What is new in the world of space electronics?

Jochen Rust
Head of Studies

we think electronics dependable
DSI Aerospace Technologie GmbH is an SME located in Bremen, Germany which provides following electronic equipment:

- Platform & Instruments Computers
- Payload Data Handling Units (incl. MMBs)
- Data Processing Units
- Test Systems (EGSE)
- Engineering Services

Aerospace Electronics since 1997
A few recent projects...

**Hayabusa-II MASCOT**
- On Board Computer
- Status: In Orbit

**ExoMars**
- Control and input/output modules incl. BSP of the Payload Data Handling Unit
- Status: In Orbit

**JUICE CDMS SSMM**
- Solid state mass memory board
- Status: PFM delivered

**MetOp-SG ICI**
- Command & data processing unit of the Ice Cloud Imager instrument
- Status: EQM delivered, PFM under manufacturing

**Biomass**
- Payload data handling unit
- Status: EM delivered, EQM under manufacturing

**FLEX**
- Payload data handling unit
- Status: under development

**PLATO CDMS SSMM**
- Solid state mass memory board
- Status: FuMo delivered

**KOMPSAT-7**
- Data storage and compression equipment
- Status: EQM delivered, PFM under manufacturing
A brief introduction to space electronic
  - Design challenges
OddSpace versus NewSpace
Trends in space electronics
Resume
Why is the design of space electronics somehow difficult?

- **Deep space explorer**: > 2,000,000 km
- **Medium Earth orbit (MEO)**: 2,000 km – 35,786 km
- **Low Earth orbit (LEO)**: 200 km – 2,000 km
- **Geostationary orbit (GEO)**: 35,786 km
Radiation Effects on Electronics: Resume Picture

Qualification is indispensable

TOTAL IONISING DOSE EFFECTS
- Creation of electron-hole pairs
- Charge build-up, excitation, transport

DISPLACEMENT DAMAGE EFFECTS
- Atomic dislocation, nuclear displacement in lattice
- Reduction in current concentration
- Increase in dangling bonds / free radicals
- Increased defect concentration
- “Rapid annealing” of minority carrier lifetime
- “Soft errors” (shorter lifetime)
- Changes in circuit parameters: operating point, gain, impedance, drive

SINGLE EVENT EFFECTS
- Localisation (volume effects)
- Single Event Latch-Up (SEL)
- Generation of parasitic npn/pnpn structures causing anomalous switching behaviour of main transistor and large draw currents. Possible permanent failure.
- Single Event Upset (SEU) temporary “bit-flip” in memory element caused by internal charge deposition
- Single Event Transient (SET) transient current or voltage pulse. If propagated and latched by memory element, may result in “bit-flip”
- Single Hard Errors (SHE) such as gate-electric rupture, burn-out, in high V junctions traversed by heavy ions

Typically this only concerns:
- Electro-optic sensors, diodes, opto-couplers, solar cells, wide-base bipolar transistors

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Three common ways to deal with radiation impacts to electronic systems in space

1. **Radiation hardened (by design) devices** that can operate in the planned environment
2. **Redundancy** that considers fault-tolerance, e.g. 3 copies of each functional box and a voting system
3. **Extensive Error Detection and Correction algorithms**

Normally, we consider a combination of each of these methods
Radiation-hardened components

Most important: Classical Space Electronics are composed of rad-hard and qualified components

- Coarse-grained technology nodes
  - Lower frequencies (high propagation delay)
  - Higher power dissipation (heat)
- Huge footprints
- Extremely expensive

- Examples:
  - FPGA: Microchip RTAX, Xilinx Kintex Ultrascale
  - MPU: CAES GR740 Quad-Core LEON4
  - SoC: nanoXplore NG Ultra
We can not only detect errors... we can also correct them

- Widely used e.g. in channel coding
- We can include Parity-Checks
- Commonly used are Reed-Solomon Codes (or Hamming codes)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Code</th>
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<tr>
<td>A</td>
<td>10001</td>
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<tr>
<td>B</td>
<td>00100</td>
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<tr>
<td>C</td>
<td>01010</td>
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In order to increase reliability and fault tolerance, we can include redundancy

- Common technique is TMR/ → Triple Modular Redundancy/Dual Modular Redundancy (with parity)

Redundancy further increases availability/reliability

TMR can be applied on system level, component level or block level... or even Software

- However....
  - Increased overhead (three times)
  - More power consumption
  - More complexity (weight)
  - New failure models (e.g. is the voter correct???)
Paradigm shift for established space industry (and its implications)

- Exploitation of commercial-of-the-shelf (COTS) products for LEO
  - Mainly for communication purposes

- Existing, evolving constellations e.g. Starlink, OneWeb2, Telesat, Amazon, ...
  - Up to 30,000 CubeSats
  - Commercial interest far beyond classical agency driven missions
• Collisions lead to avalanche effect and uselessness of orbits
• Regulations required, as commercial interests > care taking (littering)

Solutions available: Who pays the bill?
• Lifetime of COTS is critical

<table>
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<tr>
<th>Environment</th>
<th>LEO Equatorial</th>
<th>LEO Polar (Sun Sync)</th>
<th>GEO / Interplanetary</th>
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<td>Look for data on DSEE for critical parts</td>
<td>Consider mission consequences of all SEE, and look for data on dose failure distribution on similar parts</td>
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• Higher computational performance, fast time to market
• If hardware costs are reduced extensively, we can just send more satellites (yep)
Trends in (traditional) space electronics
Satellite networks and mobile communications

Non-terrestrial Networks
- Basic coverage of rural areas
- Satellite constellations as remote units
- Modes
  - U(LL)RC
  - mMTC

Non-terrestrial Nodes
- 3D networks
- Satellites as base station
- Resilient communication
**Key features**

- Kintex UltraScale for Space Applications
- Various interfaces/communication protocols available

**Interfaces**

- Frontpanel: HSSL-based connectors
- Backplane: Compact PCI Serial Space (cPCI-SS)
- 2 Mezzanine connectors for expandability

**Mechanical properties**

- Form factor: 6U
- Mass: < 800g (without mezzanine extension)
Impact of AI for Space Applications

Health Monitoring of Spacecrafts

Autonomous Navigation

Communication Satellites

Feature detection for planetary exploration
Architectural design

• Storage Capacity 48Tbit BOL
• Bandwidth up to 20Gbps (recording and playback)
• Power consumption ~20W
• Mass < 20kg
• Form factor < 2x 6U

Selection and up-screening of suitable Flash devices

• Comprehensive NAND flash technology examination
• Up-screening

PCB manufacturing

• Comprehensive NAND flash technology examination
Upcoming Deep Space Explorer Missions...
TRIPLE: Technologies for Rapid Ice Penetration and Subglacial Lake Exploration

- Actual applications on top of abstracted HW avionic
- Resource friendly, reusability of resources (e.g. sensors), ...
- Execution in secure containers, updateability, flexible extension

Virtualization / Abstraction
- Hardware virtualization (shared resources)
- Increase HW utilization for processing
- Split data producer from data consumer

Networking
- Reliable (redundant) interconnection
- Traffic-Classes (RT + BE)

- Federated Hardware-Architecture (N+R)
- Mixed Criticality / Rad-Hard /COTS
- HW/SW-Co-Design, ARM, RISC-V, FPGA fabric

nanoAUV Hardware
- Sensors, Actuators
- Scientific payload
Development of a Space-Grade processor platform

- Core unit: Teledyne LS1046-Space
- Quad ARM core (Cortex A72)
- Suitable for various applications
  - Image processing
  - LIDAR
- PCB development, manufacturing, validation and test
- Rapid Prototyping
What is new in the world of space electronics?

• The battle NewSpace vs Traditional Space is still ongoing
  • High performance only possible when utilizing COTS parts, but those tend to faulty behavior in space
  • Agencies are getting more and more open-minded for COTS devices
  • NewSpace will face some serious issues
• Modern applications steadily raise the performance demands of space-grade-boards and -devices
  • Novel Generation of RHBD devices, e.g. FPGAs or SoCs, will decrease the commercial and non-terrestrial gap
  • Power/Thermal dissipation
• AI is key enabler for various space-applications
  • How to efficiently perform on-board ML?

DSI will provide different space-grade PCBs to compete with these challenging goals
Thank you for your attention!
Questions?
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