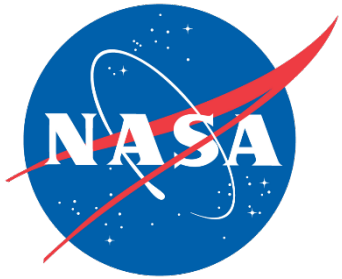
National Aeronautics and Space Administration



Commercial Off-The-Shelf (COTS) Electronics Reliability for Space Applications

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To be published on nepp.nasa.gov.

Acronyms

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

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**

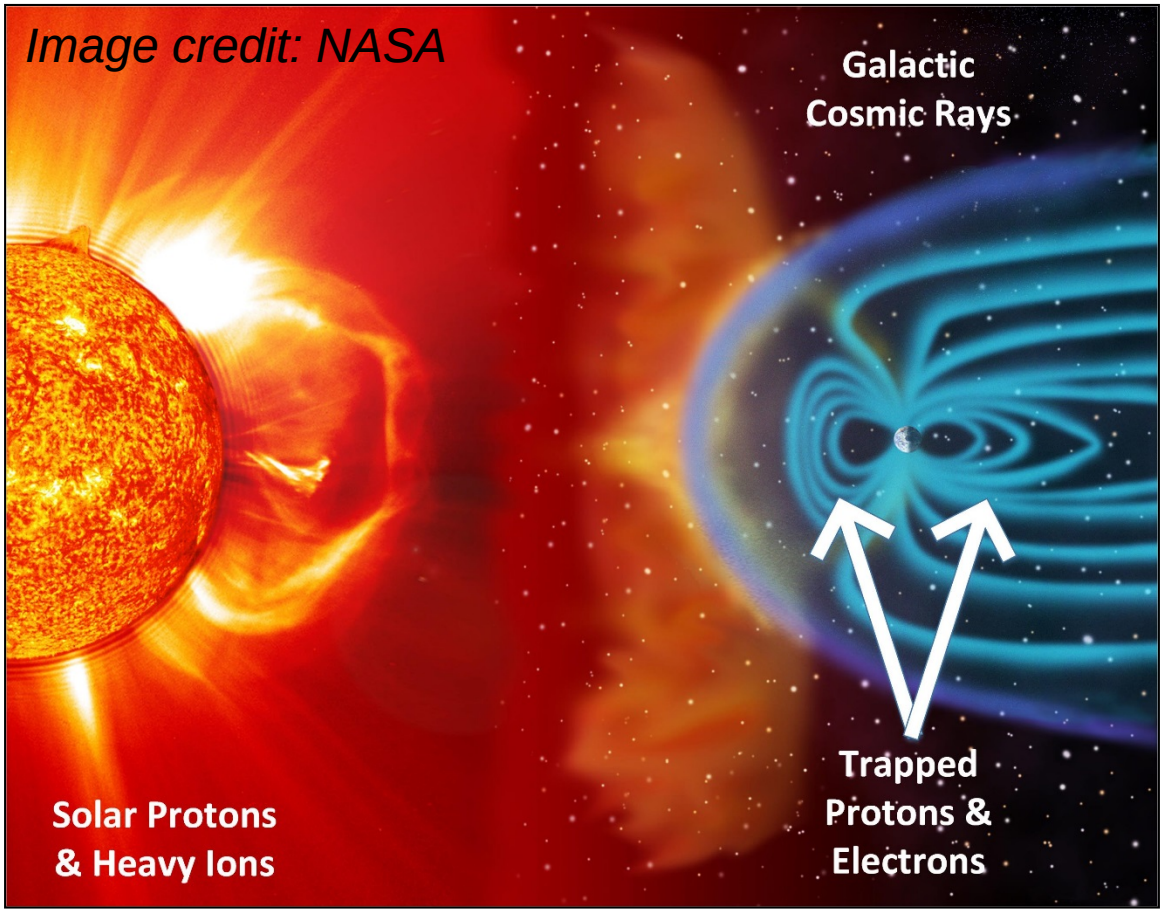
Near-Earth Space Environment

Thermal

Vacuum

Launch

Lifetimes



Radiation

Servicing limitations

Trajectory / Orbit

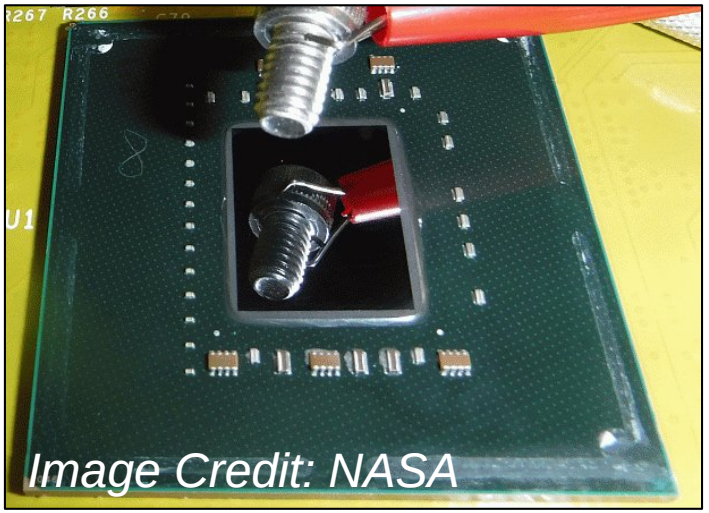
Et cetera

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

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*)**



Xilinx Virtex-7 FPGA prepared for radiation testing

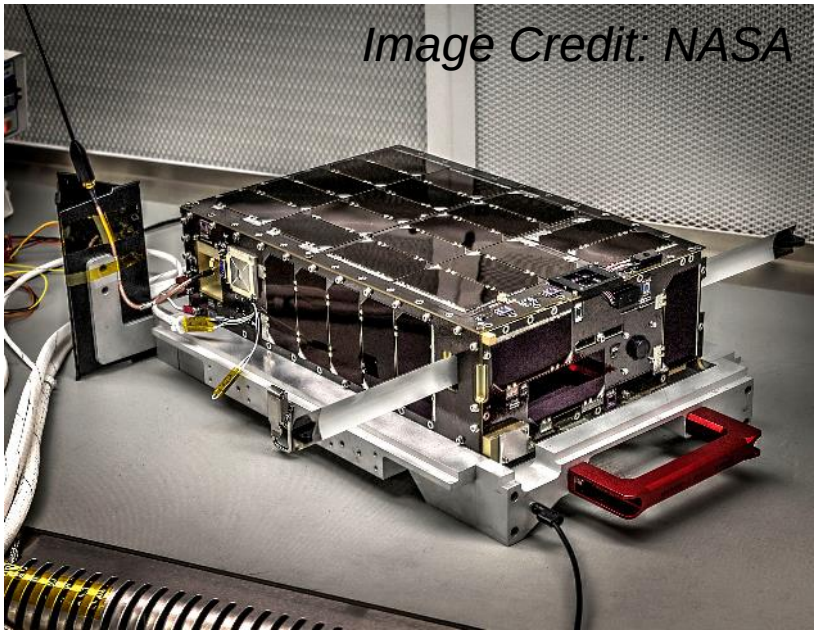
Spacecraft and Payloads Are Still Largely Custom-Built

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

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**

Accelerating Use of COTS Parts in Space Applications

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

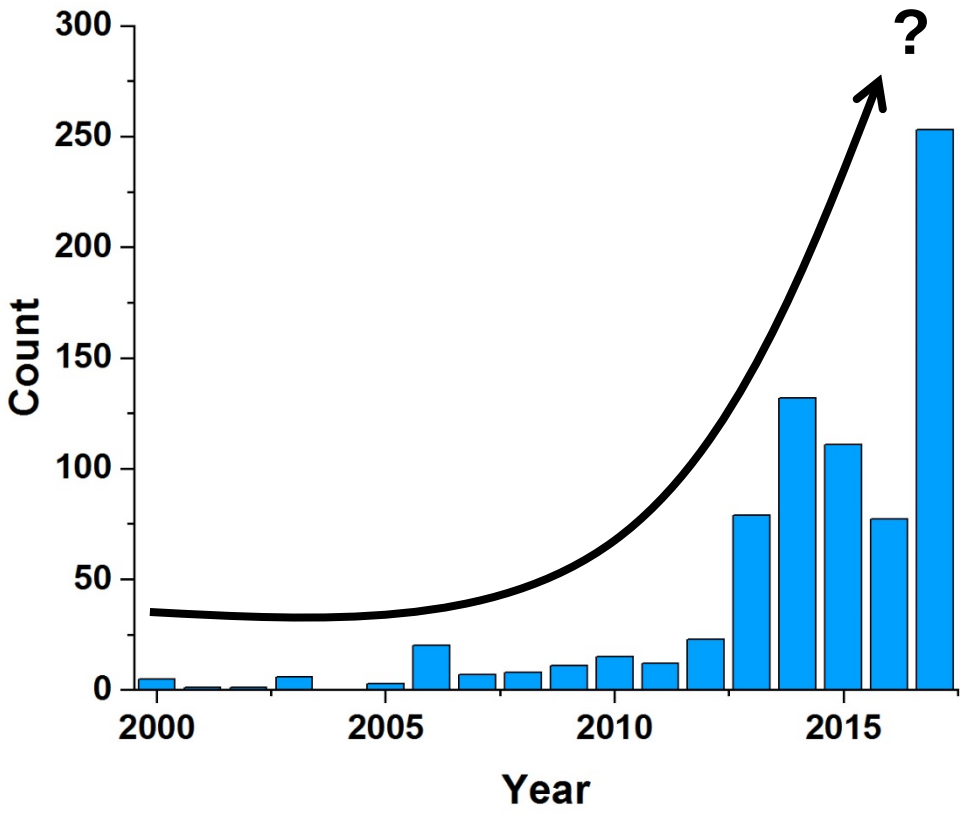


Chart adapted from: M. Swartwout, “Online CubeSat Database,” https://sites.google.com/a/slu.edu/swartwout/home/cubesat-database (20-Dec-2017)

Traditional Use of COTS Parts

NASA Users' Perspectives

Military Specifications & Standards (U.S. listed; parallels in Europe & Japan)		Community Consensus Standards
Performance *(Examples)*	Testing *(Examples)*	Testing *(Examples)*
MIL-PRF-19500 MIL-PRF-38535	MIL-STD-750 MIL-STD-883	ASTM JEDEC

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

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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

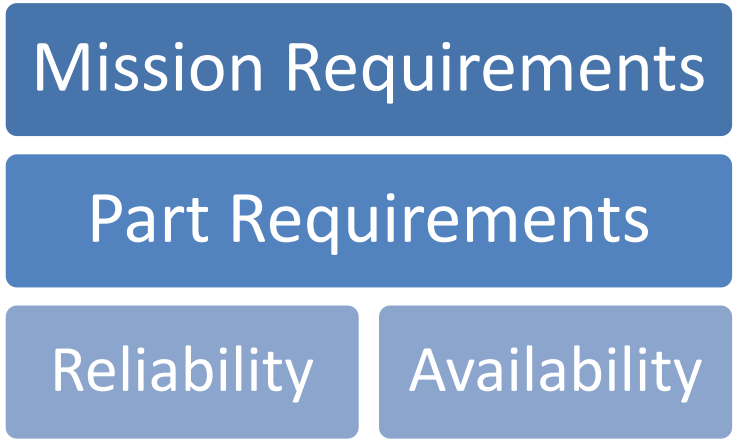
Traditional Use of COTS Parts

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

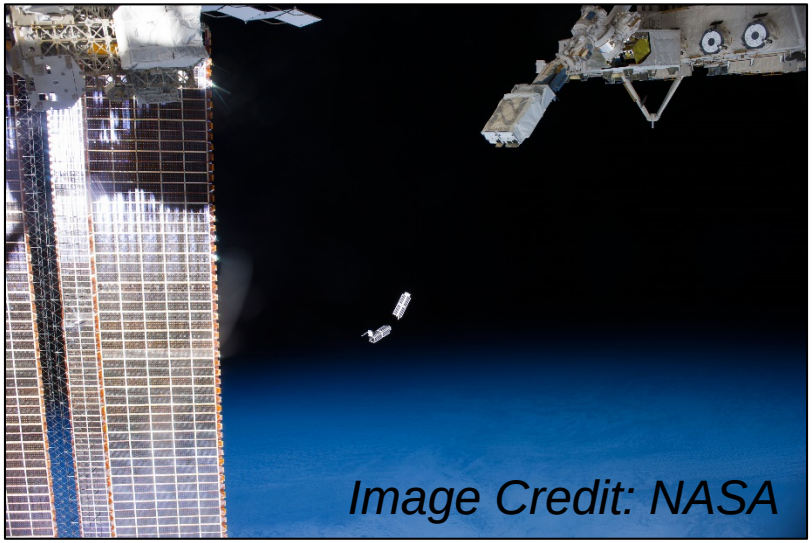
Effective mapping of part-level requirements to mission expectations is essential



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**



CubeSat launch from ISS

Adapted from R. Ladbury, *IEEE NSREC Short Course*, New Orleans, LA, 2017.

Evolving Use of COTS Parts

Intentional Operational Feedback

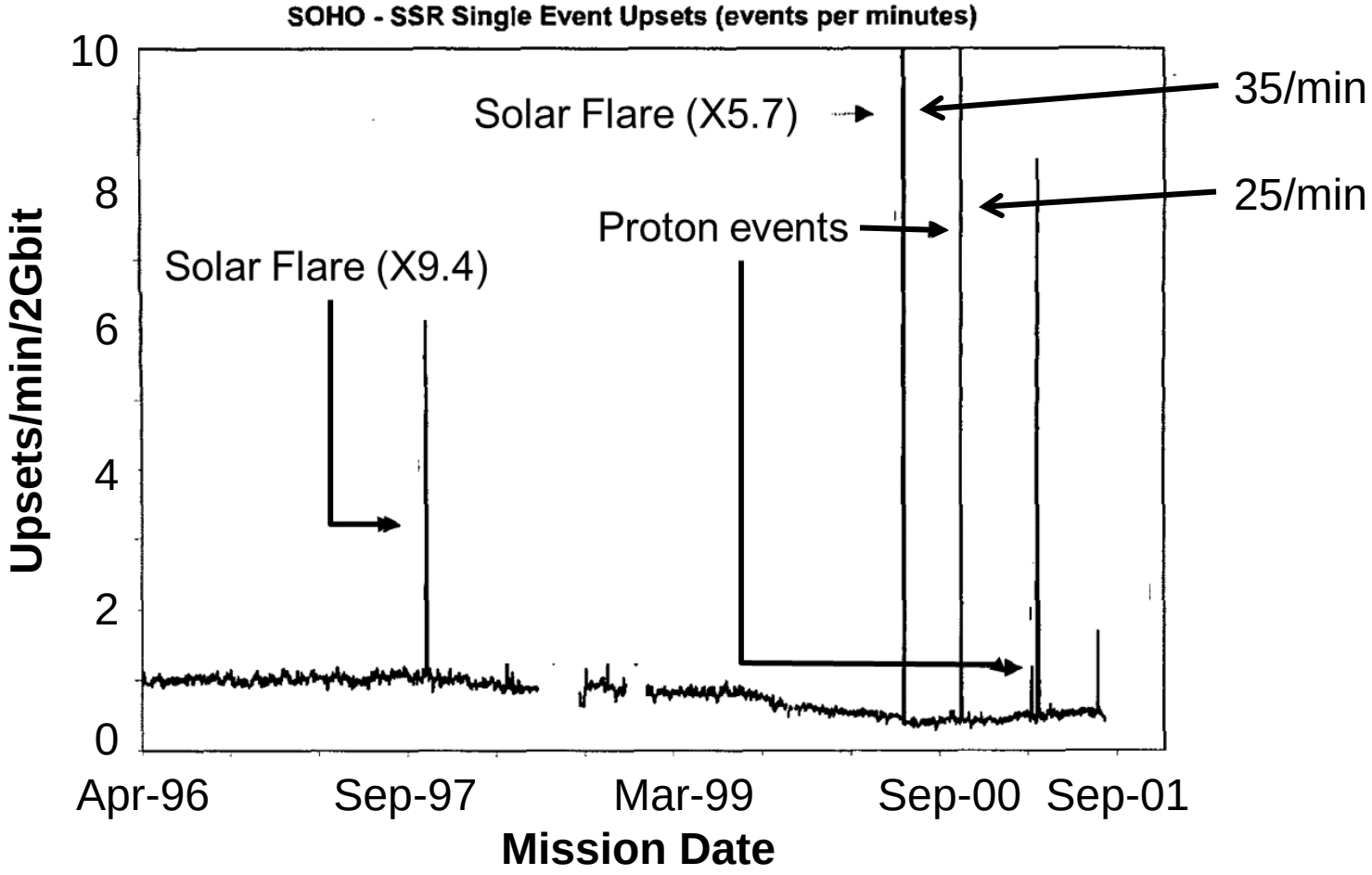
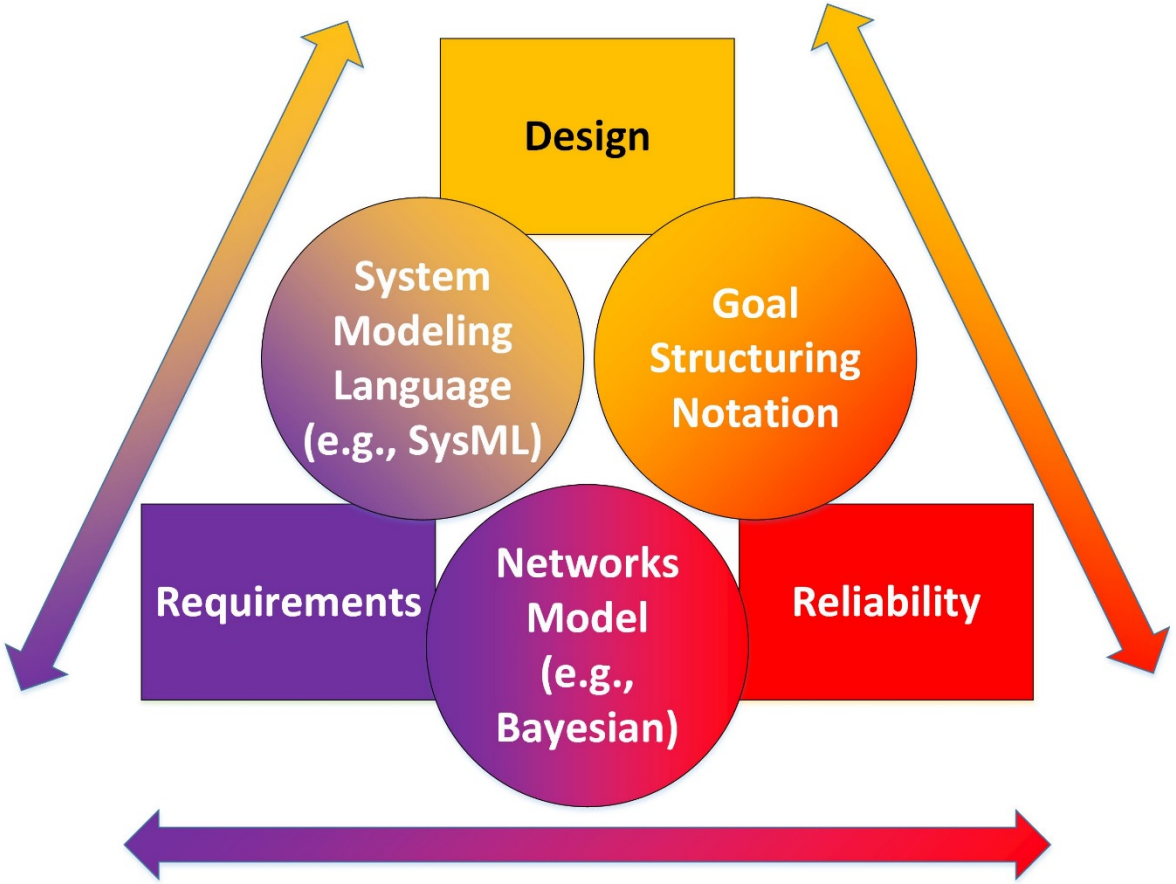


Figure adapted from R. Harboe-Sorensen *et al.*, *RADECS*, 2001.
R. Kwasnick *et al.*, *IEEE International Reliability Physics Symposium*, 2017.

Evolving Use of COTS Parts

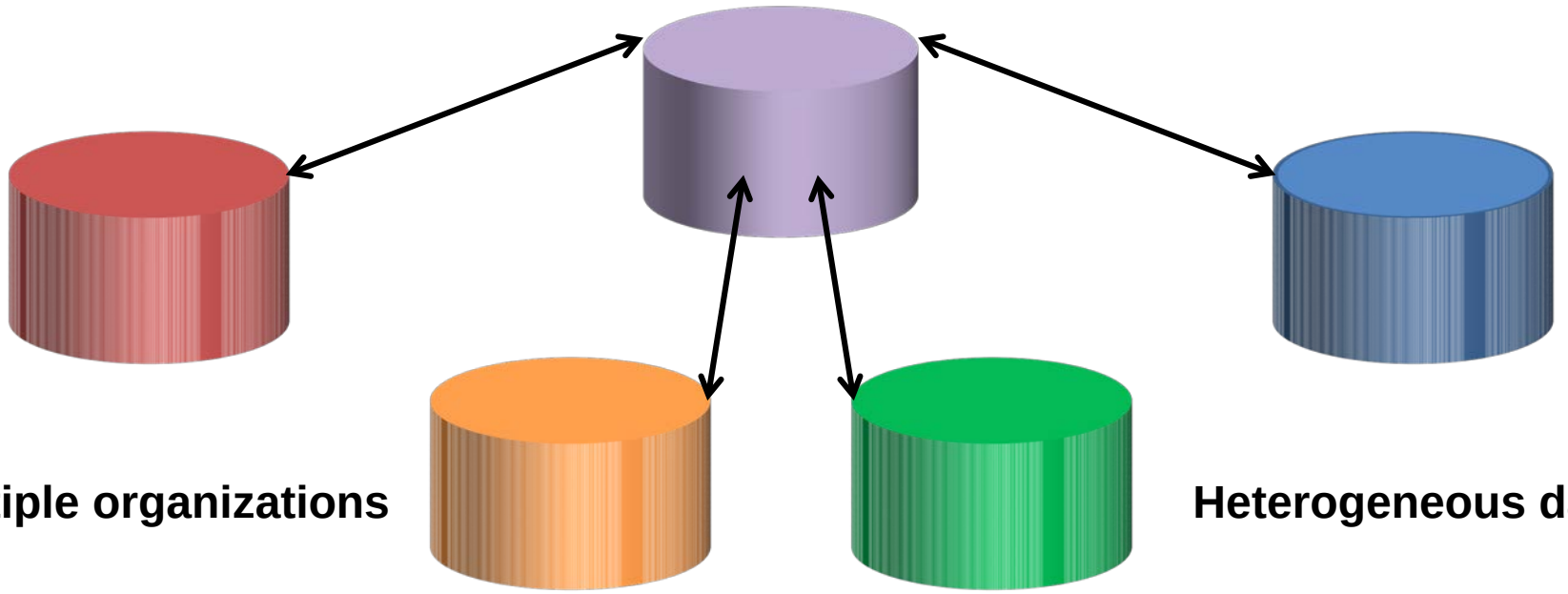
Model-Based Mission Assurance (MBMA)



J. Evans *et al.*, *IEEE Reliability and Maintainability Symposium*, 2016.
Figure after A. F. Witulski *et al.*, *NEPP Electronics Technology Workshop*, 2017.
R. A. Austin *et al.*, *IEEE Reliability and Maintainability Symposium*, 2017.

Evolving Use of COTS Parts

Cross-Organization Data Sharing



Multiple organizations

Heterogeneous data

- **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**

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**