



EXPLORESpace TECH
TECHNOLOGY DRIVES EXPLORATION

Advanced Packaging Applications and Needs at NASA

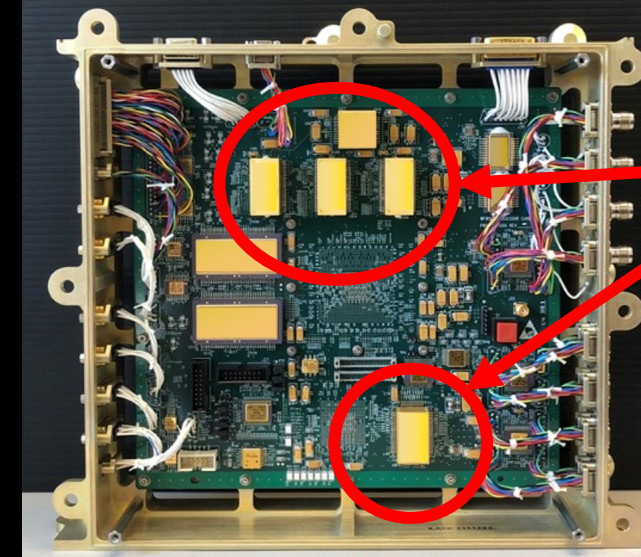
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To be presented at the 2023
Advanced Packaging Summit,
Moffett Field, CA, April 18-19,
2024

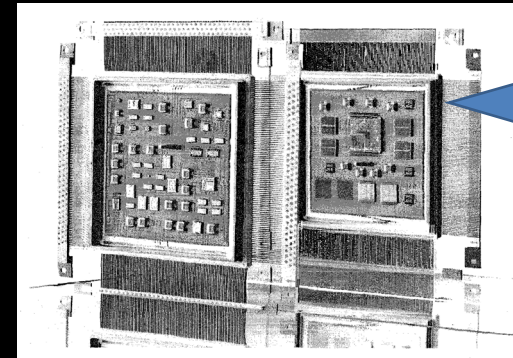
Advanced Packaging and NASA



- To date, there has been limited use of advanced packaging on NASA missions
 - Stacked memory devices
 - Hybrid power converters
 - Embedded Services Node (ESN, circa 1997)
- However, there are several candidate NASA applications where NASA can benefit from advanced packaging technology
 - Avionics
 - Robotics
 - Instruments



Processor Board Using Stacked Memory



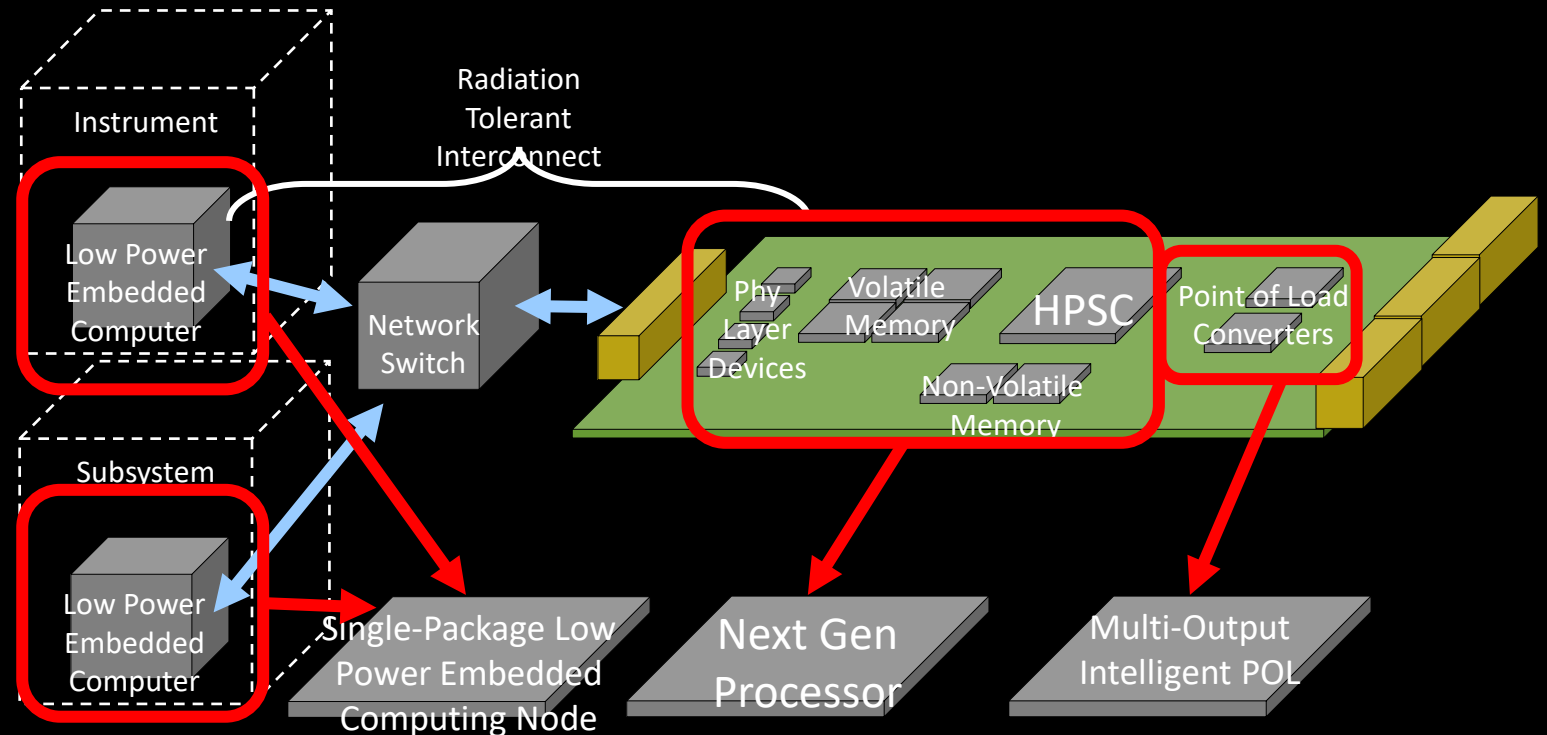
Processor
Peripherals
Memory
1553 Interface
Data Converter

Embedded Services Node

Candidate NASA Applications - Avionics



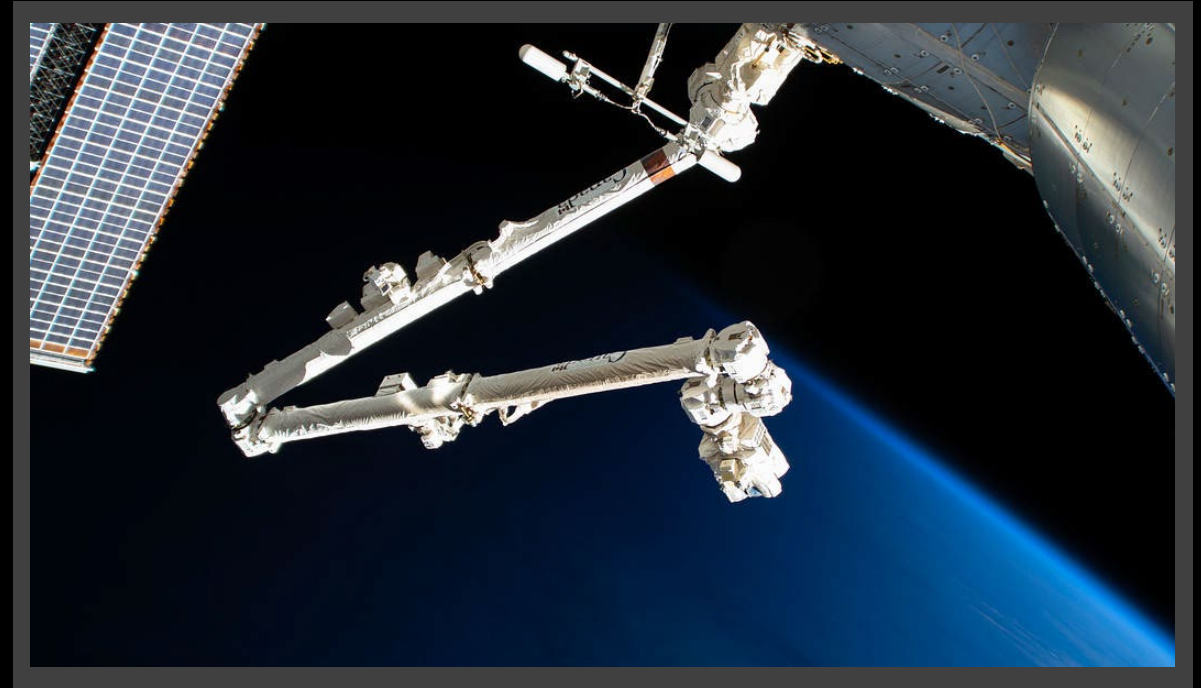
- Next generation processors
 - Combine processor, coprocessor, memory, and transceivers in single package
 - Allow use of optimal processes for each circuit function
- Single-Package Low Power Embedded Computing Nodes
 - Similar in function to ESN, but with current technology
- Point of Load (POL) converters
 - Multiple outputs
 - Add intelligent management and standard control bus interface
- Benefits
 - Increase performance
 - Reduce power
 - Reduce size and mass
 - Improve reliability



Candidate NASA Applications - Robotics



- Single-Package Low Power Embedded Computing Nodes can reduce SWaP to enable distributed processing throughout a robot
 - Motors
 - End effectors
 - Sensors
- Allows distributed processing to reduce complexity
- May require extreme temperature operation

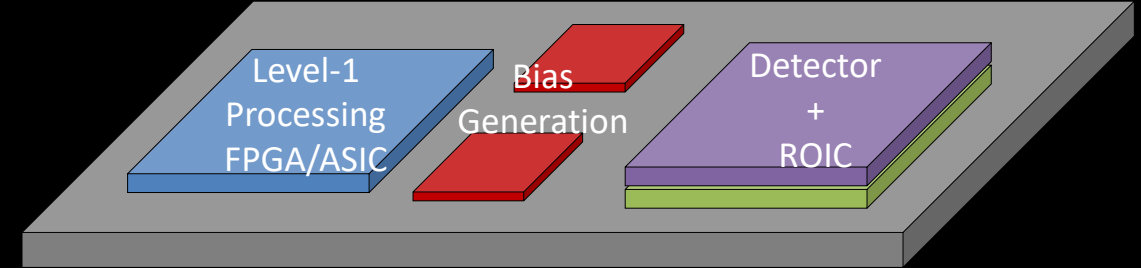


International Space Station Robotic Arm

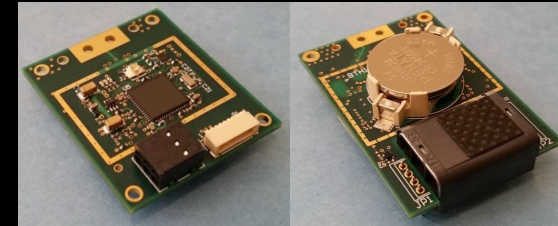
Candidate NASA Applications - Instruments



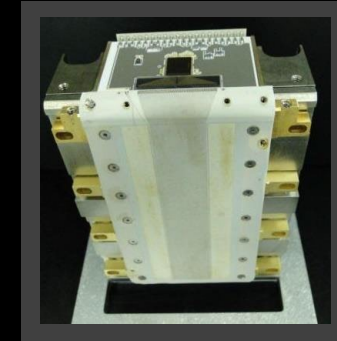
- Single package sensor for science instruments
 - Combined sensor, ROIC, biasing, and Level-1 processing
- Wireless sensor nodes
 - Distributed monitoring with crewed habitat
 - Sensors on deployable structures
- Novel science sensor approaches
 - Enabled with additive manufacturing



Single Package Sensor



Wireless Sensor Node

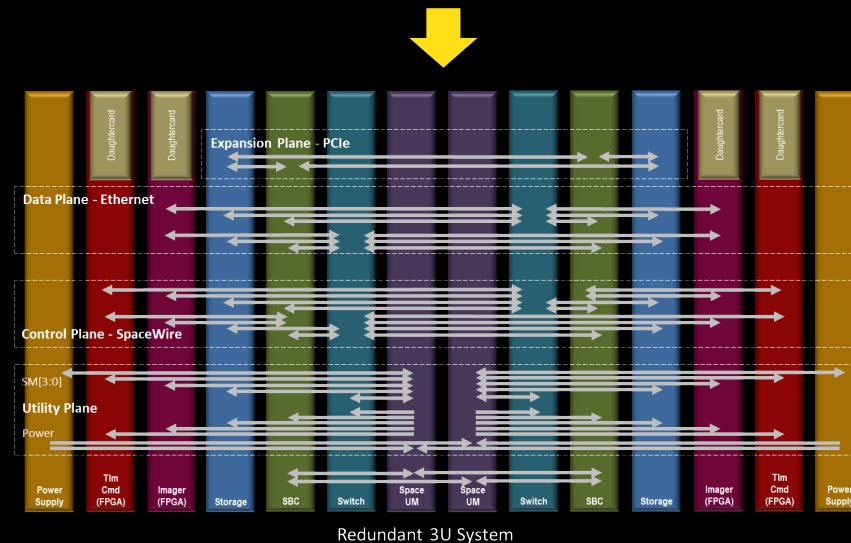
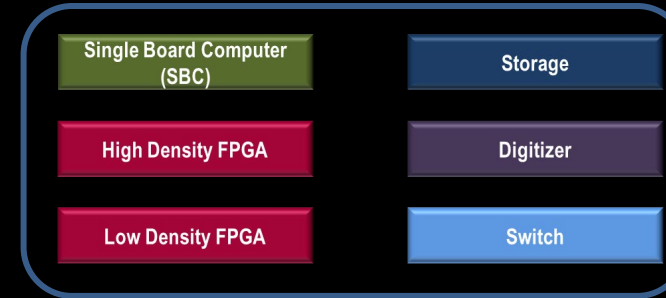


Next Generation X-Ray Polarimeter

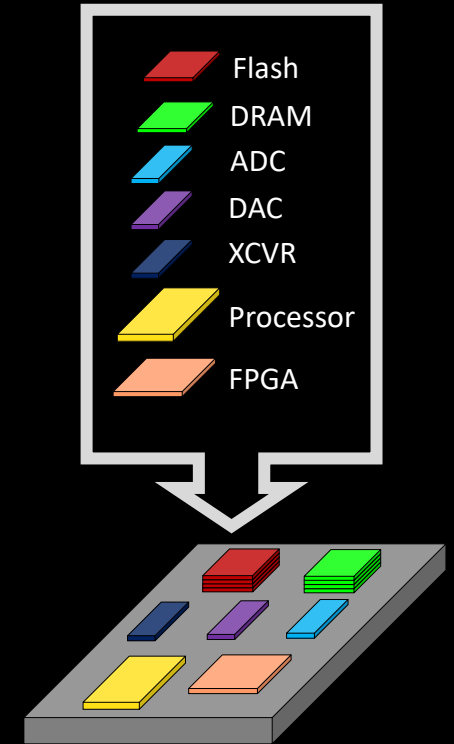
Avionics and Chiplets



- NASA is currently working to establish interoperable SpaceVPX standards at the avionics card level
 - Allow system developer to compose a system using an ecosystem of cards from multiple vendors that can interoperate
- Chiplets can be seen as a parallel to this, albeit at a smaller scale
 - It's expected that chiplets within a package may have varying degrees of radiation/fault tolerance
 - Fault tolerance is needed to either operate through or recover from fault within individual chiplets
 - This may drive a need for fault tolerant interconnect
- Allows different technologies for different components to optimize performance, power, reliability of functional unit implemented in the module
- Optimum level of modularity and granularity of function for maximum usability and minimum cost must be determined



SpaceVPX Concept

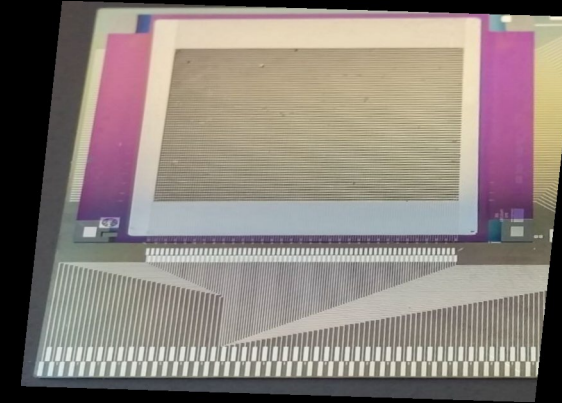


Chiplet Concept

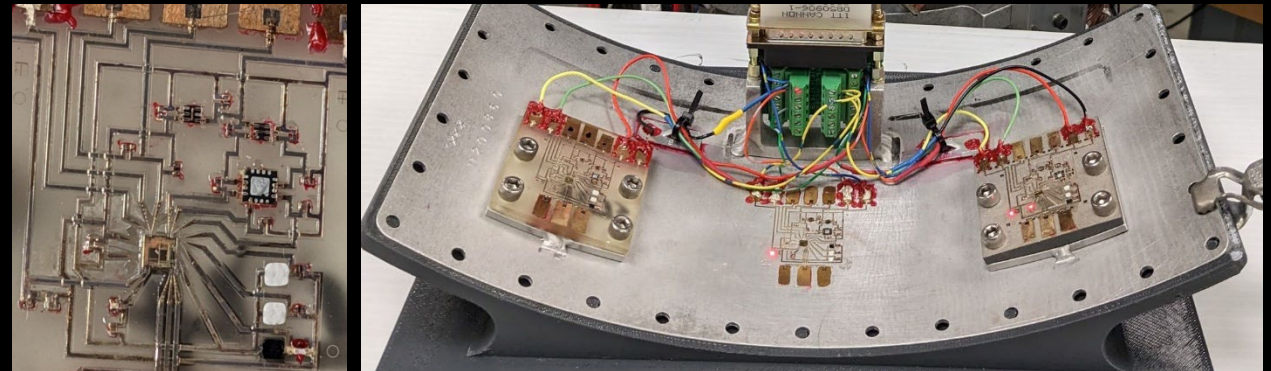
NASA Advanced Packaging Research and Development



- On-Demand Manufactured Electronics (ODME) is a project within NASA's Space Technology Mission Directorate (STMD) developing in-space and terrestrial additive manufactured electronics
- Within ODME, Printed Hybrid Electronics (PHE) are being prototyped for several applications
 - Next generation X-ray polarimeter
 - Next generation microshutter arrays
 - Sounding rocket demonstration
- The NASA Electronics Parts and Packaging (NEPP) program is studying 2.5D/3D packaging from industry and exploring radiation test methodologies for 2.5D/3D packaging.



Microshutter Array



Arduino Test Circuit on Sounding Rocket Panel

Advanced packaging challenges for NASA applications



- Avionics must operate in extreme environments, which can vary widely between missions
 - Thermal
 - Typical “Warm” Avionics: 0 – 40°C
 - Lunar Surface: -160°C – 120°C
 - Mars Surface: -150°C – 20°C
 - Venus Surface: 470°C
 - Cryogenic Instrument: -230°C
 - Radiation
 - Most avionics have requirements to tolerate < 100 kRad Total Ionizing Dose (TID)
 - Some missions require > 1MRad TID
 - Vibration and Shock
 - Varies across launch vehicles



Lunar Surface



Mars Surface



Europa

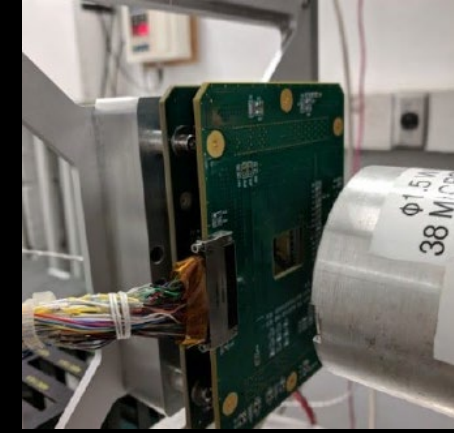


Venus

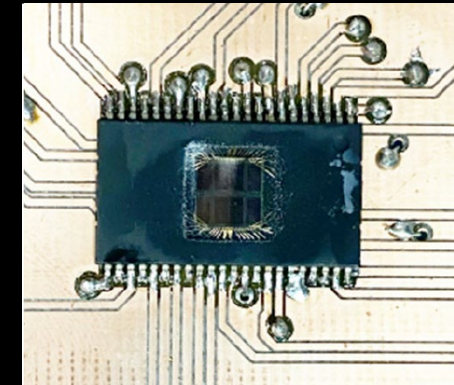
Advanced packaging challenges for NASA applications



- Low production volumes drive need for low NRE
- Requirements for high reliability
 - Long duration missions
 - Servicing and maintenance is usually not possible
- Manufacturing challenges
 - Known good die
 - MIL-PRF-38354 evaluation
 - Repair and replacement of bad die
 - Module level burn in and test
 - Managing yield and cost
- Challenges of radiation testing with complex packaging
 - Complex packaging can limit the efficacy of heavy-ion single event effect (SEE) radiation testing
 - Heavy-ion testing typically requires de-lidding to allow change deposition in the sensitive volume of a transistor
 - Stacked die can cause spallation



Single Event Radiation Testing



Device De-Lidding

Acronym List



ADC	Analog to Digital Convertor
DAC	Digital to Analog Convertor
DRAM	Dynamic Random Access Memory
ESN	Embedded Services Node
FPGA	Field Programmable Gate Array
HPSC	High Performance Spaceflight Computing
kRad	KiloRad
MIL-PRF	Military Performance Specification
MRad	MegaRad
NASA	National Aeronautics and Space Administration
NRE	Non Recurring Engineering
ODME	On-Demand Manufactured Electronics
PHE	Printed Hybrid Electronics
POL	Point of Load
ROIC	Read Out Integrated Circuit
SEE	Single Event Effect
STMD	Space Technology Mission Directorate
SWaP	Size Weight and Power
TID	Total Ionizing Dose
XCVR	Transceiver