NASA Electronic Parts and Packaging (NEPP) Program

SEE Test Results and Community Efforts

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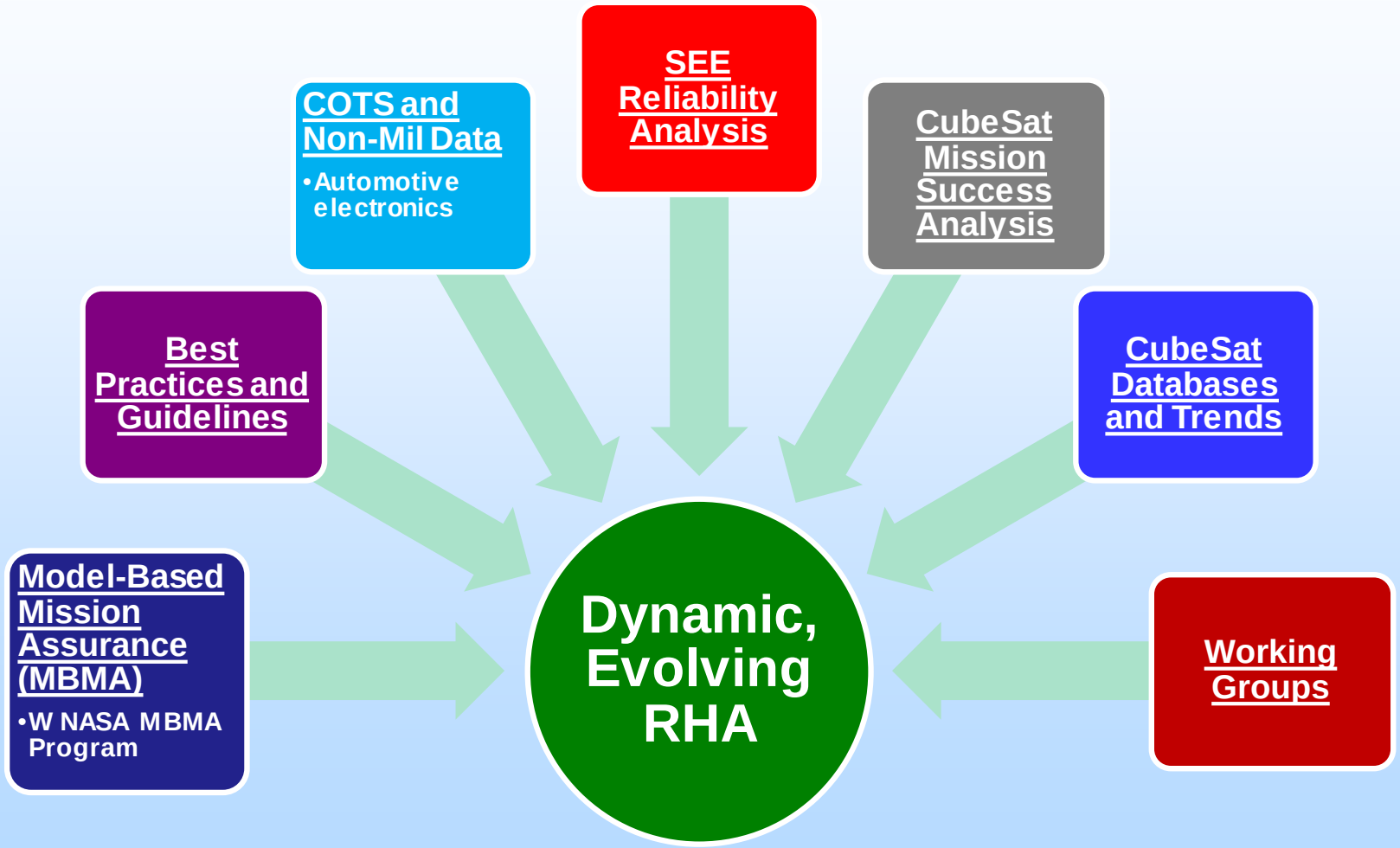
NEPP - Small Mission and Emerging Architectures Efforts



Outline

- Introduction – Current issues facing SEE testing

Best Practices and Guidelines

- Laser User Guide
- COTS de-packaging

COTS and Non-Mil Data

- Automotive electronics

- SEE Database
  - Laser Database
- Metadata Analysis
- Recent SEE Results/Challenges

CubeSat Databases and Trends

Working Groups

- GaN SEE-Reliability
- Generic SEE RTC?

Current Issues Facing SEE Testing

- Device Complexity and Testability
- Beam Availability & Beam Energy
- Workforce
- Siloed community efforts

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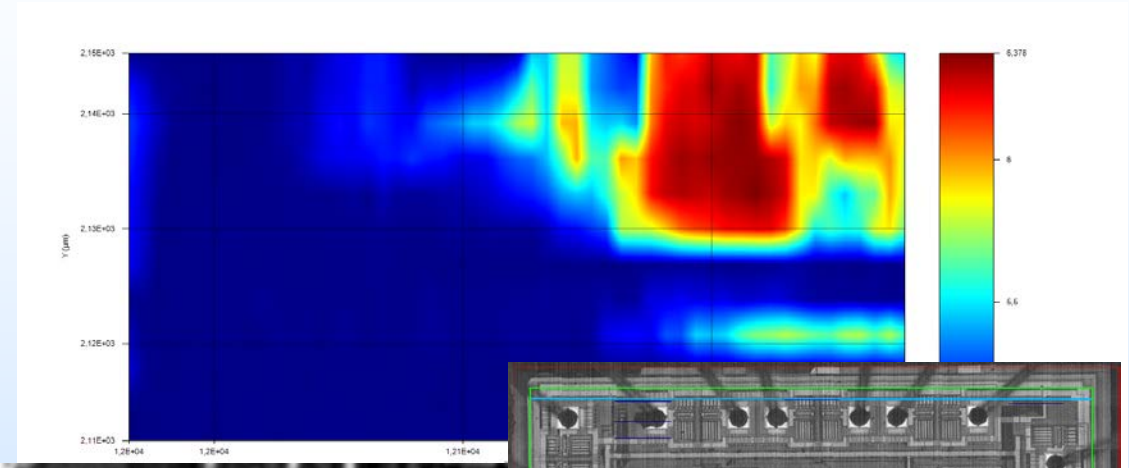
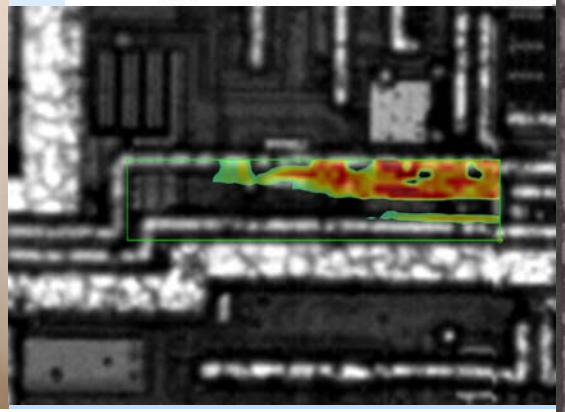
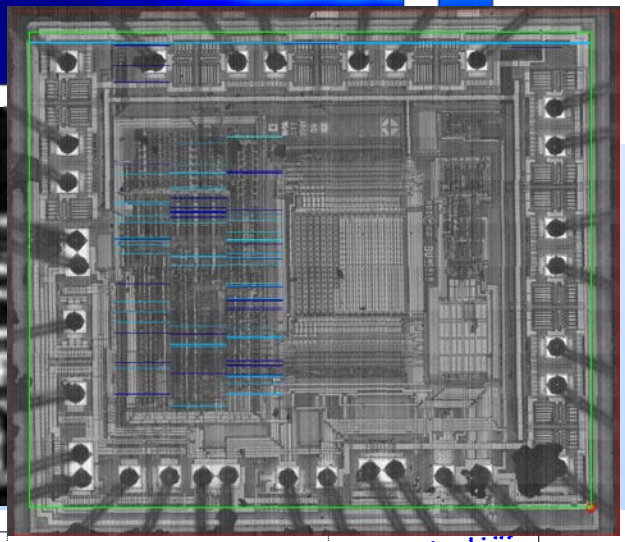
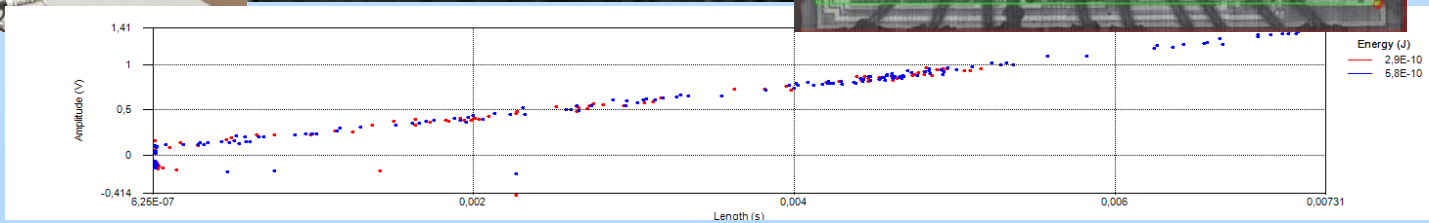
Single Photon Laser – PULSCAN SPA 1064nm pulsed

Best Practices and Guidelines









Initial Laser Usage

Best Practices and Guidelines

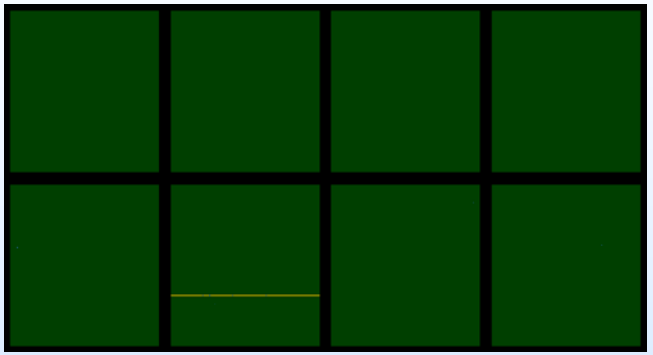
CubeSat Databases and Trends

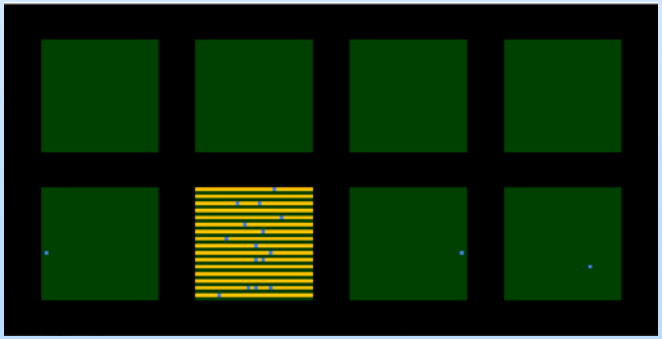
- Intend to run every single device we SEE test through the pulsed laser system to develop a correlated library.
- Die micrographs, laser sensitivity maps, and correlated heavy ion characterization data will be populated in a database.
- Practical user's guide for SEE laser testing
  - Scanning approaches
  - Device preparation
  - Lessons Learned

Recent Challenges: DDR2

COTS and Non-Mil Data
- Automotive electronics

- **Multiple test setups required for full radiation characterization campaign**
  - **Automated test equipment used to measure parametric degradation over TID.**
  - **Custom test system used to gather stuck bits at room temp (varying refresh rate).**
  - **High speed test system to collect data at different clock frequencies DLL enabled.**
  - **Flight like test system with SEFI mitigation for validation.**





Recent Challenges: DDR2

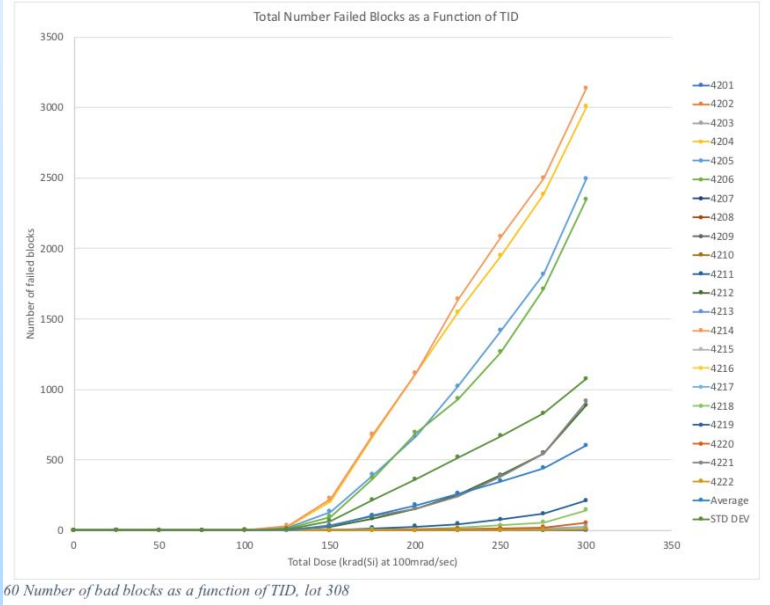
COTS and Non-Mil Data
- Automotive electronics

- **Observation**
  - Different test systems (board/controller/component) with same memory component have different cross sections
  - Memory controller / routing affects sensitivity to certain mode register SEU and interface handshaking affects SEFI rates (specifically handling of data strobes or off beat data).
  - Signature of SEFI depends on system (processor hang vs. junk data vs. controller reported failure mode)
  - Observed order of magnitude difference in SEFI rate between unmitigated controllers.
  - Further substantiates the “test it like you fly it” mantra
  - Testing of flight memory controller IP required for flight SEFI rates.

Recent Challenges: NAND Flash

COTS and Non-Mil Data
- Automotive electronics

- **High Density NVM always of value**
  - **Detailed testing can yield extreme variability (true of SEE and TID).**
  - **Dose steps, fluence steps, refresh period can change part usability.**



60 Number of bad blocks as a function of TID, lot 308

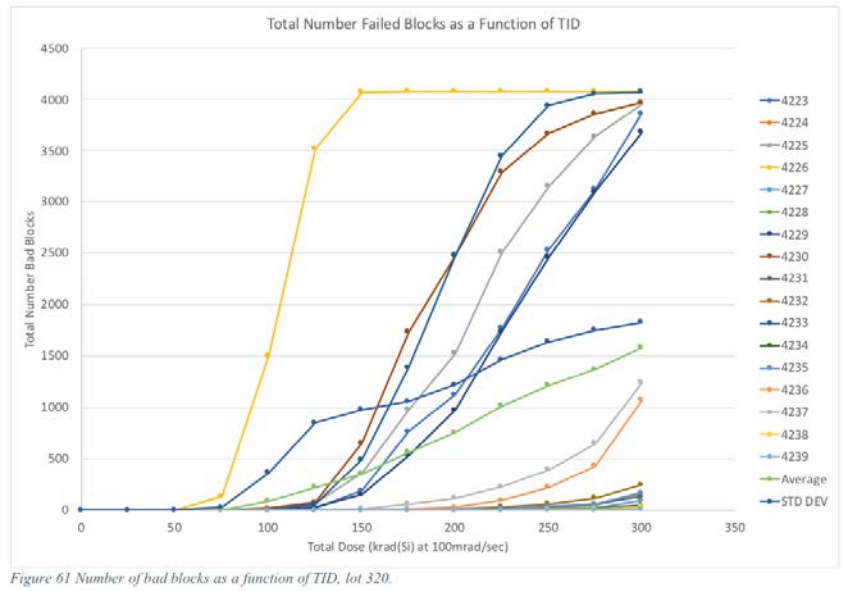


Figure 61 Number of bad blocks as a function of TID, lot 320.

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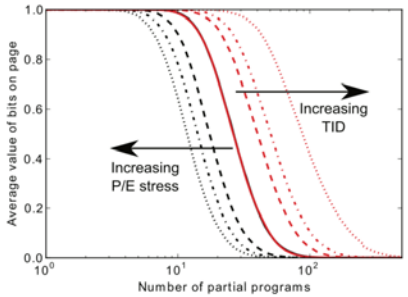
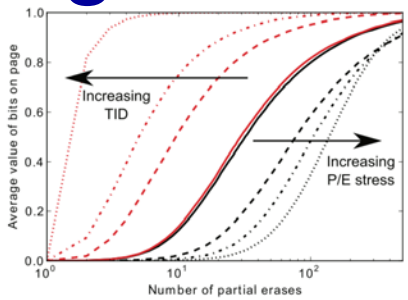
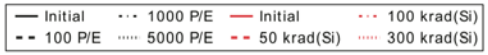
Recent Challenges: NAND Flash

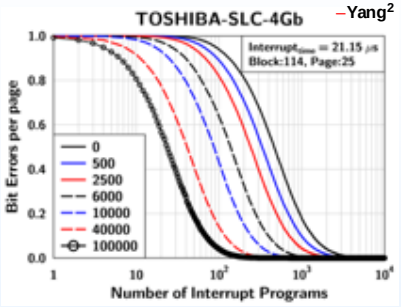


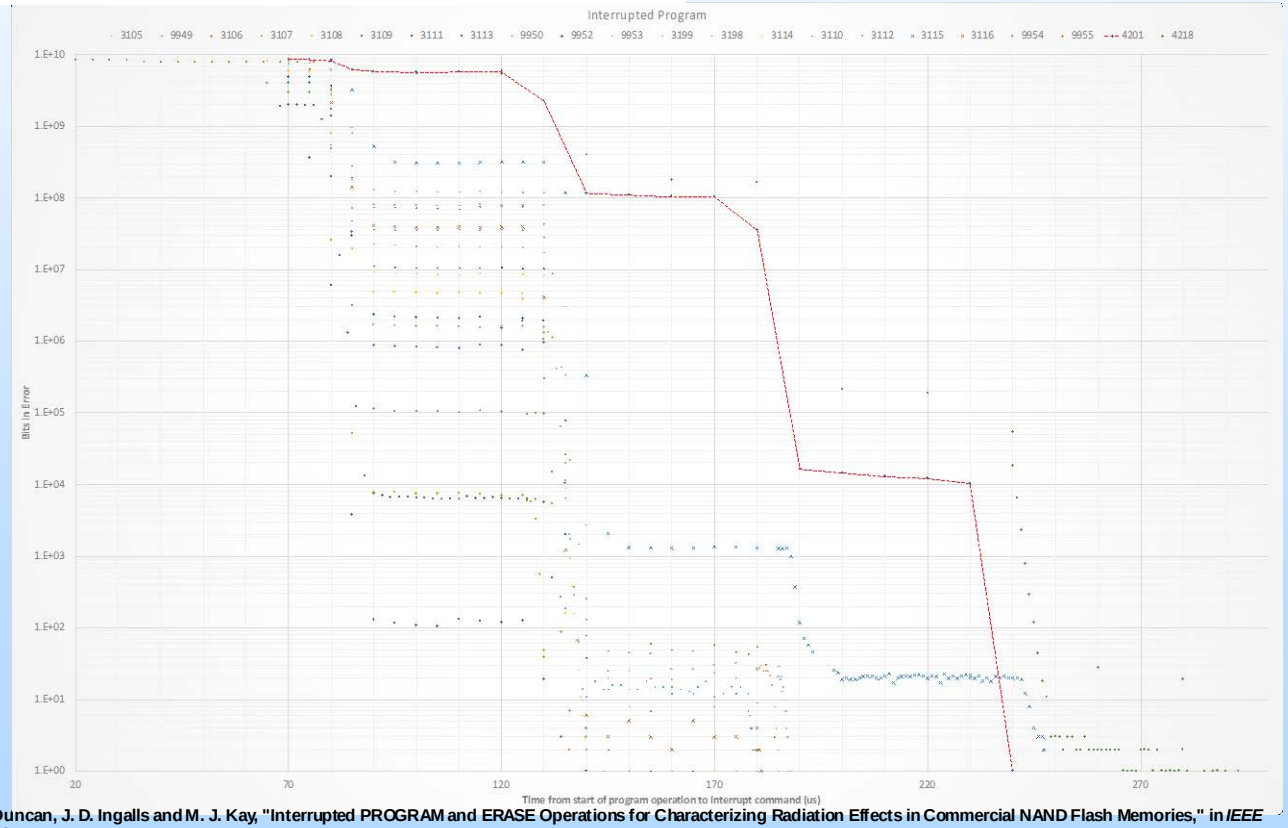




–Roach[1]

–Yang[2]





–[1] A. H. Roach, M. J. Gadlage, A. R. Duncan, J. D. Ingalls and M. J. Kay, "Interrupted PROGRAM and ERASE Operations for Characterizing Radiation Effects in Commercial NAND Flash Memories," in *IEEE Transactions on Nuclear Science*, vol. 62, no. 6, pp. 2390-2397, *Dec. 2015.*

–[2] J. Yang-Scharlotta, "Method of Smart-Screening for NAND Flash Memory Parts Based on Weak Bits", *JPL R&TD 2017*, JPL Task #R17002

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Recent Challenges: NAND Flash

COTS and Non-Mil Data

- Automotive electronics

Initial Test Results

Dose krad(Si)	125	150	175	200	225	250	275	300	110us @ 0krad	160us @ 0krad	160us @ 300krad	Threshold (krad(Si))	Date Code
Site:	Number Failed Blocks (Program)								Number Errors				
CH2	0	0	0	0	0	0	0	0	3333	1	7829	325	749
CH3	0	0	0	0	0	0	0	0	120	0	400867	325	749
CH0	0	0	0	0	0	0	0	1	2	0	19104	300	749
CH1	0	0	0	0	0	1	3	3	3	0	44038	250	749
CH4	**0**	**0**	**0**	**0**	**0**	**4**	**7**	**15**	**171**	**0**	625464	**250**	**004**
CH12	0	0	0	0	0	0	0	0	5.71E+06	17	337002235	325	749
CH7	0	0	0	0	1	1	1	3	5.83E+07	257	536248796	225	749
CH10	**0**	**0**	**0**	**0**	**0**	**7**	**22**	**49**	**7.61E+07**	**27**	838911278	**250**	**004**
CH9	1	3	3	4	8	21	38	57	2.81E+07	35	919952124	125	749
CH14	**0**	**0**	**2**	**5**	**20**	**53**	**119**	**252**	**4.46E+07**	**10**	545489447	**175**	**004**
CH8	**0**	**1**	**9**	**30**	**80**	**140**	**328**	**584**	**8.77E+07**	**74**	709161252	**150**	**004**
CH11	**0**	**1**	**5**	**23**	**65**	**145**	**349**	**632**	**1.25E+08**	**23**	1194042440	**150**	**004**
CH6	**1**	**3**	**11**	**48**	**149**	**269**	**489**	**828**	**2.69E+08**	**772**	1433695202	**125**	**004**
CH13	**0**	**1**	**11**	**63**	**179**	**360**	**825**	**1461**	**3.74E+07**	**13**	767066038	**150**	**004**

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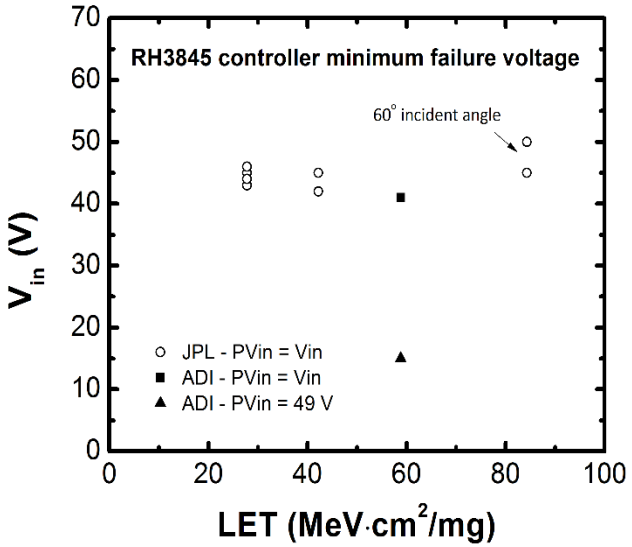
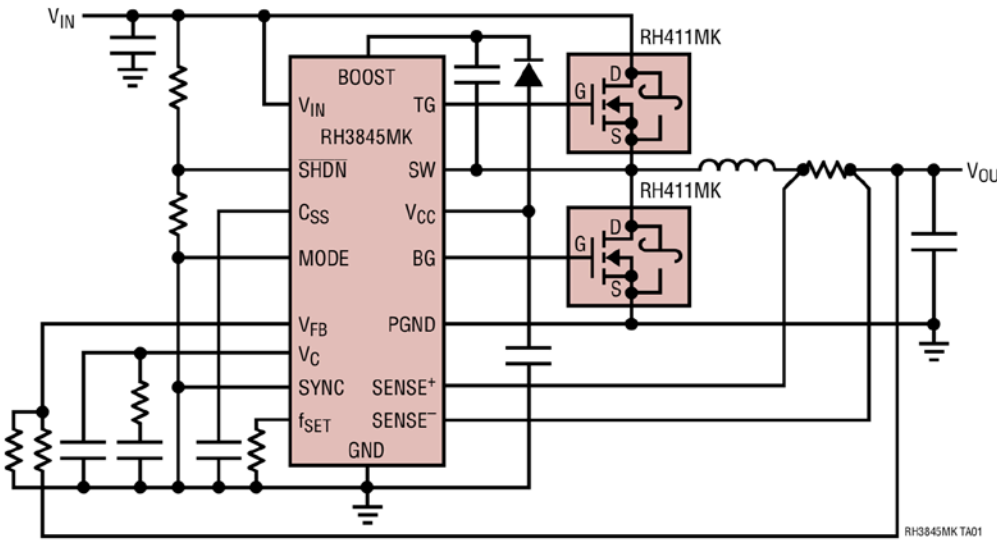
Recent Challenges: Analog Devices

COTS and Non-Mil Data
- Automotive electronics

- Destructive Effects
- Load Dependent SEFI modes
- Transient Effects



TYPICAL APPLICATION



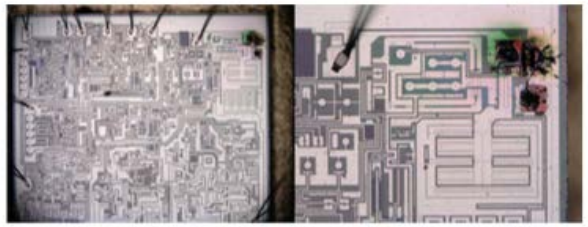


Fig. 7 Photomicrographs of a RH3845 that exhibited destructive SEE.

TABLE III
RH3845 SEE test results.

Device	SEDR Threshold (MeV-cm²/mg)	SEDR Saturation Device Cross-section (cm²)	SET Threshold (MeV-cm²/mg)
RH3845	< 20	$1x10^{-5}$	< 20

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Recent Challenges: Analog Devices

COTS and Non-Mil Data

- Automotive electronics

Signal	Color
Top V_{GS}	Orange
Bot V_{GS}	Green
Switch Node	Pink
V_{OUT}	Purple

Parameter	Value
PV_{IN}	50V
V_{IN}	12V
V_{CC}	12V
V_{OUT}	5V
I_{LOAD}	10mA

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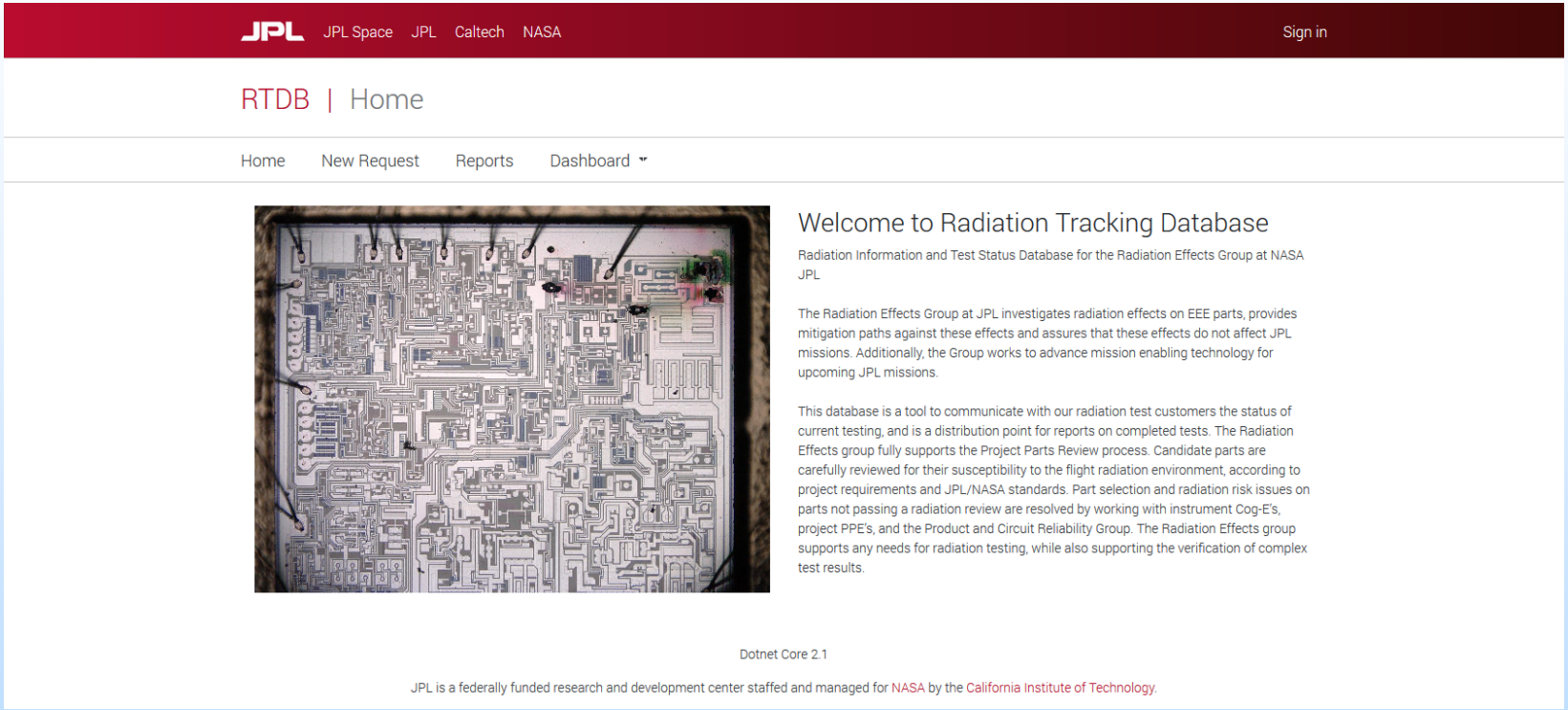
RADCENTRAL – Don't Call it a Comeback

CubeSat Databases and Trends



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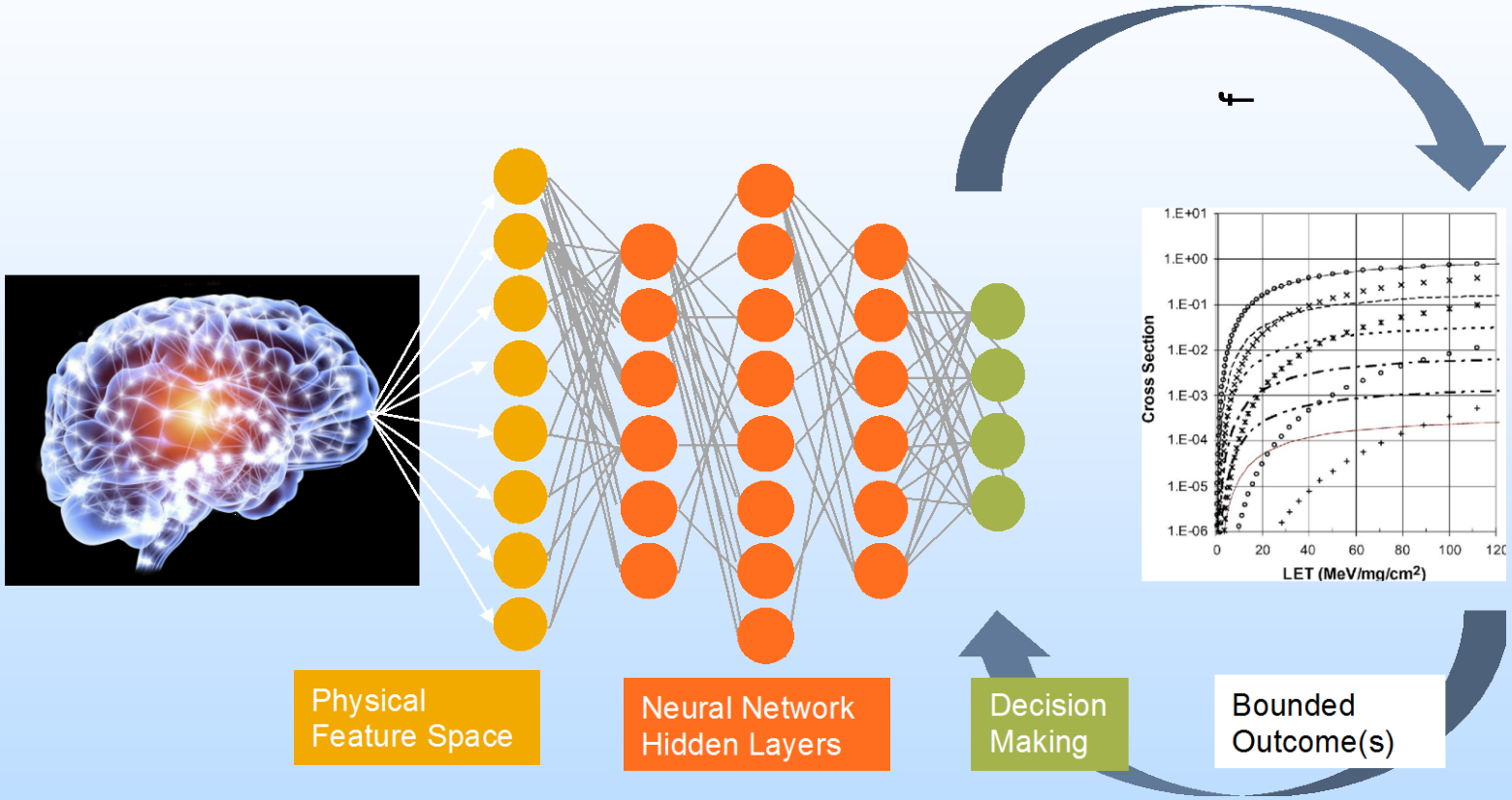
Metadata Analysis

CubeSat Databases and Trends



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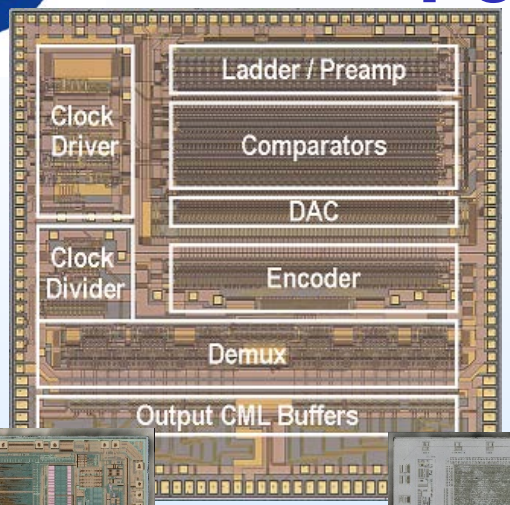
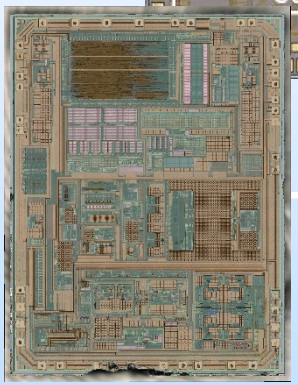
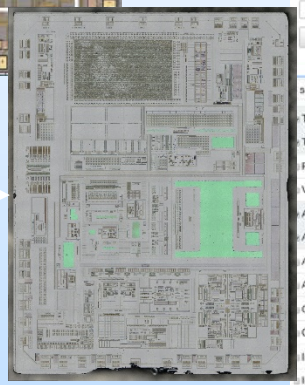
Metadata Analysis - Physical Feature Space

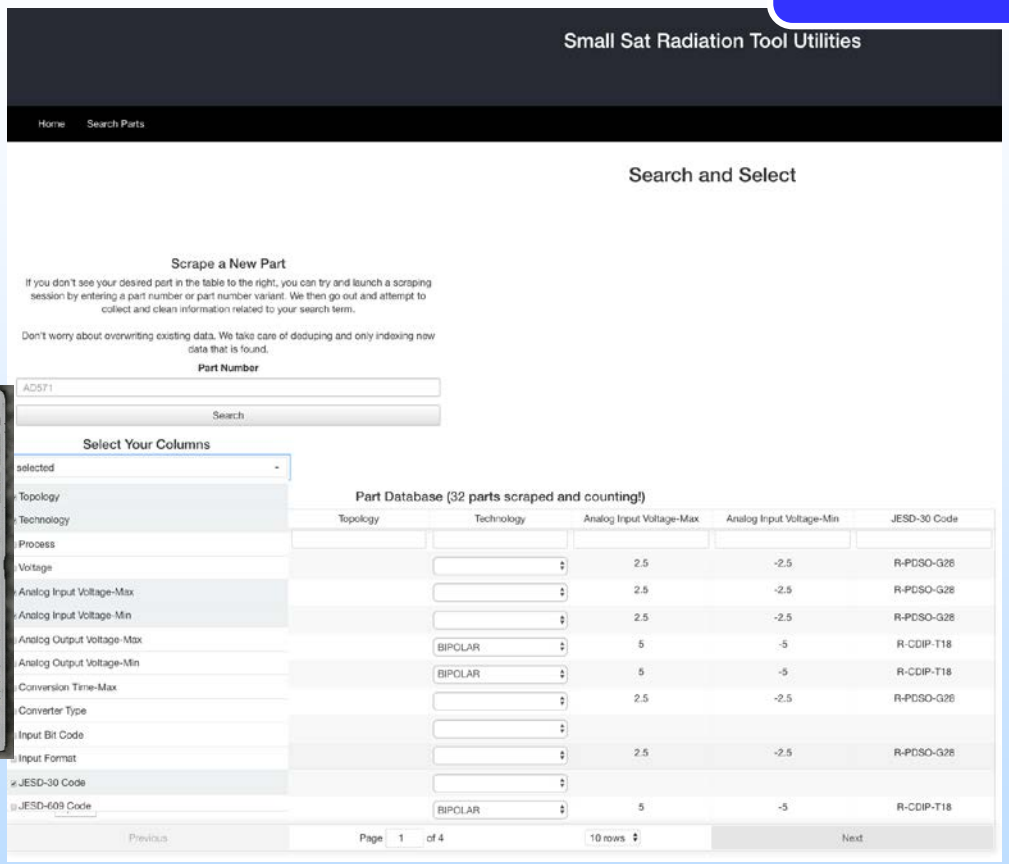
CubeSat Databases and Trends





–IC de-layering





–Image recognition – machine

–learning based feature recognition

–Automated datasheet driven data scraping

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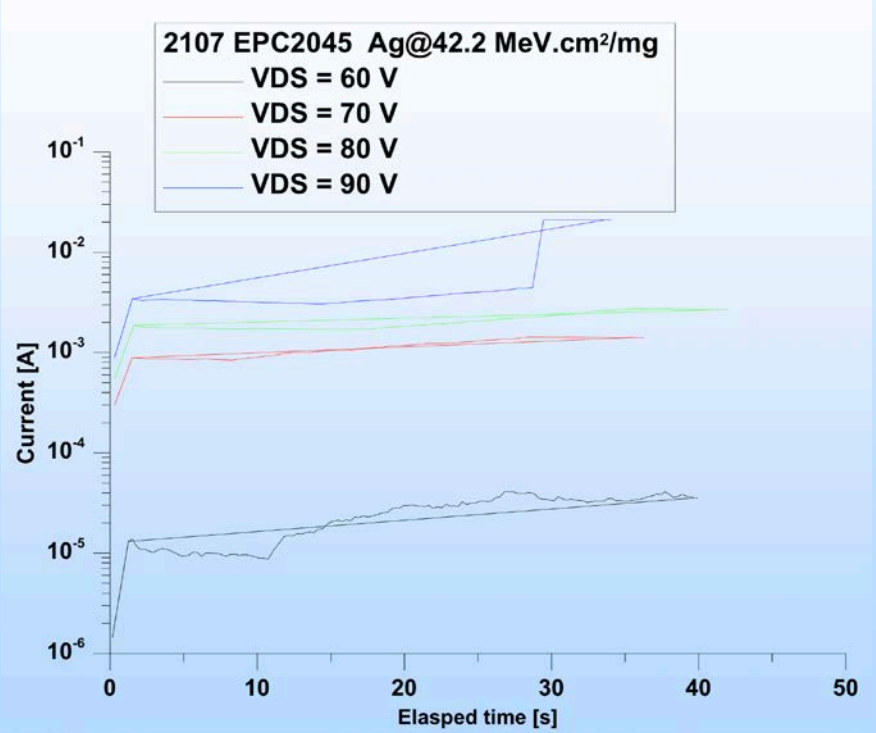
Current Collaborations – GaN Radiation-Reliability

Working Groups

- **SEE Mechanisms fairly well understood, but combined SEE reliability needs work.**
- **Collaboration brewing between JPL, GSFC and ESA to understand the impact of combined effects.**



Future Collaborations – RTC?

Working Groups

- How do we drive the future of collaboration for JPL, the Agency, and the radiation effects community?
- How is this syndicate structured?
- How do we leverage wide engineering resources across the aerospace community and efficiently use the limited facility resources?
- How do we share “trusted data” – a unified radiation database?