## Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
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<tr>
<td>COTS</td>
<td>Commercial off-the-shelf</td>
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<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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<tr>
<td>GOES</td>
<td>Geostationary Operational Environmental Satellite</td>
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<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>ISS</td>
<td>International Space Station</td>
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<tr>
<td>MBMA</td>
<td>Model-Based Mission Assurance</td>
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<tr>
<td>MMS</td>
<td>Magnetospheric MultiScale</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NEPP</td>
<td>NASA Electronic Parts and Packaging (Program)</td>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<td>NSREC</td>
<td>Nuclear and Space Radiation Effects Conference</td>
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<td>SOHO</td>
<td>Solar and Heliospheric Observatory</td>
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<tr>
<td>SSR</td>
<td>Solid-State Recorder</td>
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Purpose

• Describe the accelerating use of COTS parts in space applications
• Understand component reliability and threats in the context of the mission, environment, application, and lifetime
• Provide overview of traditional approaches applied to COTS parts in flight applications
• Discuss challenges and potential paths forward for COTS systems in flight applications – it’s all about data!
Outline

- COTS parts from a space user’s perspective
- Accelerating use of COTS parts
- Traditional use of COTS parts in space applications
- Evolving approaches for COTS parts and systems in space applications
- Conclusions
Near-Earth Space Environment

Can induce a variety of cumulative degradation effects as well as soft and hard errors

Image credit: NASA

Thermal

Vacuum

Launch

Lifetimes

Solar Protons & Heavy Ions

Galactic Cosmic Rays

Trapped Protons & Electrons

Radiation

Servicing limitations

Trajectory / Orbit

Et cetera

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What Are COTS Parts?

Space Users’ Perspectives

• Parts designed for applications where the specifications, materials, etc. are established solely by the manufacturer / vendor pursuant to market forces
• Parts not explicitly designed for space applications
  – May have additional requirements imposed by users or external organizations
    • Assess product quality (screening) and reliability (qualification)
Spacecraft and Payloads Are Still Largely Custom-Built

- Assembly techniques have advanced considerably, however…
- Touch labor and significant testing for validation
- Traditionally, little to no economy of scale

Image Credit: NASA

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COTS Parts in Space

Artist’s rendering of GOES-R Spacecraft

Launched: 19-Nov-2016
Operational as GOES-16

NASA GSFC Dellingr CubeSat
Released to Orbit: 20-Nov-2017

COTS parts → Mostly COTS systems

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Accelerating Use of COTS Parts in Space Applications

Secondary payloads (e.g., CubeSats) launched each year, including commercial constellations


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Traditional Use of COTS Parts

NASA Users’ Perspectives

- Provided detailed and relevant knowledge about the performance and reliability of the actual parts to be flown
- Nearly-closed ecosystem leveraged to maximize reliability

Military Specifications & Standards (U.S. listed; parallels in Europe & Japan)
- MIL-PRF-19500
- MIL-PRF-38535
- MIL-STD-750
- MIL-STD-883

Community Consensus Standards
- ASTM
- JEDEC

Performance (Examples)
Testing (Examples)
Testing (Examples)

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Traditional Use of COTS Parts

NASA Users’ Perspectives

• Up until early 1990s, only used COTS parts when there was no Military / Aerospace option to fulfill requirements – or in non-critical applications

• Key performance requirements (e.g., size, weight, power, etc.) drove COTS parts into the mainstream

Magnetospheric Multiscale (MMS) observatories processed for launch

Early use of NAND flash in solid state recorder; launched 12-Mar-2015

Image Credit: NASA

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Traditional Use of COTS Parts

*NASA Users’ Perspectives*

- Upscreening is the classic approach used for deploying COTS electronics in flight systems
  - Perform a series of tests over extended parameters, coupled with application information, to determine if a part can meet a mission’s reliability & availability requirements
  - Includes temperature, vacuum, radiation, shock, vibration, etc.

**Expert-Friendly**

Effective mapping of part-level requirements to mission expectations is essential

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Evolving Use of COTS Parts

In many newer systems using COTS parts...

• Schedule is critical
• Budget is limited
• Size, weight, and power are limited
• Performance or availability were likely sole reasons for COTS parts selection
• If not possible to qualify by analysis, that leaves testing, but…
• Higher risk tolerance ≠ lower qualification budget


Image Credit: NASA

CubeSat launch from ISS

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Evolving Use of COTS Parts

Intentional Operational Feedback

Figure adapted from R. Harboe-Sorensen et al., RADECS, 2001.

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Evolving Use of COTS Parts

Model-Based Mission Assurance (MBMA)

Figure after A. F. Witulski et al., NEPP Electronics Technology Workshop, 2017.
R. A. Austin et al., IEEE Reliability and Maintainability Symposium, 2017.

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Evolving Use of COTS Parts

Cross-Organization Data Sharing

- Advocate for a community-consensus electronic part data exchange standard
- Bootstrap from other implementations (e.g., Health Level-7) – can still protect intellectual property
- Aggregate data to avoid being data-starved – statistical significance

Multiple organizations

Heterogeneous data

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Conclusions

• Innovation requires an increasing number of COTS-based space applications
• Understanding component reliability and availability requirements in the context of mission expectations remains a key challenge
• Operational telemetry enables us to stumble / fail smart and improve our models
• Sharing and aggregating component data enables more design creativity