Radiation Effects Considerations for Instrumentation and Control in Space Nuclear Systems

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NASA MSFC



Bottom line up front

Space nuclear systems impose *unprecedented* combined environments.

All systems need sensors and controllers.
Critical ones need early investment.

‘Rad-hard’ is very case-dependent.
The fine print matters.

Test!

Radiation Environment Operational Experience

DEFENSE

Very short durations
Very high rate
Neutrons + Gammas

SPACE

Moderate Duration
Low-mid rates
Charged Ions

SNAP10A – *EEEE Failed*

TERRESTRIAL

Long duration, but serviceable
Variable rates (shields work)
Neutrons + Gammas



SPACE NUCLEAR

Encounters MOST of above but not quite…

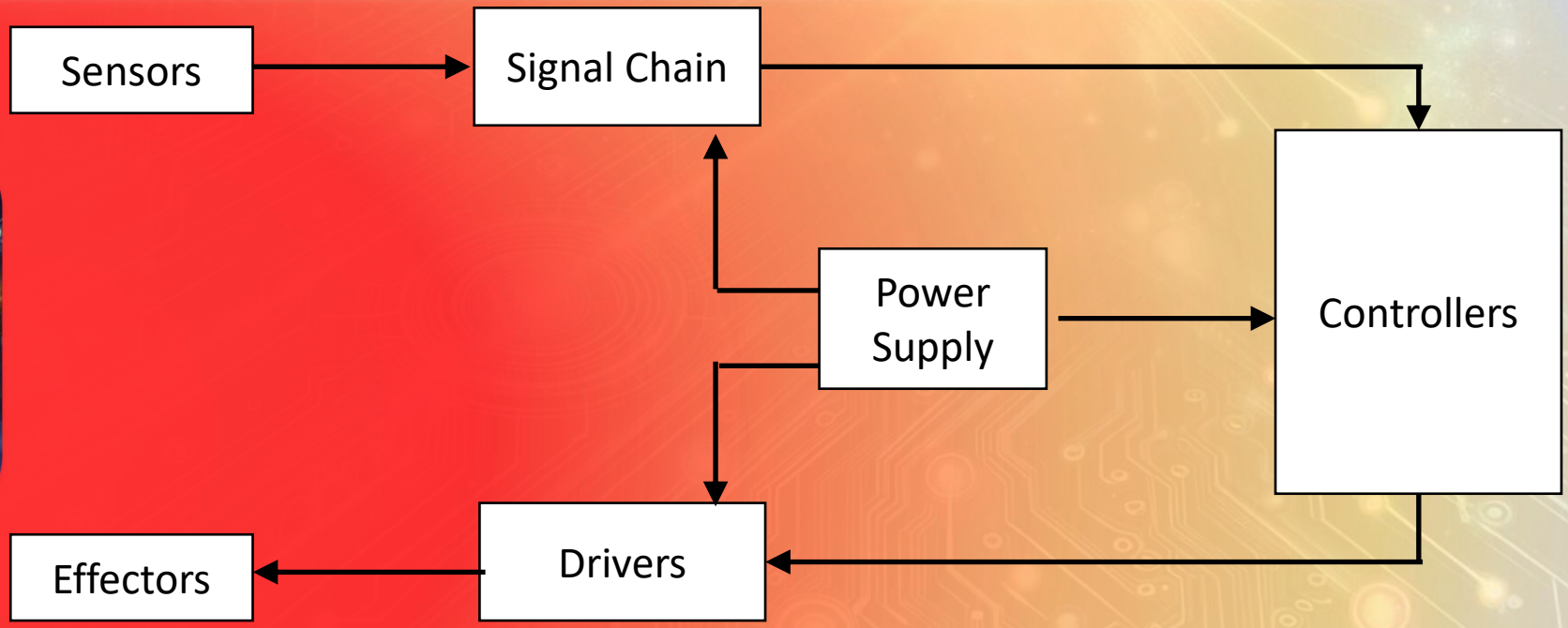
Instrumentation and Control is Critical

Electronic, Electrical, Electro-mechanical, Electro-optical (EEEE) components likely to be the **most radiation-sensitive components** in a nuclear system

AND

With few exceptions*, **radiation will be the biggest challenge in EEEE design**





Sensors and actuators must operate reliably in the most extreme conditions (*temperature/pressure/corrosion)
More complex signal chain and logic may use DISTANCE or SHIELDS to access modest (but still challenging) environments.

Radiation Hardness is Case-Dependent

Existing Radiation Hardness Assurance (RHA) Methodologies:

- MIL and ASTM standards are *mostly* applicable – Some exceptions
- Total Ionizing Dose (TID) and Neutron Displacement (DDD)
  - Methods translate well to space nuclear applications
  - Account for **difference in rates** – e.g. ELDRS and Self-Annealing
  - Account for **difference in spectra** – e.g. ASTM Std E722 1-MeV Neutron Equiv. (Si & GaAs only)
- Single Event Effects (SEE) in logic / FPGAs / CPUs
  - Broad class of effects that grows in prevalence as hardware architectures shrink
  - Translation of risk between environments is active research (proton – neutron – heavy ion)
- Neutron induced single event effects (nSEE)
  - *Known hazard in logic systems… VERY relevant to our systems…*
  - *Understand how Boron and other contaminants affect your systems [$^{10}B(n,\alpha)^{7}Li$]*

Components with identical part numbers may differ significantly in rad-tolerance (lot-to-lot or wafer-to-wafer variability)

When in Doubt… Test

There may be satisfactory existing data at a piece-wise level…

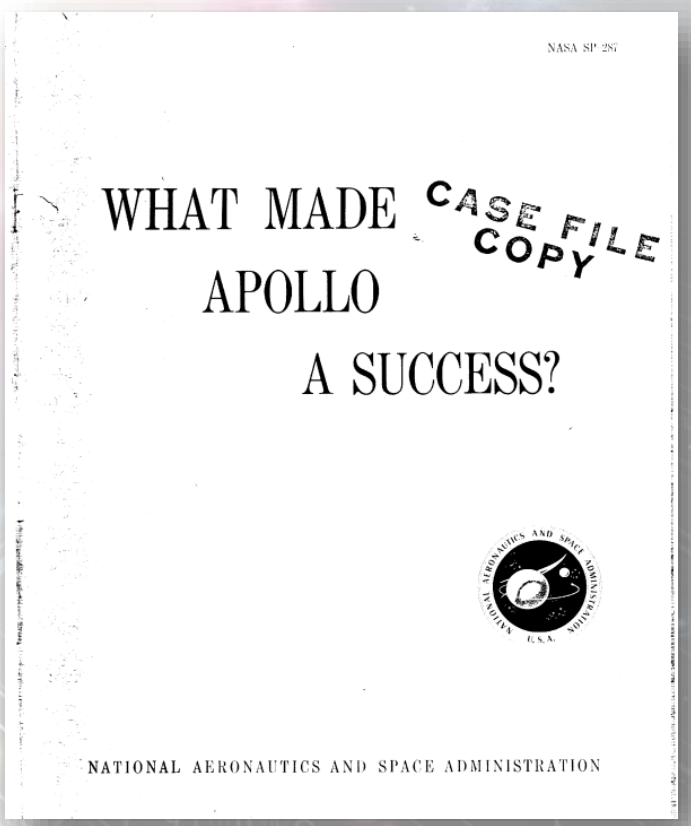
Talk to your local expert… save money and time where you can!

But plan to:

Test early *(component level)*

Test often *(minor mods, single -> integrated)*

Test correctly *(e.g. appropriate radiation)*

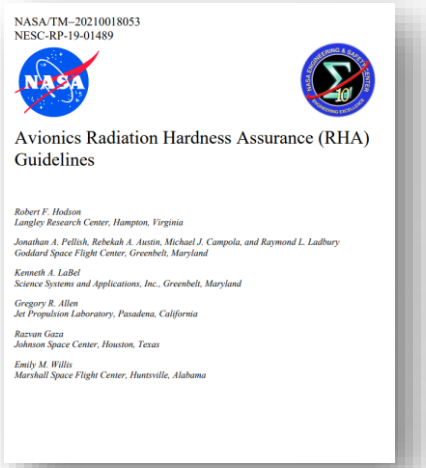


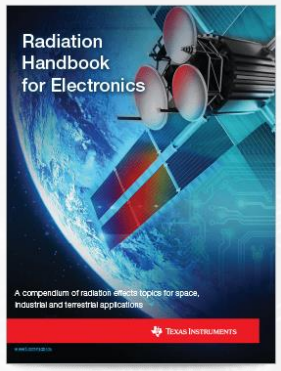
Test as you fly!

Powered/quiescent – Hardware I.T.L. – Thermal Vac – etc.

Recommended Resources

Starting Literature

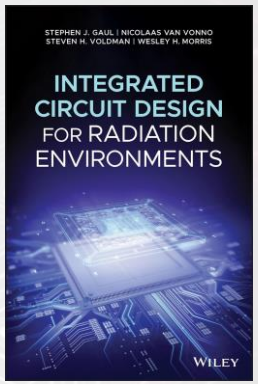

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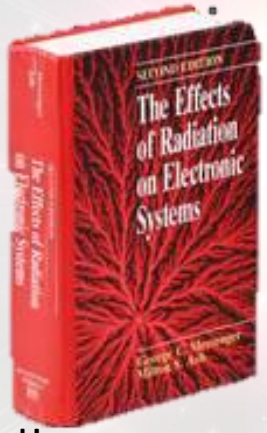


Texas Instruments Radiation Handbook for Electronics


NASA CR-1787

Reference Texts





Several!

Conferences

IEEE - Nuclear & Space Radiation Effects Conference
https://nsrec.com

Hardened Electronics and Radiation Technology (HEART)
https://www.heartconferenceus.org/

Organizations (a VERY incomplete sampling…)



ORNL - Nuclear and Extreme Environment Measurement Group (NEEM)
POC: Dianne Ezell

Propulsion Research Center
NASA MSFC
POC: Jarvis Caffrey

NASA Goddard Radiation Effects Group
https://radhome.gsfc.nasa.gov/

NEPP
NASA Electronic Parts and Packaging Program
https://nepp.nasa.gov/