# Robust & Resilient Electronics Adaptive Development (RREAD)

David Caldwell, Peter Carian,
Horacio Saldivar, Sunny Yu,
Chris Le, John Morales
Electronics and Power Systems Department
Electronics Engineering Subdivision

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# *RREAD: Robust & Resilient Electronics Adaptive Development*

*Leverage COTS advantages to mitigate COTS risks*

## Specific Problem

*Space qualified power modules are used throughout satellites to reduce design burden and risk, but cost and lead times do not fit low-cost fast-paced programs. Commercial off-the-shelf (COTS) power modules are not intended for the space environment.*

## General Solution

*RREAD is a balanced iterative approach to electronic design for space systems. Advantages of COTS components are leveraged to mitigate risks in application of COTS components. Examples include modularity, fault management & perceptive telemetry.*

## Opportunity & Impact

*Customers are demanding faster, cheaper and good enough. COTS focus is on high-throughput digital, so power tends to be overlooked. Internal & Research & Development (IR&D) is opportunity to brainstorm & push boundaries not practical in program execution.*

***Highly integrated proven products reduce cost, schedule and risk of unique design***

# *RREAD Terminology & Philosophy*

*Goal: Clarity & Balance*

- **OTS:** Volume production devices, both parts and assemblies
- **COTS:** Less than space grade (consumer, industrial, auto, medical, military, etc.)
- **AGP:** Alternate grade implies terrestrial applications less tolerant of failures
- **Physics of Failure (PoF):** Insight to understand stress-induced degradation
- **Graceful degradation**
  - *Parts or subassemblies perform out-of-spec but continue to meet minimal functionality*
  - *Out-of-spec performance does not induce catastrophic failure of critical functions*
- **Slop-tolerant:** Design for graceful degradation (allow for out-of-spec behavior)
  - *Large margins are not limited to derating*
  - *Insensitivity to common radiation degradation effects like leakage, offset and speed*
- **Sloppy:** Rushing and skipping steps like analysis, testability and fault tolerance
- **Robust & Resilient**
  - *Robustness Analogy: Soldiers are well equipped, trained and led to minimize casualty*
  - *Resiliency Analogy: Sending enough soldiers to win the war despite losses*

***Resiliency OR Robustness or Robust AND Resilient?***

# *RREAD Overview*

*Balanced iterative approach to electronic design for space systems*

**RREAD the Future of Space Electronics**

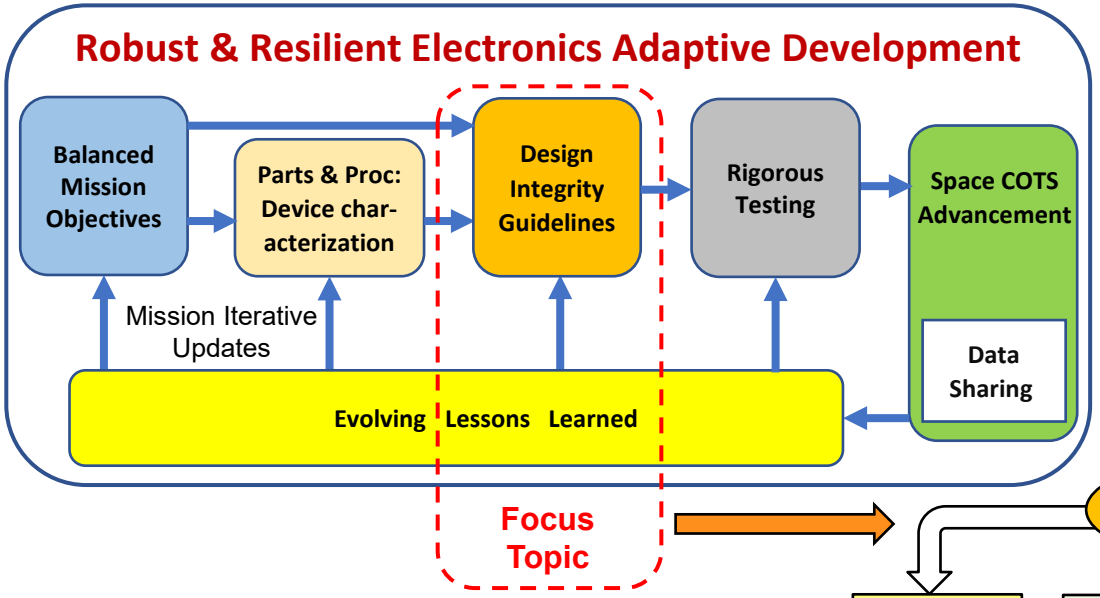

**Off the Shelf and Into Space[9]**

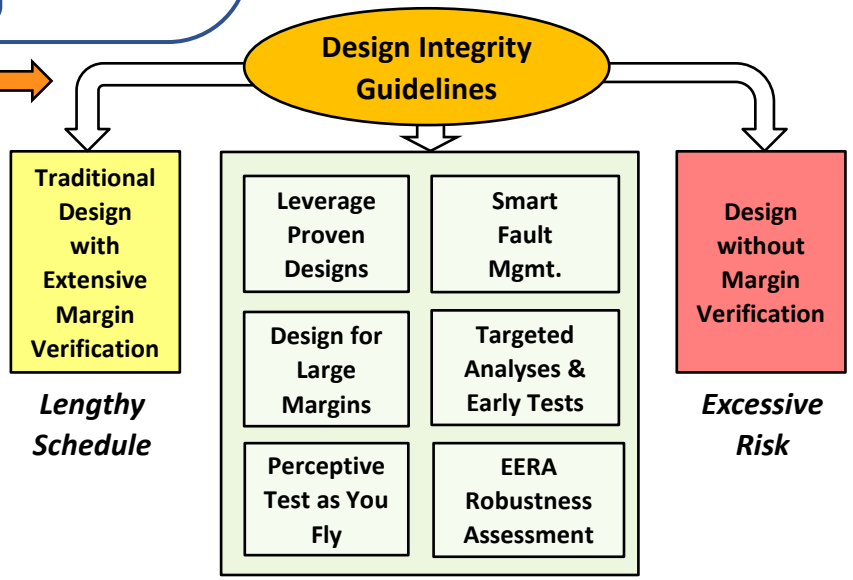
- **RREAD is a practical application of agile mission assurance for electronics design**
  - *Balanced mission objectives[1]*
  - *Device characterization and application[2,3]*
  - *Design integrity guidelines (DIG) [3] & mitigations[4,5]*
  - *Rigorous testing[2,4,6]*
  - *Space COTS advancement[6,7]*
  - *Evolving lessons learned[5,6,7,8]*
- **Evolution (streamlined processes) over revolution (optimistic step skipping)**

***Good parts do not make up for bad design & good design does not make up for bad parts***

# Traditional vs Slop-Tolerant vs Sloppy

*RREAD balanced iterative approach through DIG*




**Evolution not Revolution**

Iteratively apply lessons learned by streamlining proven processes rather than skipping steps

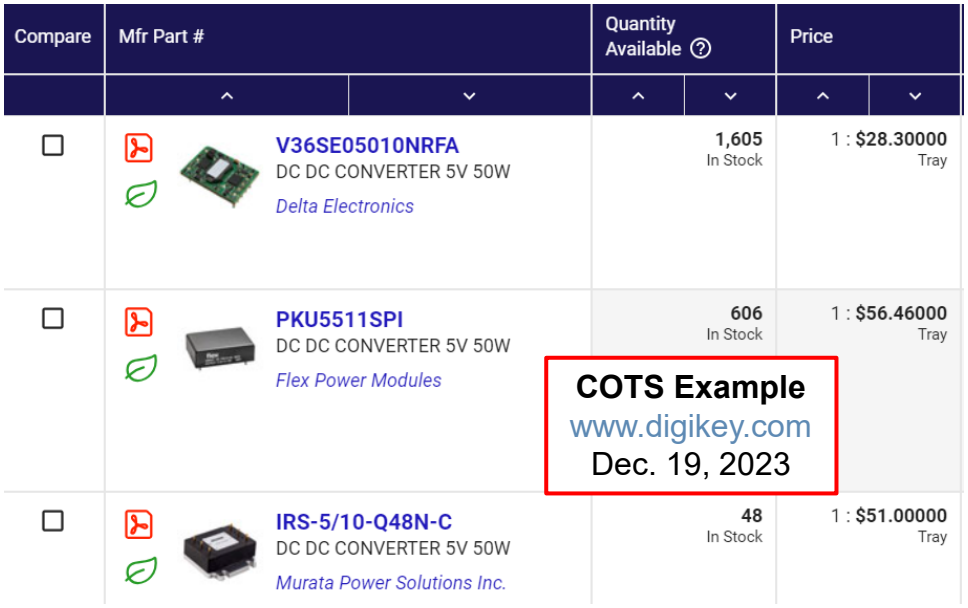
***Good, fast, cheap products take a good amount of time and money to develop***

# *RREAD Motivation to DIG into Power Modules*

*Satellite subsystems tend to be reliant on power converter modules*

- **Space power modules**
  - *Expensive ~$10K*
  - *Long lead: ~6mo.*
  - *Easy to apply, proven & rad hard*
- **COTS power modules**
  - ***Advantages***
    - Cheap & readily available
    - Standardized size & features
  - ***Challenges***
    - Unknown tech & derating
    - Space environment
  - ***Mitigation***
    - Derating: Vin = 18V to 75V
    - Modular perceptive application
    - Characterization data matched to mission objectives


**Space Qualified Example**
www.microchip.com
Dec. 13, 2023



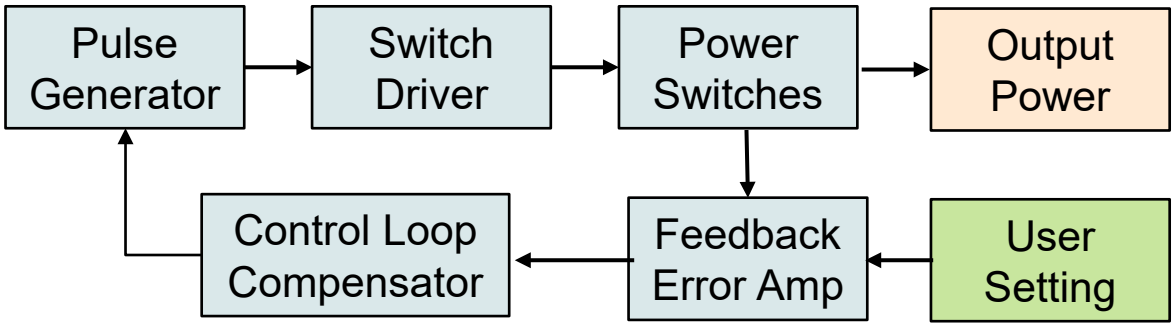

**COTS Example**
www.digikey.com
Dec. 19, 2023

***COTS power has incredible potential, but risks need to be investigated and mitigated***

# *COTS Power Circuit Total Dose Radiation Data[8]*

*Point of Load (PoL) power converter example*

- **Circuit-level performance far exceeded piece part hardness**
  - *Some parts exceeded datasheet specifications in the 5Krad to 15Krad range*
  - *All parts expected to perform adequately to at least 50Krad by circuit requirements*
  - *PoL functional to 118Krad Co60 low dose rate, plus Xray to 400Krad total*
- **Compensating circuit elements**
  - *Individual circuit blocks degraded like switching frequency and off-state current*
  - *Control loop continued to adjust switch duty cycle to achieve desired output voltage*
  - *Slop-tolerant design with adequate circuit performance despite out-of-spec parts*



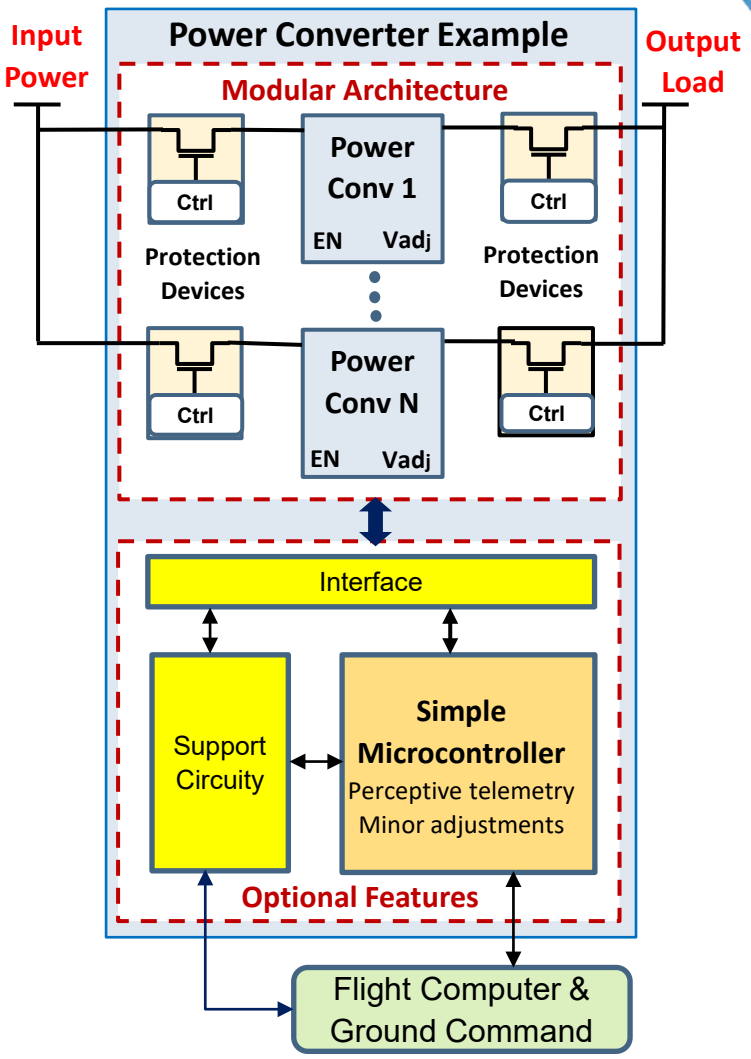

**Self-Compensating Switching Power Converter Block Diagram**

***Encouraging data to methodically pursue COTS space power***

# Power Module Characterization Opportunity[3]

*Aerospace IR&D FY24 test & demo*

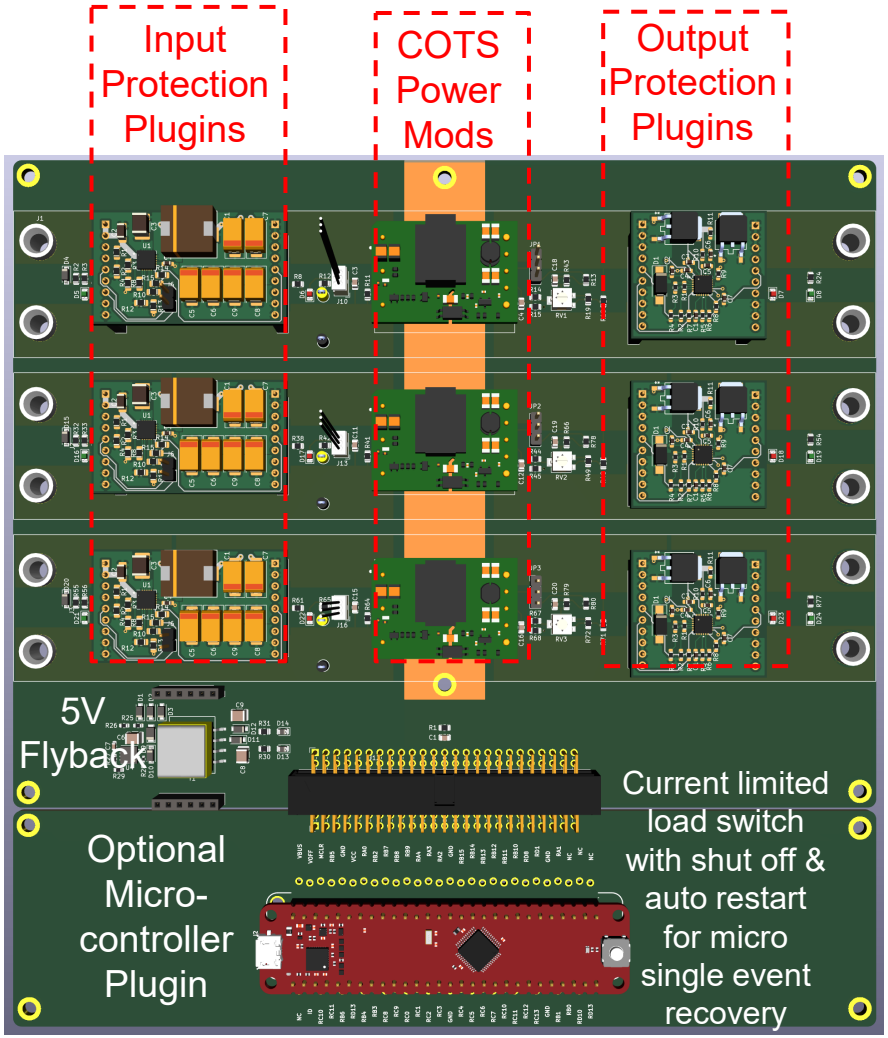
- **Modularity**
  - *Scalability to reduce future custom design*
  - *Single fault tolerance instead of full redundancy*
- **Protection**
  - *Ideal diodes provide efficient rectification & more*
  - *Integrated features include soft-start, current sensing and limiting, over and under voltage protection, thermal shutdown, warning flags*
- **Perceptiveness**
  - *Micro detects & reports degradation (PoF)*
  - *Lessons learned to further COTS evolution*
- **Adjustments**
  - *Limited range to modify performance, but not push operation out of bounds*
  - *Potential for life extension on future missions through PoF lessons*




***Goal is to identify COTS weaknesses and mitigations***

# Protected Modular Testbed

*IR&D to advance space COTS through data sharing*




- **Power modularity & fault tolerance**
  - *Three parallel power paths*
  - *Separate Power & Control boards to enable phased test and development*
  - *Input protection, power module, output protection and microcontroller plug-ins*
  - *Housekeeping and micro single event recovery circuits*
- **Anticipated challenges to investigate**
  - *Current sharing over life with dynamics*
  - *Thermal in vacuum (COTS mods use fans)*
  - *Fault injection and recovery*
  - *Radiation susceptibility*
- **Mitigations dependent on results**
  - *Tweak converter reference designs provided by control chip vendors*
    - Opto feedback to magnetics isolator
    - FET, reference & capacitor selection
  - *Large margins and derating*

***Concept illustration for robust & resilient electronics adaptive development***

# *Electrical & Electronics Robustness Assessment*

*EERA Goal: Maximize product understanding with minimal burden*

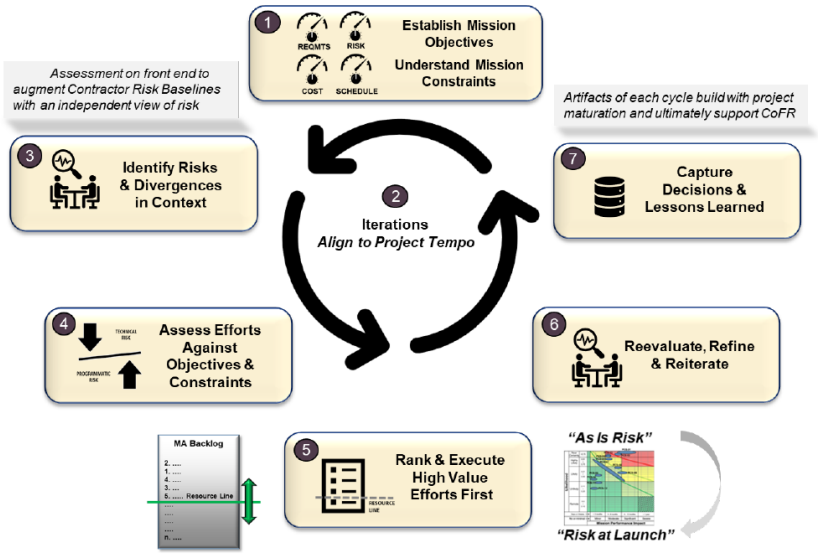
- **Clear concise documentation (informal but informative)**
  - *Block diagrams, functional description and operational objectives*
  - *Fault tolerance, testability, interconnects and grounding*
  - *Parts selection and de-rating*
- **Robustness confidence (balance risks to objectives[4])**
  - *Credit for heritage and simplicity (unnecessary "cleverness" is for IR&D not missions)*
  - *Compliance to "spirit" of worst-case circuit analysis (WCCA) for large design margins*
  - *Early informal analysis and/or breadboard test results for anticipated challenges*
- **Independent peer review by veteran contractor and government experts**
  - *Early enough to shape robust design and minimize test discovery*
  - *Assess criticality, uniqueness & challenge vs. robustness of circuit functions*
- **Objectives for proposed process**
  - *Promote extra consideration in design phase over empirical design-test-modify*
  - *Encourage fault tolerance to enable graceful degradation without full redundancy*

***DIG into a new EERA of Space COTS in Power Electronics***

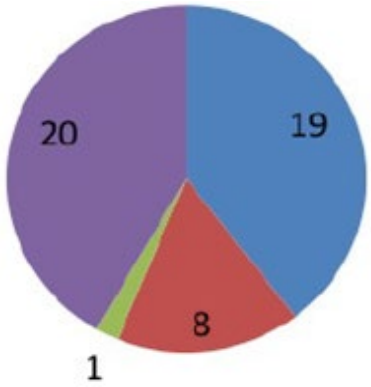
# *REEAD for Rapid and Agile Power Systems*

Spanning balanced mission objectives to space COTS advancement

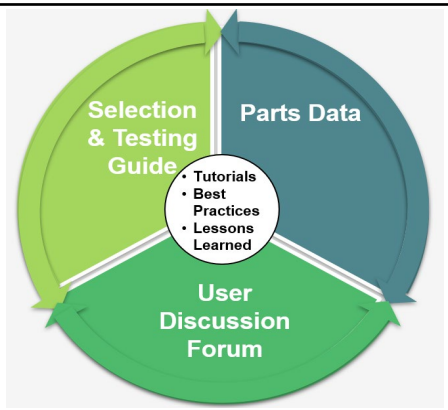
Agile Mission Assurance[1] as a class agnostic process that evolves iteratively




**RREAD:** Perfect design is unobtainable due to competing factors in semiconductors and applications. Optimal solution balances critical factors to satisfy realistic objectives.




CubeSat industry wide experience[5]




PMPedia[6] (More than COTS radiation data)
www.PMPedia.space

***RREAD builds on Aerospace's commitment to adaptability and teamwork***

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