CMSE '24
COTS Mission Success Improvement Workshop Update

Dr. Ryan Rairigh, Lockheed Martin Space
ryan.p.rairigh@lmco.com
303-977-7313

2023 COTS MSIW Leads

Brian Kosinski, Aerospace CCEO
Steve Lau, Aerospace DICED

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Commercial off the Shelf Parts (COTS) MSIW

Outline/Goal

- Why a COTS MSIW?
- Charter and Core Team membership
- Overview documents produced
- Examples of other collaborative efforts
- The need for additional COTS efforts
- Path forward open discussion

<u>Commercial Off The Shelf (COTS) components are</u>:
A cataloged EEE (Electrical, Electronic, Electromechanical) part designed for commercial applications for which the item manufacturer or vendor solely establishes and controls the specifications for performance, configuration, and reliability (including design, materials, processes, and testing) without additional requirements imposed by users and external organizations.

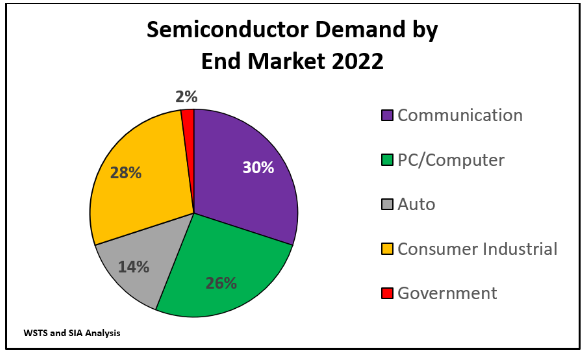
Goals of this Briefing

1. Increase awareness of COTS MSIW documents produced and collaborative effort value
2. Discuss our follow-on activity

Why a COTS MSIW? US Space Dominance Is Under Threat

We must innovate, procure, design, and launch faster

- MIL-SPEC and Space Qualified part challenges:
  - *Becoming more expensive and harder to get*
  - *Do not meet performance needs of next generation space assets*



USG is not driving the market

- COTS Opportunities for Space Applications:
  - *Used successfully on new launch vehicles, CubeSats, LEO constellations and commercial GEO satellites:*
    - Less expensive and more readily available (eases supply chain challenges)
    - Higher performance (with SWAP benefits and reduced part count)
    - Flexible (programmable and scalable)
    - Reliable if used properly (built on high volume automated production lines)
  - *USG moving toward constellation architectures and disaggregated systems and willing to take more risk:* ***Frank Calvelli****, Assistance Sec of Air Force, Memo 4/2023 "…transform space architecture to a more proliferated and resilient form"*

The Space Industry must pivot to meet the rapidly evolving changes and needs of the space industry. Use of COTS must be part of this strategy

COTS Mission Success Improvement Workshop (MSIW)

- COTS MSIW Charter:
  - *"Define and develop practical guidance and tools to navigate through the complicated process of assessing the viability and use of COTS for space applications"*

- Industry and US Government team including reps from:
  - *Ball Aerospace Corp, Blue Canyon, Boeing, L3 Harris, Lockheed Martin, MAXAR, Northrop Grumman, Raytheon, and SEAKR Engineering*
  - *NASA: JPL and Goddard Space Flight Center*
  - *Aerospace Corporation*

Two documents produced move us in the right direction
Collaboration, relationships formed, shared briefings etc. equally important
…extremely grateful for everyone's efforts and contributions

Acquisition Considerations to Expand Space Design Options Using COTS Electrical, Electronic and Electromechanical (EEE) Parts and Units, ATR-2023-01981

- Status:
  - *Published 27 March 2024*

- Special thanks to:
  - *Tom Wunderlich (Ball) for leading the sub-team and providing most of the draft document content*
  - *Eli Minson (MAXAR), Barbara Braun, Steve Mo, Art McLellan, John Ranaudo, & Allyson Yarborough (Aerospace) for valuable content additions, suggestions, and editing*

PM&P

Reliability

Counterfeit Parts

Prohibited Materials

Traceability

CDRLs

QMS

Acquisition Areas Addressed

(excerpt from ATR-2023-01981)

Acquisition Considerations to Expand Space Design Options Using COTS Electrical, Electronic and Electromechanical (EEE) Parts and Units, ATR-2023-01981

Abstract: This Aerospace technical report (ATR) is intended for reference when a customer is considering the use of commercial off-the-shelf (COTS) electrical, electronic, and electromechanical (EEE) parts and units in offerors' proposals. It provides examples of contract language that can inadvertently prevent an offeror from bidding a COTS solution and offers suggestions for alternative wording. This ATR was created in conjunction with ATR 2023-01935, Expanding Space Design Options Using COTS. These reports, when used in concert, will enable the performance benefits, shorter procurement times, and reduced costs needed to achieve critical mission needs.

Table of Contents:

Expanding Space Design Options Using COTS, ATR-2023-01935

- Status:
  - Published 13 November 2023

- Special thanks to:
  - *Steve Hogan who did the bulk of the work. Without his efforts and knowledge this work would not have been possible*
  - *Dr. Ryan Rairigh (LM), Dr. Jesse Leitner (NASA, GSFC) and Mark Porter (NASA, JPL) for great collaborative editing and suggestion efforts*
  - *The many reviewers who submitted over 400 comments (!) during the review cycle*

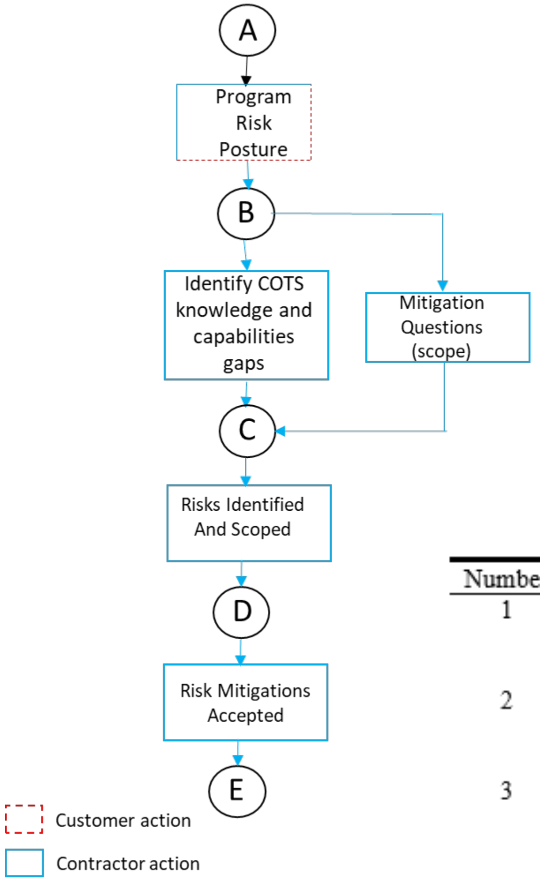
Expanding Space Design Options Using COTS, ATR-2023-01935

Abstract: The usage of Commercial Off the Shelf (COTS) components can provide impactful benefits to space programs. Space programs can benefit by accessing the latest performance technology and shorten procurement times for faster pace programs. This Aerospace Technical Report (ATR) provides guidance for determining the risk (cost, schedule, technical) of inserting COTS components or units on space vehicles as well as potential best practices and mitigations for many known COTS component or unit concerns.

Table of Contents:

Sample ATR-2023-01935 Flow Charts and Tables

"Tiered" Decision Flowcharts



Informed Risk Flow

(excerpt from ATR-2023-01935)

Table 1 Supplier Best Practices

Best Practices for COTS Components (Supplier)
Process stability for at least one year[2]
Product produced in high volume[2]
100% electrical test[2]
Multi-lot charaterization[2]
Fully automated line[2]
Undergoes in-process testing[2]
Maintains consistent yield[2]

Supplier Selection Best Practices

Table 2 General Best Practices for the Component User

Number	Best Practices for COTS component (user)
1	For a given COTS, once the program has defined the necessary best practices and mitigations, develop a plan to deal with the higher cost and schedule risk items first[3]
2	Consider not having the COTS in a critical timing/ mission path (although it is recognized that COTS is likely a part of the critical path for performance reasons)[2, 5, 12, 16]
3	Consider the fault management implications (fault/degradation mechanisms)[4, 5, 12, 16, 23]

General COTS Usage Best Practices

Table 20. Potential Radiation Mitigations

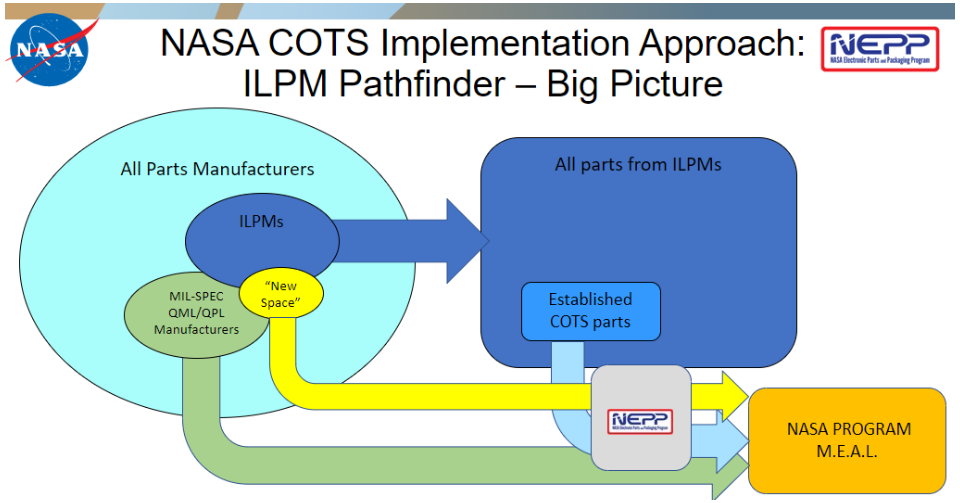
Mitigation	Radiation
	Total Dose Radiation
1a	Local Shielding
1b	Power Strobing
1c	Increased Redundancy
1d	N for M redundancy
1e	Multiple Images
1f	Multiple components in parallel
	Single Event Upsets (SEU)
1g	Periodic Refresh Period
1h	Error Detection And Correction (EDAC)
1j	Triple Modular Redundancy (TMR)
1k	FPGA based scrubbing
1l	Zener Diodes/clamps/Filters
1m	Software Rollback
	Single Event Functional Interrupt (SEFI)
1n	Local Refresh
1o	Component Reset
1p	Power Cycle
1q	CONOPS/System
	Latchup
1r	Current limiting
1s	Swap/Power Cycle (OBFM)
1t	Auto Power Cycle (hardware)
	Single Event Gate Rupture
1u	Conservative Derating

Potential Radiation Mitigations

…Plus three real-world example that pull it all together

Examples of Additional COTS MSIW Efforts and Collaborations

Equally important as the two documents produced!



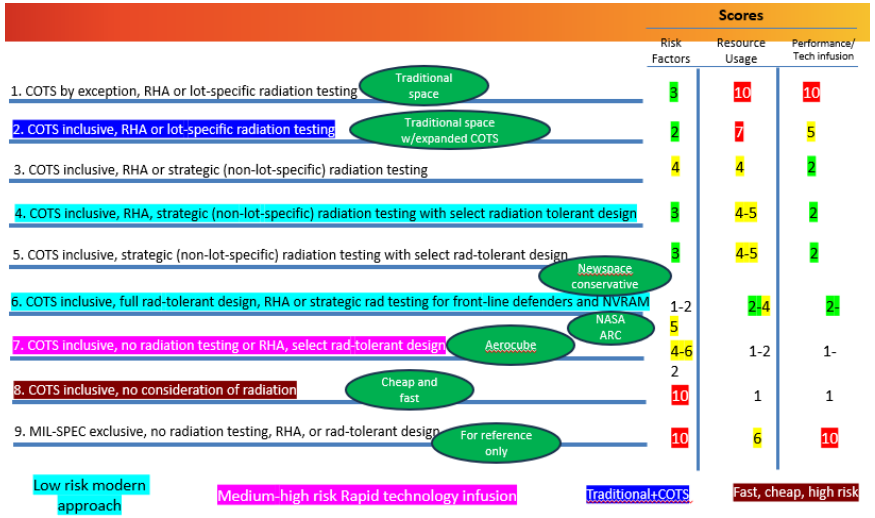
NASA COTS Phase II and ILPM Briefings

Failure Mode	Physics Impact	Physics Equation	Assumed Distribution	Logical Effort Impact
Hot Carrier Injection (HCI)	Reduction in transistor drive current. Note: HCI and BTI both contribute to this reduction.	*Median reduction in saturated drain current:* $\frac{\Delta I_{Dsat}}{I_{Dsat}} = A\, exp\left(-\frac{E_A}{kT}\right) \times \left(\frac{V_D}{V_{nom}}\right)^m \times t^n$ *Note: Calculated for both nmos and pmos transistors*	lognormal	*Increased logical effort, g:* $+\Delta g = \begin{cases} g\left(1+\frac{\Delta I_{DSAT,n}}{I_{DSAT,n}}\right) \text{ for nmos} \\ g\left(1+\frac{\Delta I_{DSAT,p}}{I_{DSAT,p}}\right) \text{ for pmos} \end{cases}$, maximum *Note: increase due to HCI only*
Bias Temperature Instability (BTI)		*Median reduction in saturated drain current:* $I_{D0} \rightarrow I_{D0n}\left(\frac{V_{DD}-(V_{Tn}+\Delta V_{Tn})}{V_{DD}-V_{Tn}}\right)^{\alpha_n}$, for nmos $I_{D0} \rightarrow I_{D0p}\left(\frac{V_{DD}-(V_{Tp}+\Delta V_{Tp})}{V_{DD}-V_{Tp}}\right)^{\alpha_p}$, for pmos	normal	*Increased logical effort, g:* $\rightarrow \begin{cases} g\left(1+\frac{\Delta I_{DSAT,n}}{I_{DSAT,n}}\right) \times \left(\frac{V_{DD}-\Delta V_{Tn}}{V_{DD}-(V_{Tn}+\Delta V_{Tn})}\right)^{\alpha_n} \text{ for nmos} \\ g\left(1+\frac{\Delta I_{DSAT,p}}{I_{DSAT,p}}\right) \times \left(\frac{V_{DD}-\Delta V_{Tp}}{V_{DD}-(V_{Tp}+\Delta V_{Tp})}\right)^{\alpha_p} \text{ for pmos} \end{cases}$, maximum *Note: increase due to both HCI and BTI*

CMOS Physics of Failure Modeling

Launched	End of Use	Years	Sum years	Vehicle	Initial perigee km	Initial apogee km	Inclination deg
09/13/12	6/17/20	8	8	AC4 A	495	800	66.4
09/13/12	09/20/12	0	0	AC4 B	495	800	66.4
09/13/12	01/30/20	7	7	AC4 C	495	800	66.4
12/06/13		9	18	AC5 A,B	469	972	120
06/19/14		8	8	AC6 A	650	650	98
06/19/14	9/16/21	7	7	AC6 B	650	650	98
10/08/15		7	7	AC5 C	500	780	64
10/08/15		7	7	AC7 A	500	780	64
05/20/15	10/9/2021	6	6	AC8 A	390	700	60
05/20/15	10/1/2021	6	6	AC8 B	390	700	60
11/11/16		5	10	AC8 C,D	550	580	98
11/12/17	8/4/2022	5	5	AC7 B	450	450	51.6
11/12/17	8/12/2022	5	5	AC7 C	450	450	51.6
11/12/17	2/21/2022	4	4	ISARA	450	450	51.6
12/16/18		4	8	AC11 A,B	500	500	85
05/21/18		4	8	AC12 A,B	450	450	51.6
04/15/19		3	6	AC10 A,B	450	450	51.6
11/02/19		3	6	AC14 A,B	450	450	51.6
11/02/19		3	6	AC15 A,B	450	450	51.6
12/01/21	6/25/22	0.5	0.5	DAILI	420	420	51.6

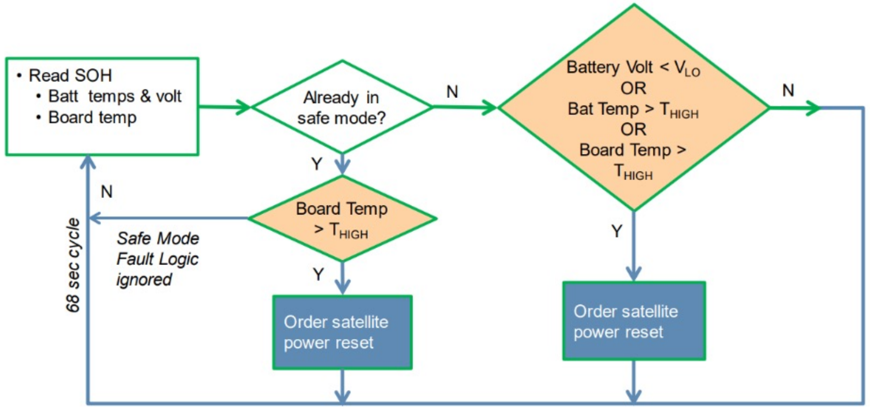
Aerospace AeroCube COTS On-Orbit Success



Radiation Approach Risk Categorization

Examples of Additional COTS MSIW Efforts and Collaborations

Equally important as the two documents produced!



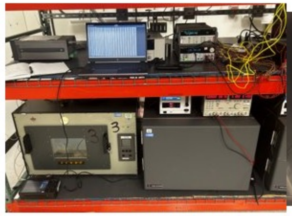
Reset logic to guard against SEL

Part vs Board level radiation testing

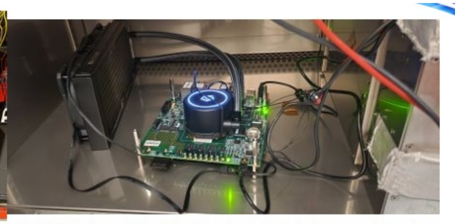
Board Level Testing

H/W biased and monitored for DSEE, NDSEE and TID degradation

- Verifies use case for all designs
- Characterize Resets
- Verify NDSEE mitigation strategies

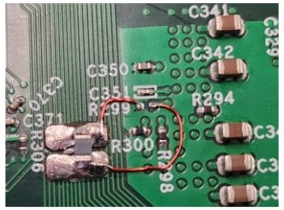


Instrumentation for stressing



LS1043A board & attached cooler in temp. chamber

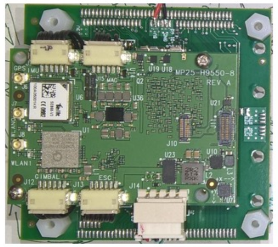
LS1043A box in Co^{60} chamber

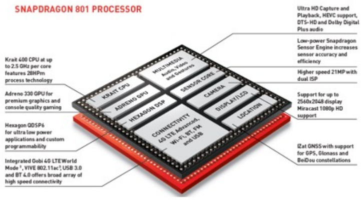


Attachment of programming resistor to effect each increase in core voltage

Small Gate Size CMOS SOC Life and Radiation Testing

- **Snapdragon® 801 (28nm) CPU - 4 cores are used**
  - implement visual navigation via velocity estimation
  - Filter propagation for flight control
  - Data management
  - Command processing
  - Telemetry generation
  - Radio communication
  - Samsung Galaxy S4/HTC One Generation phones
  - Used for Extended Kalman Filter State Estimation and vision processing corner detection algorithms
- **Navigation Camera - Omnivision OV7251**
  - 640x480 pixel sensor @ 10 frames/sec
  - Visual features are extracted from images and tracked frame to frame to provide velocity estimate
- **Return to Earth Camera – Sony IMX 214**
  - 4208 X 3120 pixel sensor (13MP), 4K video @ 30fps





"Mars Helicopter Technology Demonstrator", B. Balram, et. al. AIAA SciTech Forum 2018

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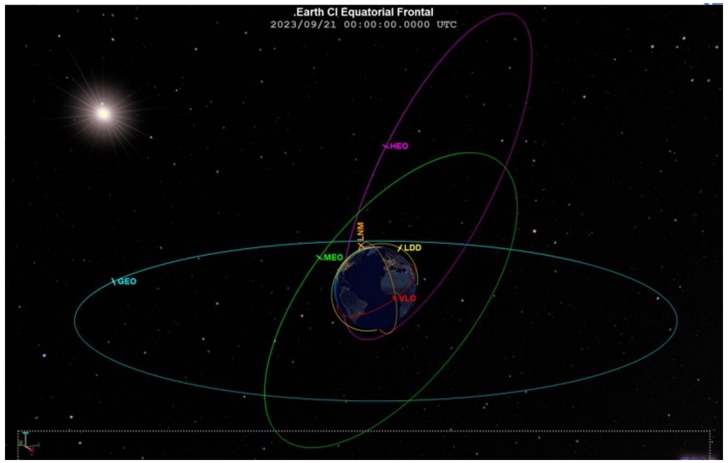
Mars Ingenuity Helicopter: COTS



Orbit Environment Characterization

COTS MSIW Path Forward

The effort continues

- Collaboration has been as valuable as the documents we produced

- Continue monthly meetings to foster implementation and collaboration
  - *Christine Rink, Aerospace Corp. Electronics and Sensors Division (ESD) is the new lead for 2024*

- Some of the near term team objectives will build off of the ATR products
  - *Discuss real world examples to “test drive” (obtain user feedback): improve the two documents we produced*
  - *Develop briefing material and “road show” to various companies and organizations (gain more awareness)*

- Additionally targeting focus areas that align with our charter
  - *Continue common interest presentations*
  - *Partner with other organizations that are pursuing similar goals (e.g. NASA ILPM pilot efforts)*

As Doug Sheldon, JPL, said “Now is the time to leverage what commercial vendors are making.”

We did some great work, but there is much more to be done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