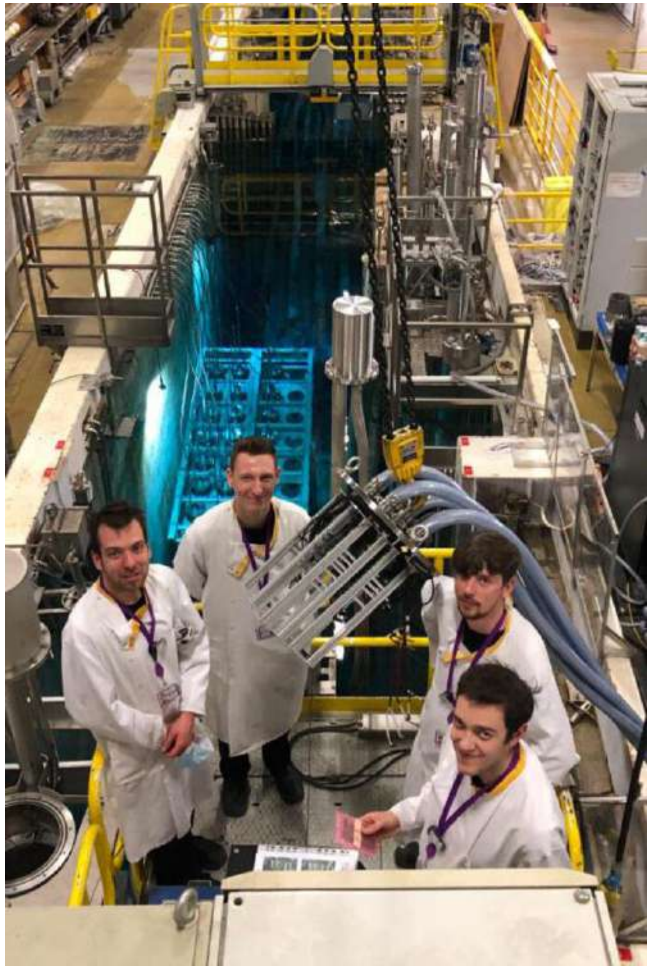
Department of Defense (DoD) policy requires that satellites be protected against natural space and nuclear radiation environments as specified in MIL-STD-3053, Military Standard: Satellite Systems Natural and Nuclear Environment Standard. The types and efficacy of the protection required depend on the satellite mission and the expected radiation and nuclear induced plasma environment. This protection standard establishes hardening performance metrics for the satellite system and verification methods to demonstrate effectiveness of the hardening design to survive in the specified environment. It may also be used to assess hardening designs of existing satellite systems.

General Information

Status:	Active
Last Modified:	2020-04-30
Distribution Statement:	[C] Distribution authorized to U.S. Government Agencies and their contractors. For authorized access, visit: USDoD DSP ASSIST.

Concept – weapons-grade AI processor

- Motion, vision and power series designed for TID > 120 Mrad
- Used in human-induced nuclear environments
  - Nuclear hot cells
  - Disaster sites (e.g., Fukushima)
- Parallel weapons-grade roadmap envisioned merging nuclear and space radiation-hardening approaches
- No free lunch / tradeoffs
  - Area
  - Power
  - Cost
  - Performance
  - Radiation-hardness
- Need for collaboration with all defence stakeholder to make right tradeoffs



Conclusion

- On-board AI and autonomy important in defending space capabilities
- Magics is uniquely positioned to address robust processing hardware needs
- Expertise in both natural and human-induced nuclear environments
- Product roadmap execution: wrapping up soft IP developments
- Open to discuss weapons-grade concept integration into roadmap
- Products also suitable for use in high-altitude air platforms, specialized robotics and dismounted forces (enabling autonomy in harsh environments)

Thank you for your attention! Questions?

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