Assuring CubeSat Electric Power Systems

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 This research was carried out in part by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration under the NASA Electronic Parts and Packaging Program (Code AE). Other data was collected from NASA flight projects.

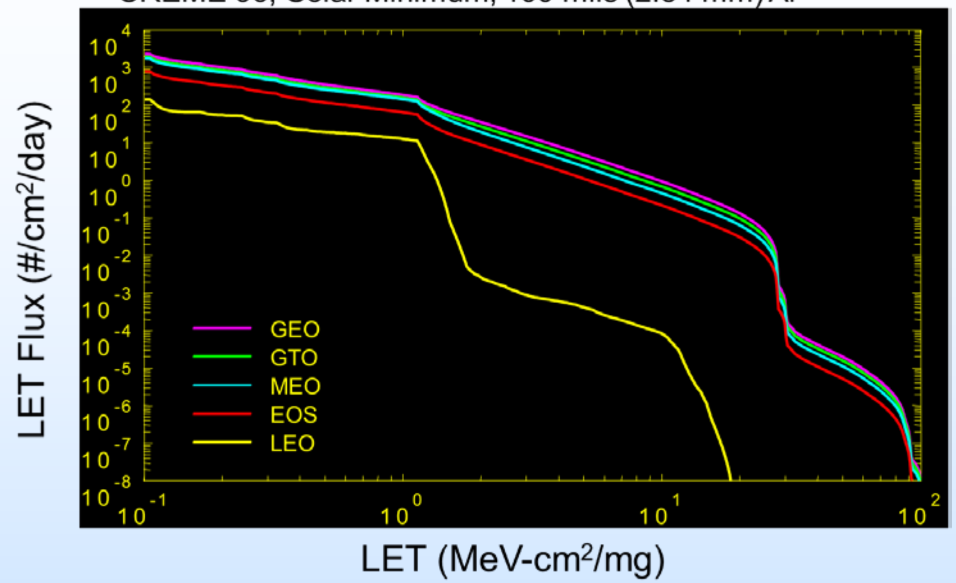
CubeSat Challenge

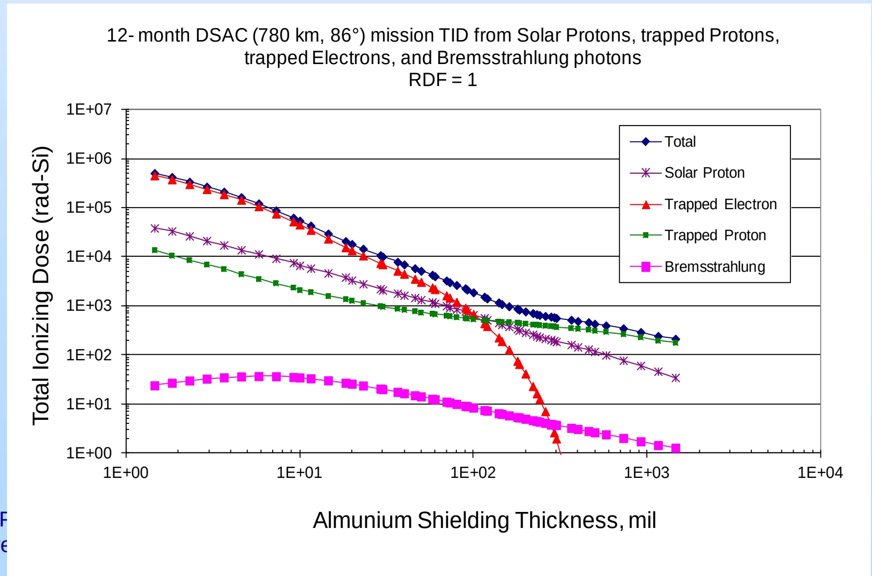
- Normal mission
  - Requirement driven
  - Blanket risk reduction
- CubeSat mission
  - Risk driven
  - Cost-trade analysis at every step
- Radiation is a slippery target
  - Mission based testing approach
  - Decide between test as you fly and worst case
  - The mission duration and target drives the test conditions

Space environments - LEO

- **For low inclination orbit (12 months)**
  - **27 krad(Si) on the surface with an RDF of 2**
  - **0.985 krad(Si) after 50 mils Al with an RDF of 2**
  - **0.979 krad(Si) after 100 mils Al with an RDF of 2**
- **Single Event Environment is benign**
- **Test condition is to 5 krad(Si) and LET 37 MeV.cm^2/mg**

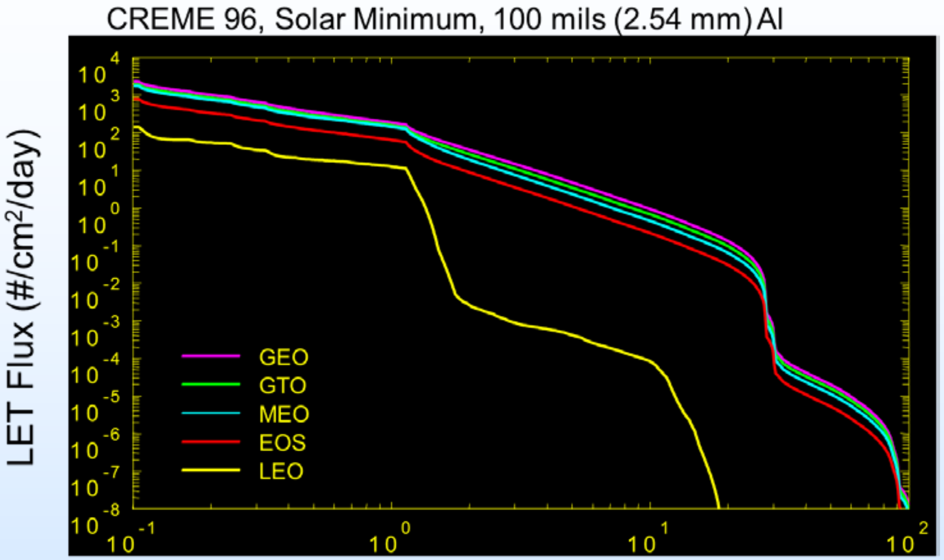
CREME 96, Solar Minimum, 100 mils (2.54 mm) Al

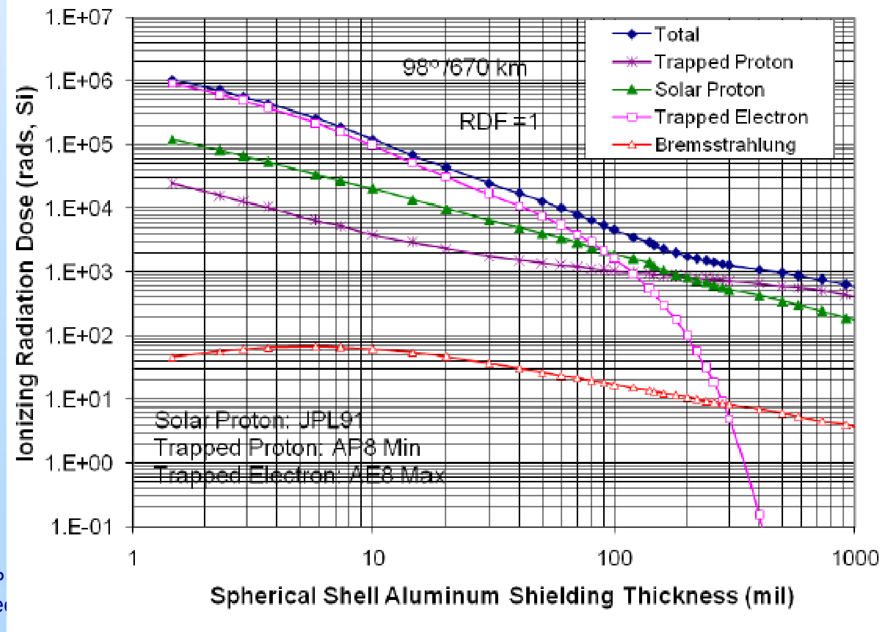




Space environments – extra orbital

- **For trip to Mars (9 months)**
  - 175 krad(Si) on the surface with an RDF of 2
  - 6.3 krad(Si) after 50 mils Al with an RDF of 2
  - 2.9 krad(Si) after 100 mils Al with an RDF of 2
- **For trip to Jupiter (12 months at site)**
  - >1000 krad(Si) on the surface with an RDF of 2
  - 50-200 krad(Si) after 50 mils Al with an RDF of 2
  - 10-50 krad(Si) after 100 mils Al with an RDF of 2
- **Test condition is to 50 krad(Si) and LET 37 MeV.cm²/mg**





CubeSat Architectures

- CubeSats defy typical space craft design
  - Small and low power mission forces single chip designs
- Reliance on one or two key components
  - Boost/buck or similar converter
  - Logic level power FETs
  - Classic DC/DCs are too big and inflexible
- No discrete systems
  - No ability to assure the system in the design
  - SEE effects on key devices are system SEE

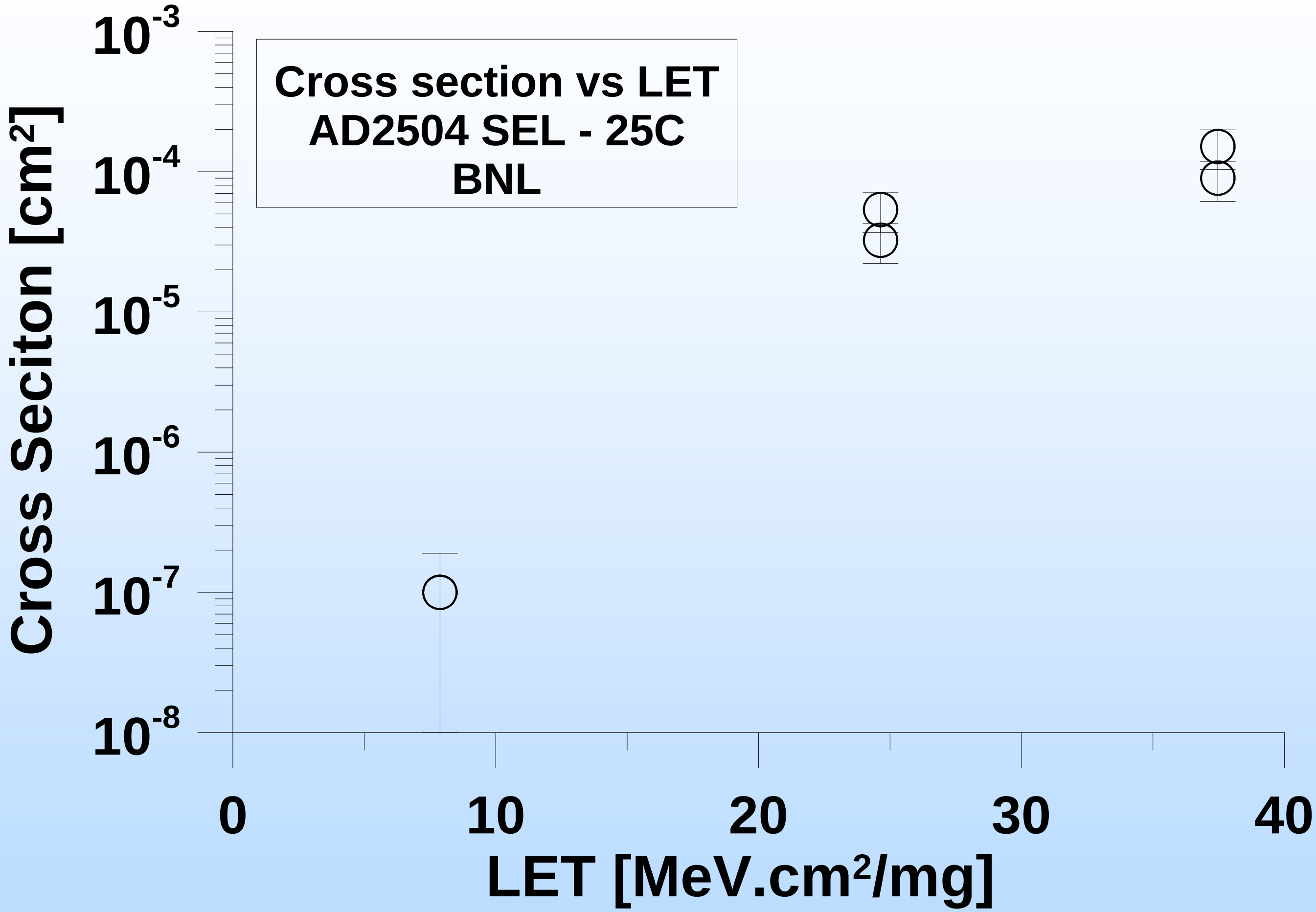
Task Approaches

- Identify known parts in service
  - Reconnoitering available CubeSat system providers
  - Contacting when available
- Identify enabling parts and technology
  - The similarity of all technologies used allows for consolidation of parts evaluation
  - Identification of uniformly vetted parts
- Test to maximize risk reduction
  - Test to typical extra-orbital deployments
  - TID to 50 krad(Si)
  - SEE to 37 MeV.cm2/mg

Task implementation

- Identify high value parts
  - Current inflight service
  - High risk parts
  - High use parts
- Part list management
  - As held by Kathryn Beckwith
  - Other identified parts held separately
- Test data separate from user or application
  - SEE and TID performance don't require
  - Test is usual case
    - Eval cards
    - Typical bias

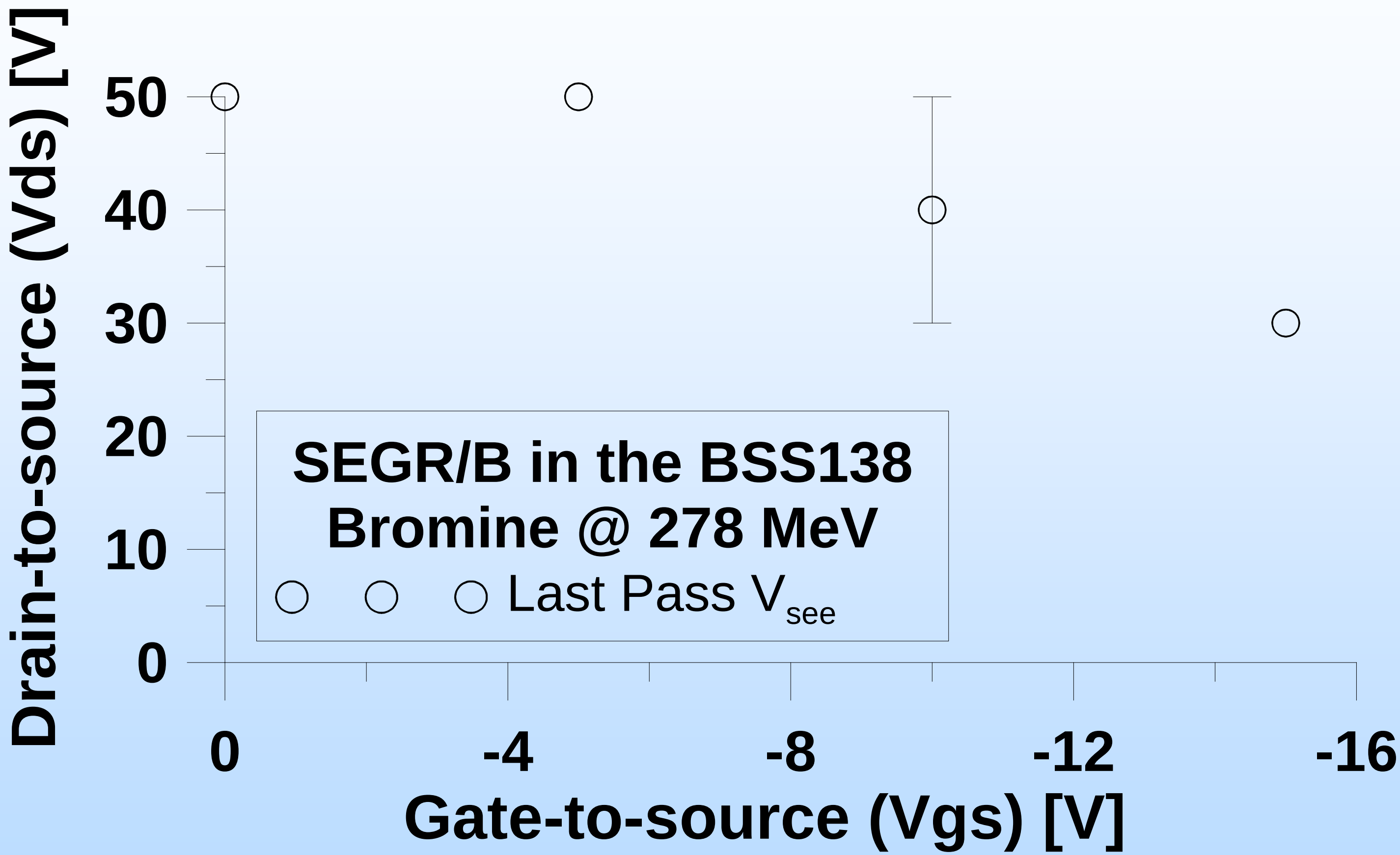
Inflight power parts SEE – Boost/buck



- SEL response of a boost/buck
- No load current, room temp, and BNL

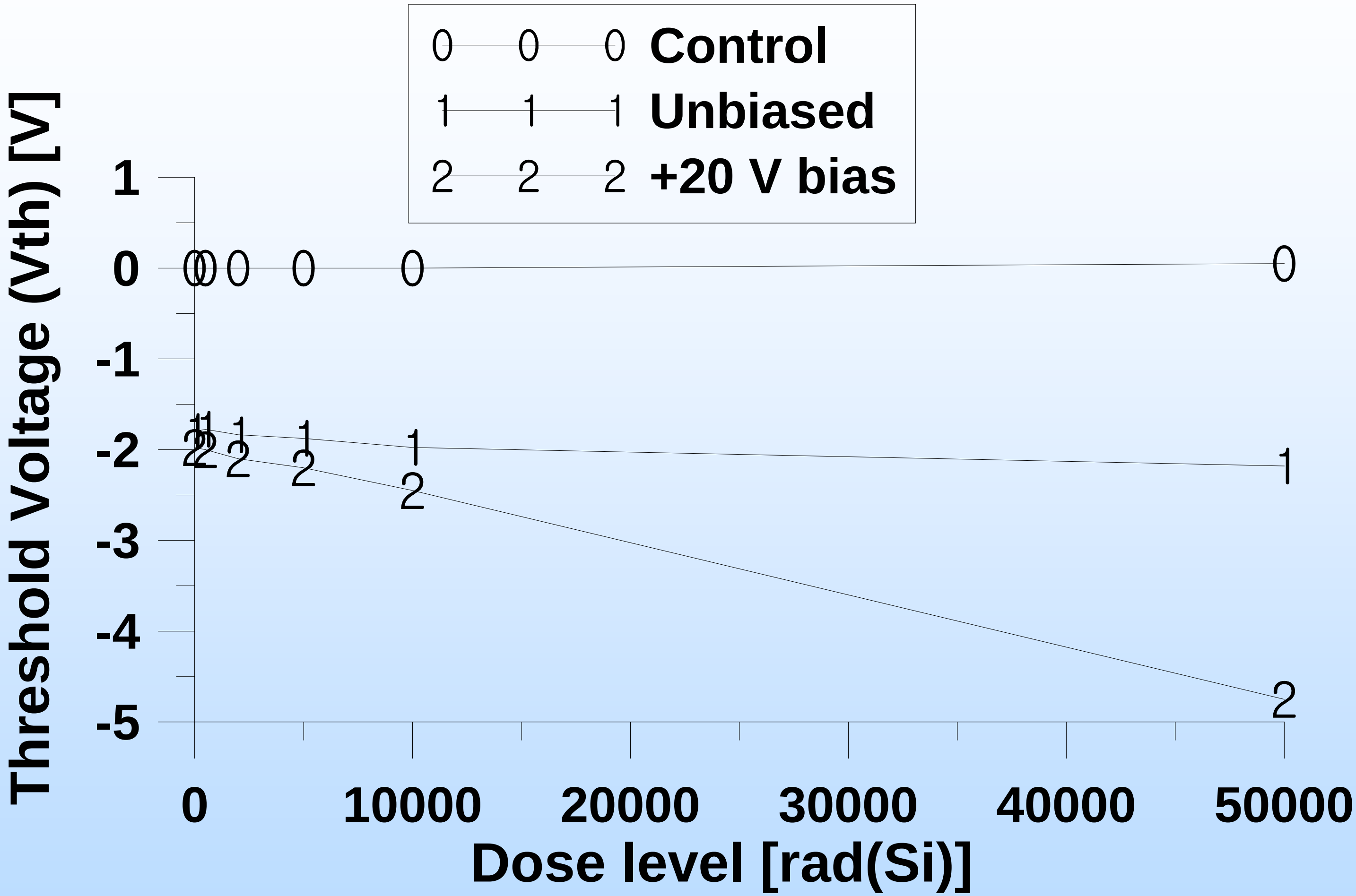
To be presented at the 5th NASA Electronic Parts and Packaging (NEPP) Program Electronic Technology Workshop June 23-26, 2015, NASA GSFC, Greenbelt, MD.

Inflight Tech – SEE in Power MOSFET



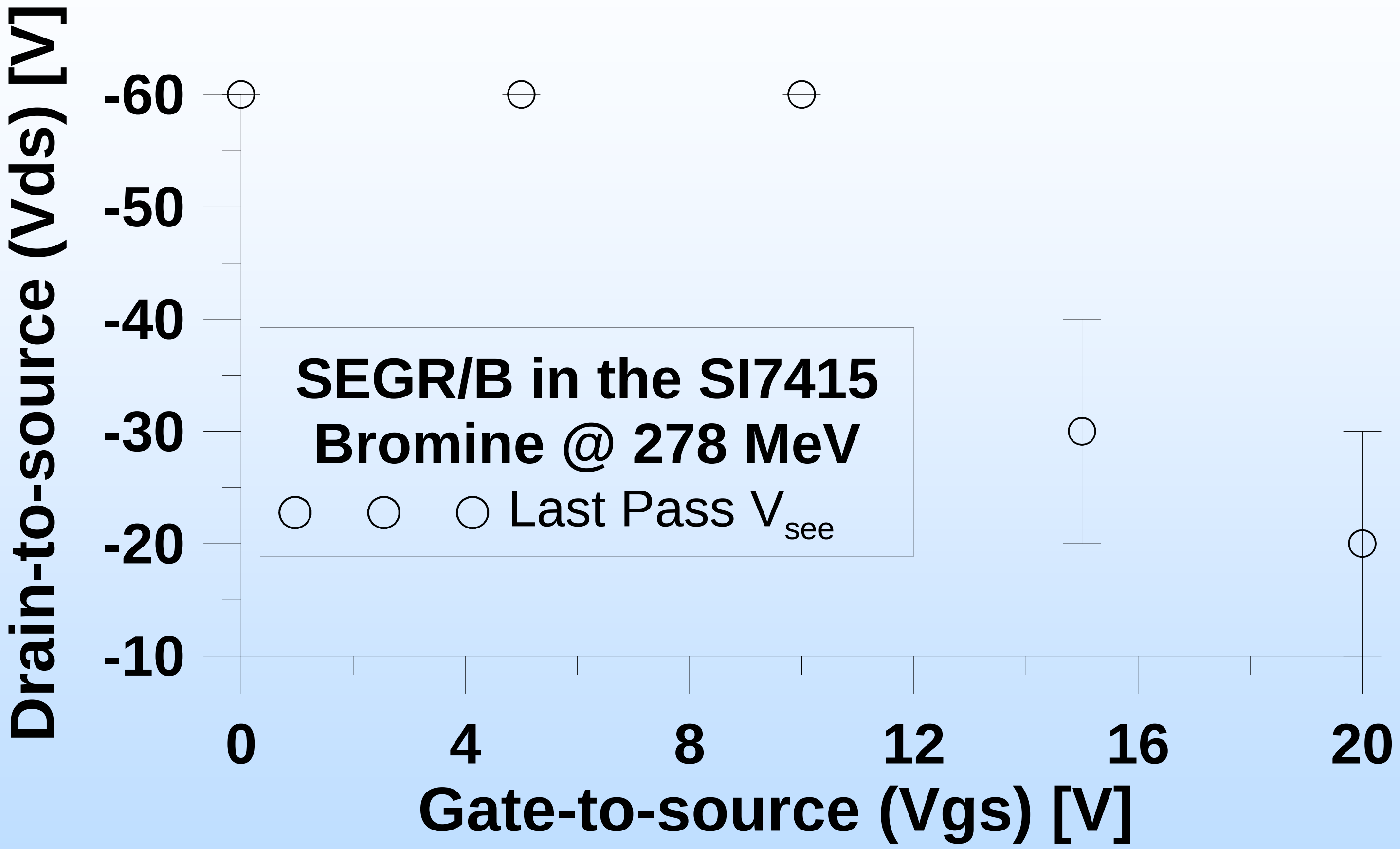
- Epitaxial layer is less than 10 um
- No angular effect

Enabling Tech – TID in MOSFETs



Device goes out of spec at 10 krad(Si)

Enabling Tech – SEE in MOSFETs



- **Epitaxial layer is less than 10 um**
- **No angular effect**

Conclusion

- COTS performance are as expected
  - TID performance ranges from 1 to 50 krad(Si)
  - SEE performance typical for commercial CMOS
  - SEGR performance better for low power MOSFET
- CubeSat power systems are boiling down to a few "go-to" options
  - Monolithic boost/buck is the favorite
  - Other buck options in study
  - Lower power MOSFETs can be analytically bounded

Thank you.

QUESTIONS?