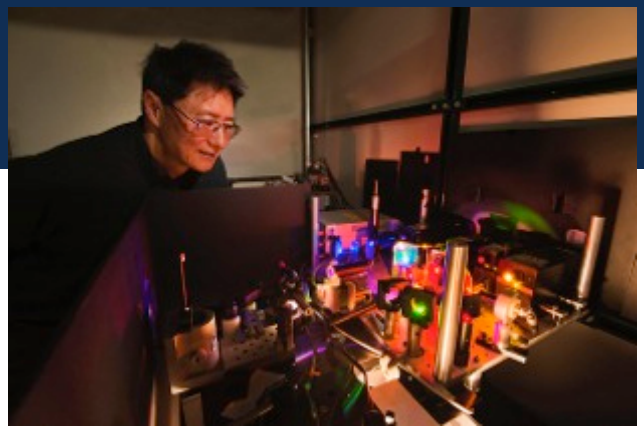
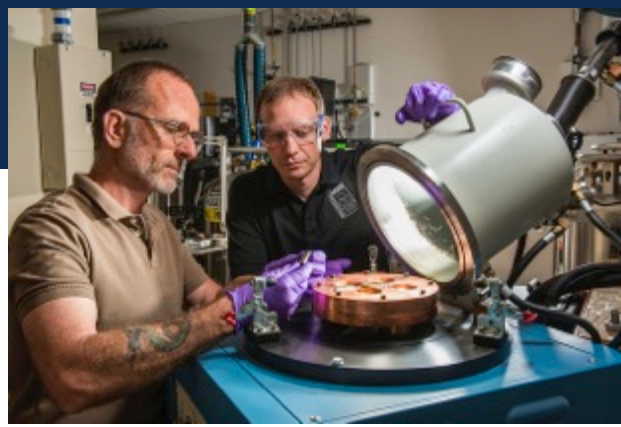
SAND2016-1366C

*Exceptional service in the national interest*

Sandia National Laboratories

# Securing Trusted Rad-Hard Electronics for the Future

**Rich Dondero**
Microsystems Assessments I
rdonder@sandia.gov

with Bruce Draper, draperbl@sandia.gov & Paul Dodd, pedodd@sandia.gov

Sandia National Laboratories

*DMSMS 2015*

*December 3, 2015*

U.S. DEPARTMENT OF ENERGY | NNSA

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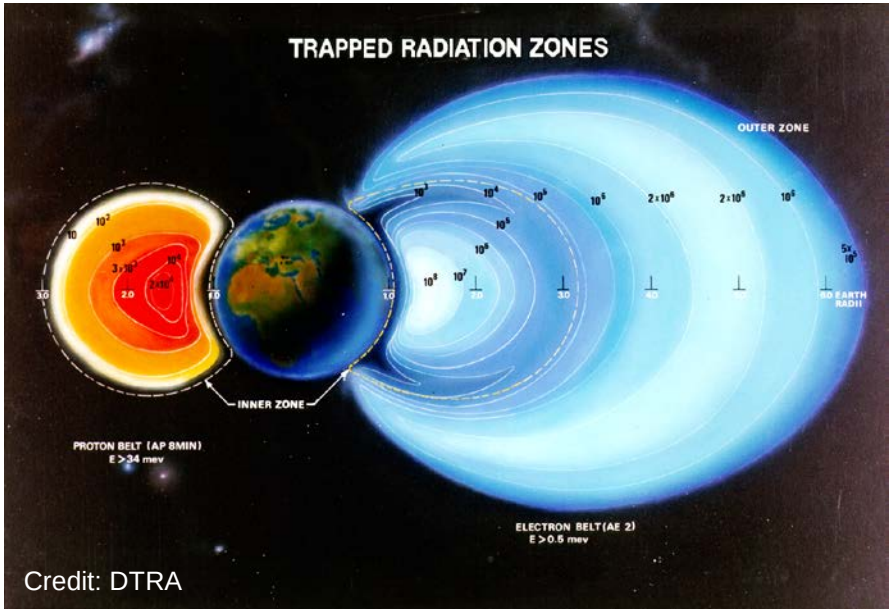
Van Allen Rad Belts




Rad Hard Microelectronics

Sandia National Laboratories

Safe
Secure
Effective

Trusted Microelectronics

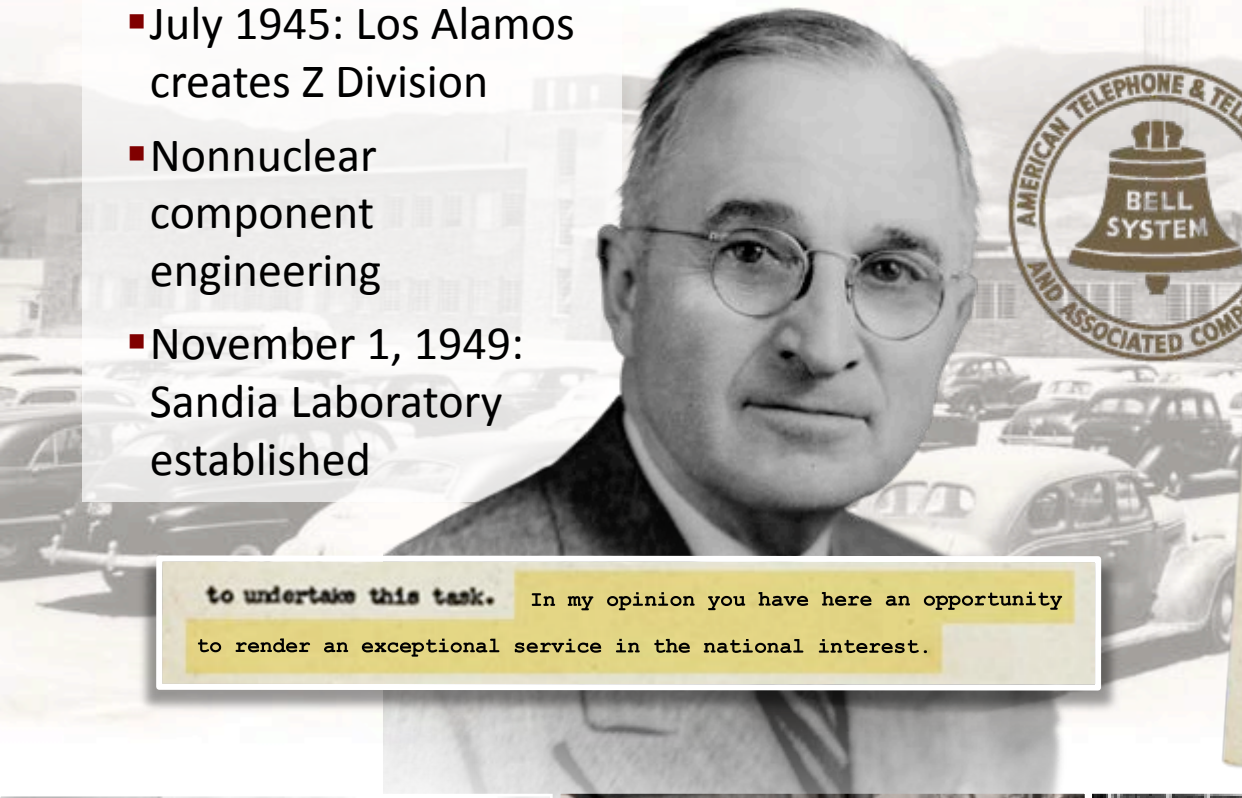


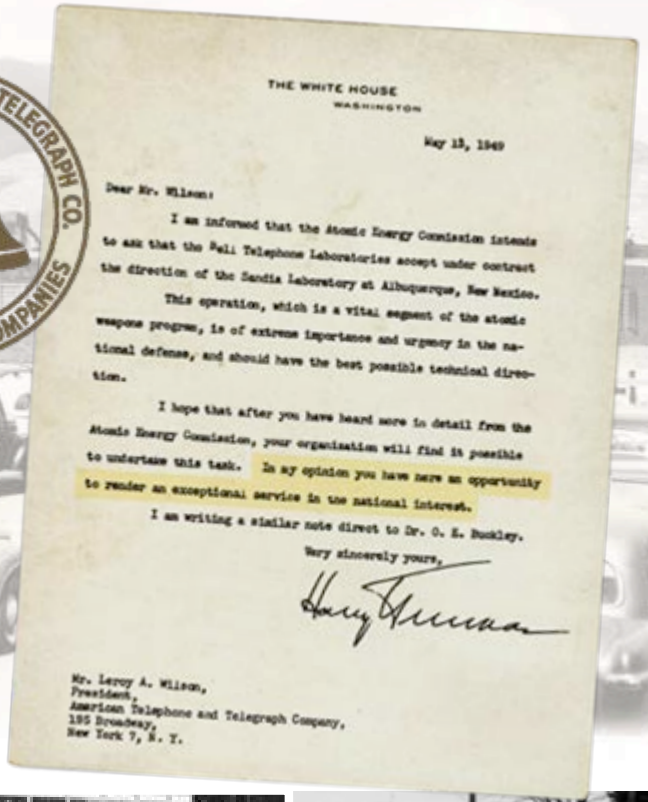
http://www.superstock.com/stock-photography/Atomic+blast+military

# Sandia's History

*Exceptional service in the national interest*

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established





THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

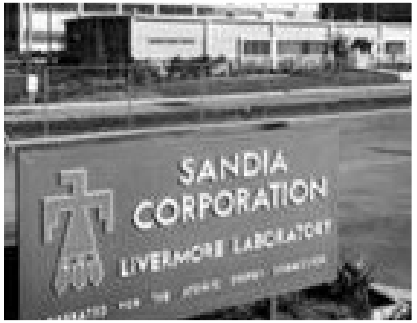
I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

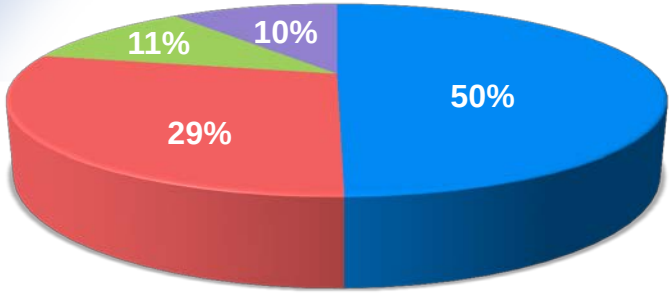
to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.




# Sandia National Laboratories

- Total Sandia workforce: 12,609
- Regular employees: 10,330
- Advanced degrees: 5,790 (56%)

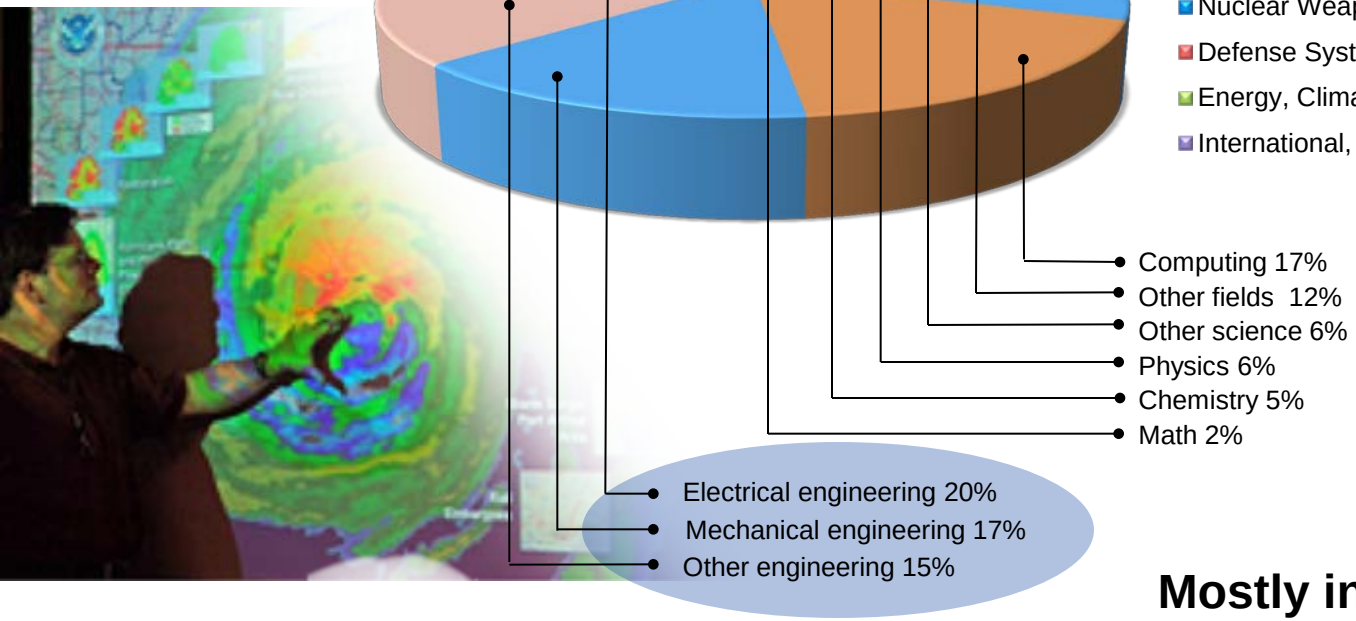
## FY14 Operating Revenue
## $2.7 billion




(Operating Budget)

- Nuclear Weapons
- Defense Systems & Assessments
- Energy, Climate & Infrastructure Security
- International, Homeland, and Nuclear Security

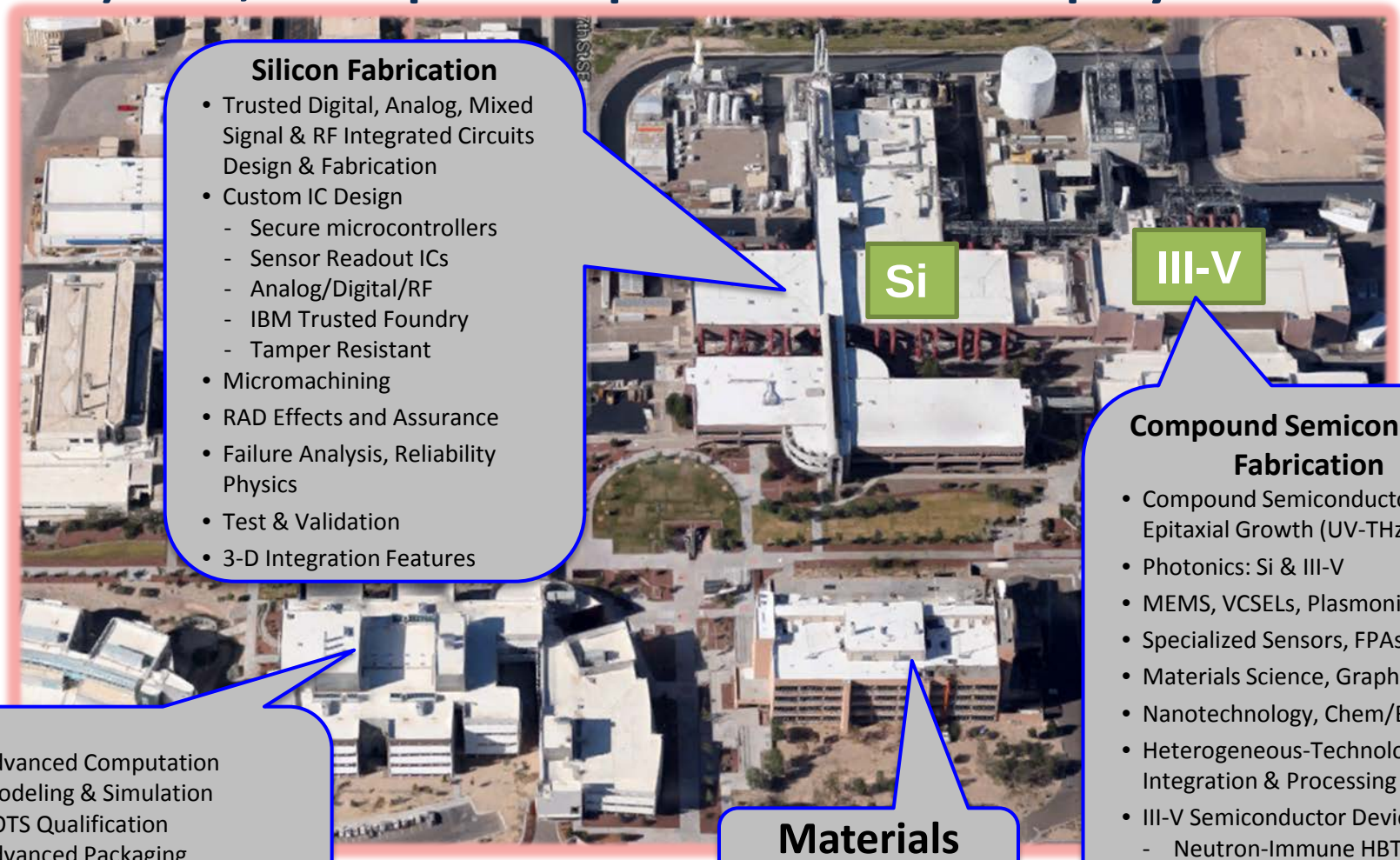
## Technical staff (5,046) by discipline




**Mostly in Albuquerque, NM**

# Microsystems and Engineering Sciences Applications (MESA): 400,000 Sq-ft Complex with >650 Employees

Sandia National Laboratories




**Silicon Fabrication**

- Trusted Digital, Analog, Mixed Signal & RF Integrated Circuits Design & Fabrication
- Custom IC Design
  - Secure microcontrollers
  - Sensor Readout ICs
  - Analog/Digital/RF
  - IBM Trusted Foundry
  - Tamper Resistant
- Micromachining
- RAD Effects and Assurance
- Failure Analysis, Reliability Physics
- Test & Validation
- 3-D Integration Features

**Compound Semiconductor Fabrication**

- Compound Semiconductor Epitaxial Growth (UV-THz)
- Photonics: Si & III-V
- MEMS, VCSELs, Plasmonics
- Specialized Sensors, FPAs
- Materials Science, Graphene
- Nanotechnology, Chem/Bio
- Heterogeneous-Technology Integration & Processing
- III-V Semiconductor Devices
  - Neutron-Immune HBT
  - Rad-hard Optical Links
  - Solid-State RF Devices
  - GaN Power Electronics

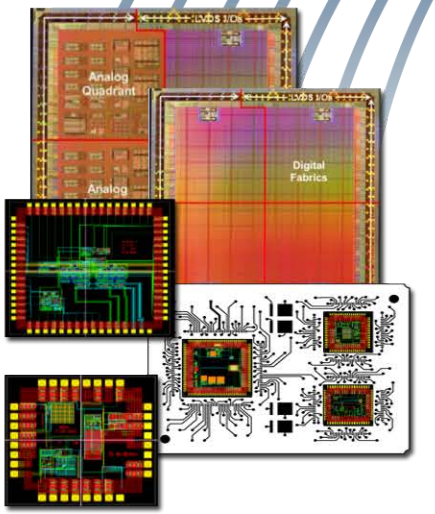
- Advanced Computation
- Modeling & Simulation
- COTS Qualification
- Advanced Packaging
- Custom Electronic Components
- System Design & Test

**Materials Research**

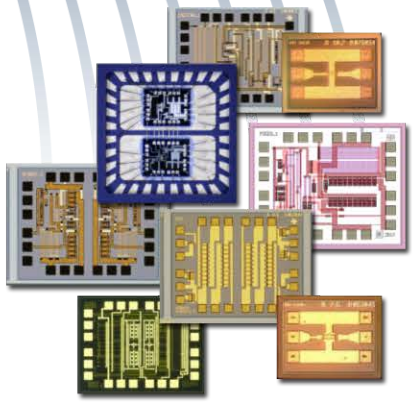
***MESA is a development and production facility for microsystem components and technology that cannot or should not be obtained commercially.***

# Manufactures Strategic Rad-Hard Trusted Components for Nuclear Weapons

Sandia National Laboratories





**Radiation-Hardened ASICs**
- >25,000 deliveries

**Rad-hard III-V Microelectronics**
- >150,000 deliveries

***Trust environment (NW, DMEA)***

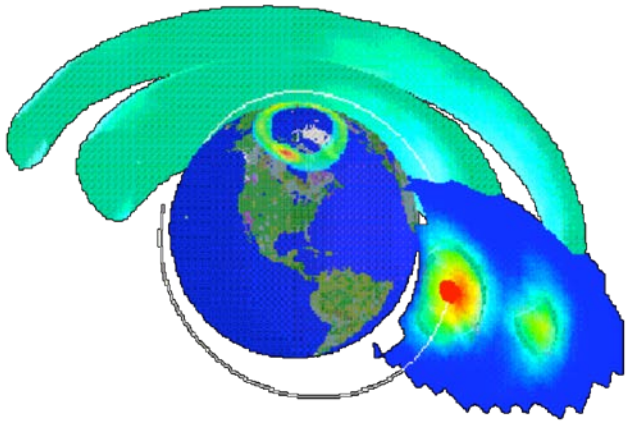
***Strong Failure Analysis, Reliability***

# Table of Contents

# Space Radiation Environments

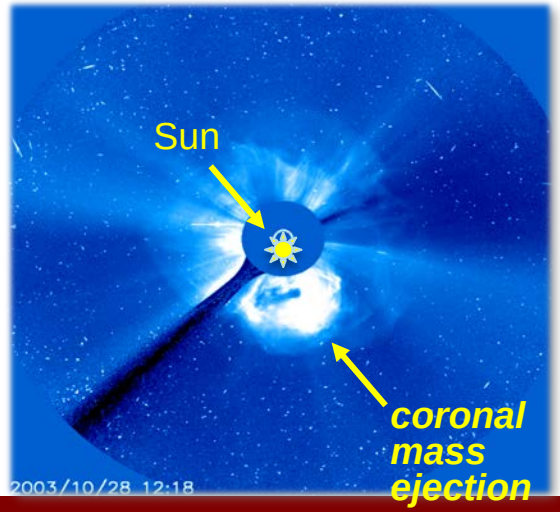
- The natural space radiation environment consists of trapped particle belts, solar events (flares and coronal mass ejections), and galactic cosmic rays
- Radiation can produce temporary malfunctions in electronics (e.g., single-event upset, single-event functional interrupts) or permanent degradation/failure (e.g., total ionizing dose, displacement damage, latchup/burnout)
- The impact of these effects can range from data corruption to instrument malfunction to mission failure

**Trapped Particle Belts**



J. Barth, 1997 NSREC

**Solar Particle Events**



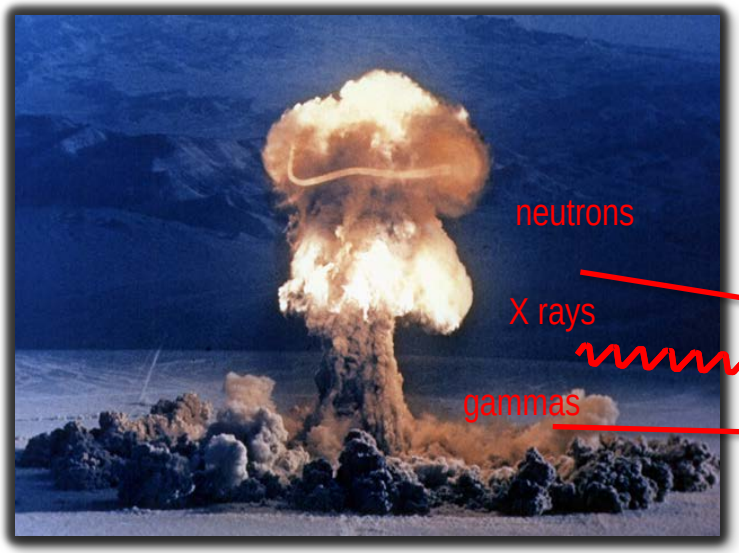

SOHO (ESA & NASA)

**Galactic Cosmic Rays**

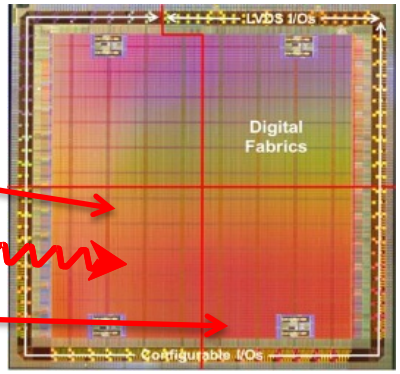
Pierre Auger Observatory

# Nuclear Weapon Radiation Environments

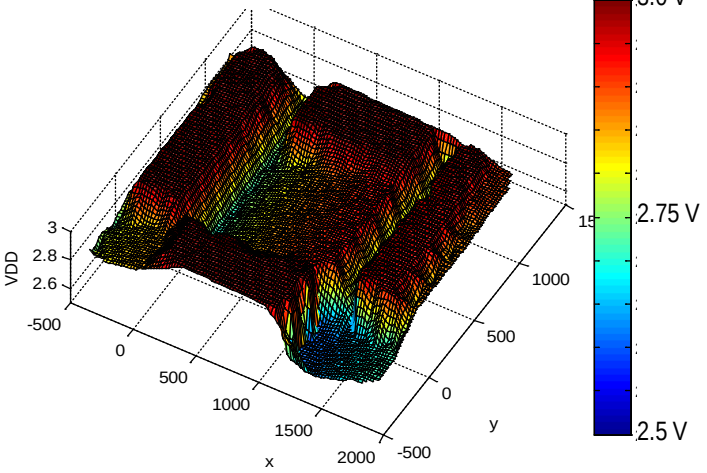
- The radiation environment near a detonated nuclear weapon contains large numbers of x-rays, gammas, and neutrons
- Some effects of this environment are similar to those of the natural space environment but different in scale (e.g., displacement damage effects in bipolar transistors), while others are unique to this extreme environment (e.g., dose-rate upset in integrated circuits)
- Detonation of nuclear weapons in space can also affect operation and longevity of critical space assets (commercial and military)




**Rad-Hard IC**

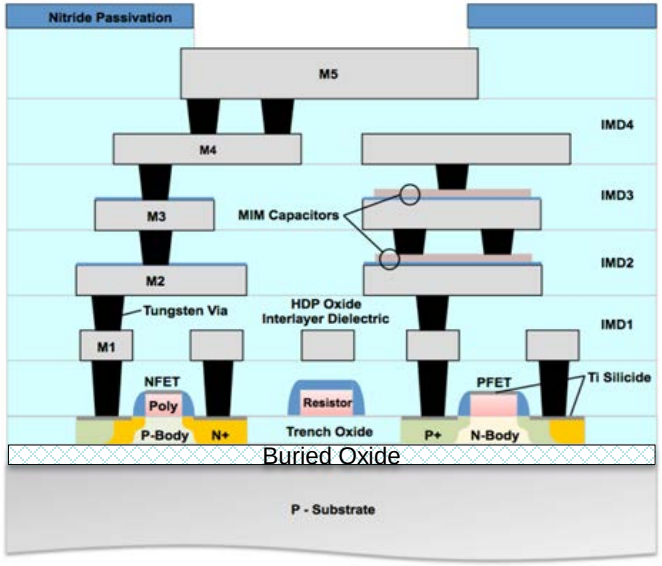



**Simulated Rail Droop at High Dose Rate**



# Several Rad-Hard Solutions

- Rad-Hard by Process (RHBP)
  - Honeywell: SOI CMOS at the 150-nm node, Rad-Hard products for satellite programs
  - Sandia National Labs
- Rad-Hard by Design (RHBD)
  - Championed by Boeing, USAF, DTRA, and others
  - Allows rad-hard at advanced CMOS nodes
- Upscreening of COTS
  - Aeroflex/Cobham

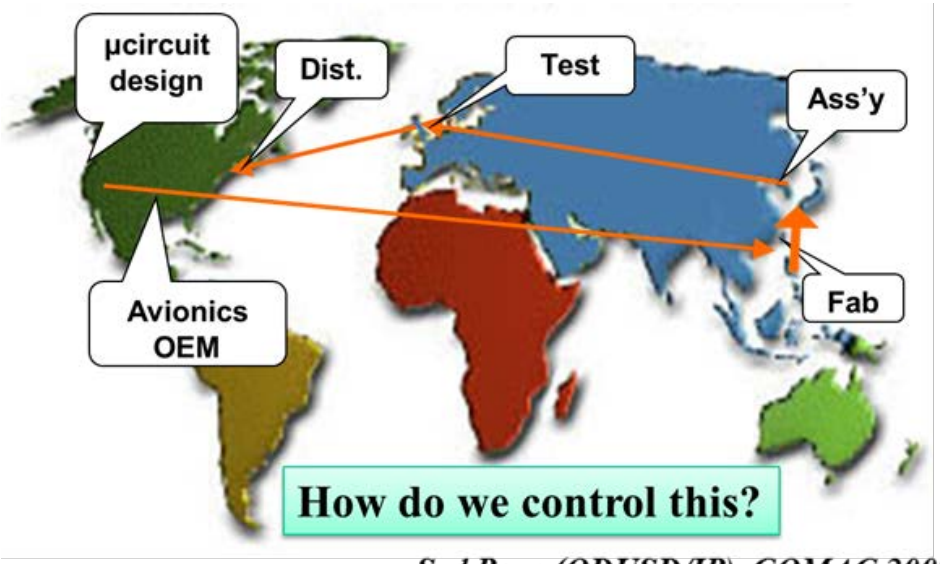



*Sandia's SOI CMOS7 Rad-Hard Technology*

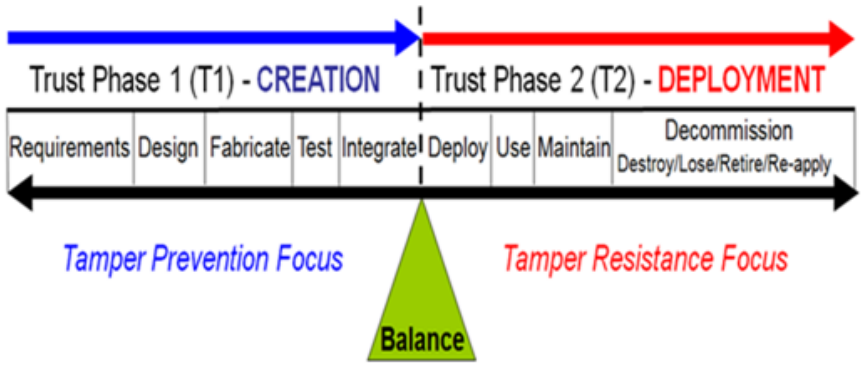
- The solutions depend on the requirements
  - "Strategic" rad-hard means different things to various customers
  - Strategic space vs. strategic nuclear weapons
- The rad-hardest solution is RHBP + RHBD
  - Generally this solution space is small
  - Honeywell, BAE Systems, Boeing Design Kit, Sandia National Laboratories, Northrop Grumman and more.

# Trust: The Issues

- Counterfeit parts are big business - Legacy parts
- Cloning is becoming a serious threat – not easy to detect.
- The rise of malicious intent: denial of service, kill switches
- International supply chain – where is the chain of custody


*Syd Pope (ODUSD/IP), GOMAC 2009*




Verification, Validation, Certification

**Cradle to Grave Concerns**

# Trust Solutions Today

- DMEA Accredited Trusted Foundry & TAPO
  - Global Foundries US 2
  - Formerly IBM TF: 52 Designs
- DMEA Trusted Suppliers - Many
  - Design to packaged parts to test
  - Roughly 60 accredited suppliers
- Legacy Parts: know your supply chain - Pedigree
- Counterfeit Detection – Verification/Validation
  - Several government and commercial services
  - Counterfeiters are adapting
  - Cloning detection – challenging

Sandia National Laboratories

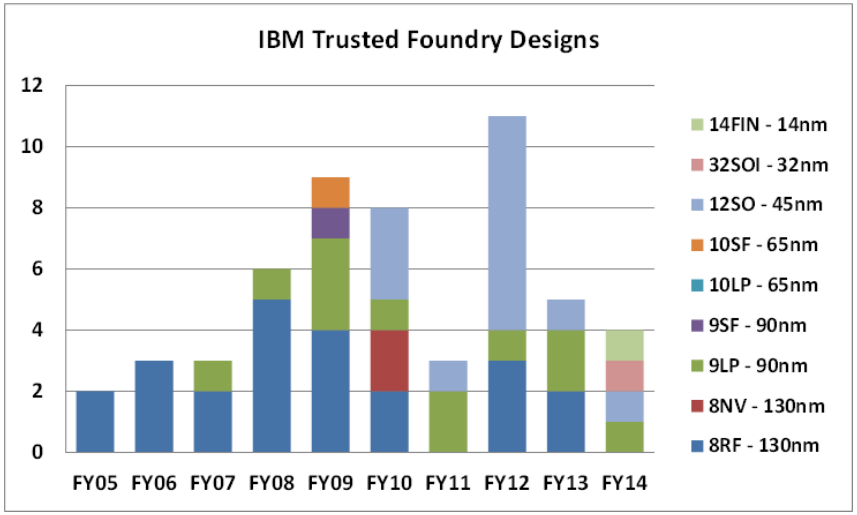
GLOBALFOUNDRIES


LANSDALE Semiconductor Inc.

TOWERJAZZ The Global Specialty Foundry Leader

NORTHROP GRUMMAN

Honeywell | Aerospace

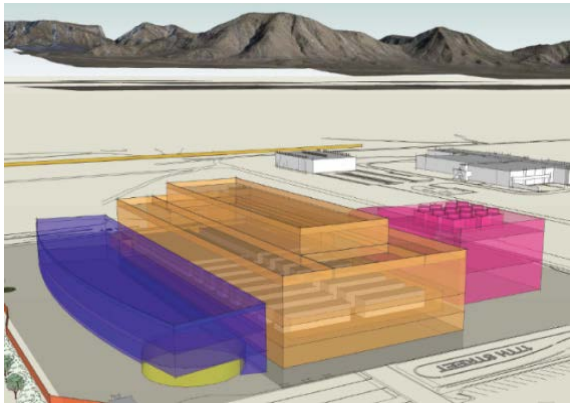


# Trust Solutions Tomorrow

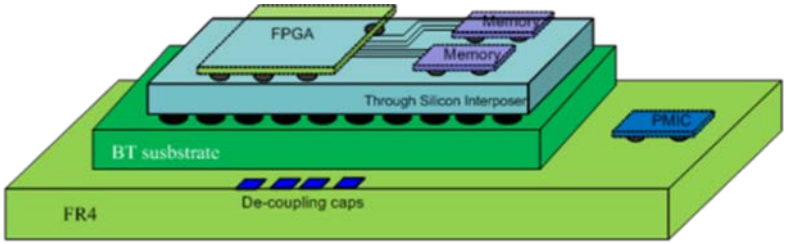
- DMEA accredited, Trusted suppliers
  - Foundry consolidation increasing foreign ownership
  - Access to Trusted state-of-the-art microelectronics limited
- State-of-the-Art is not Trusted – R&D ideas to Mitigate
  - IARPA – TIC: Split BEOL/FEOL manufacturing flow
  - SHIELD: Provide a secure hardware root-of-trust which co-packaged with an electronic component
  - CRAFT: Significantly increase reuse of integrated circuit elements
  - DAHI: Diverse and Accessible Heterogeneous Integration: Manufacturing a device across multiple commercial locations while concealing its functionality
- Areas of Opportunity?
  - Trust Metrics: qualitative & quantitative
  - Trust Resiliency – Detect/Decide/Deter
  - Obfuscation techniques
  - Faster validation techniques
  - Model and Predict trustworthiness

# Trusted & Strategic Rad-Hard Futures at Sandia

- Developing 180/150nm Technology
  - Based on BAE's technologies, but on SOI
  - Upgrading to process 200mm wafers
  - Strategic hardness with improved speed, density and configurability
- What is the proper Future capability?
  - Can CMOS be strategic rad-hard at 90nm?
    - 90nm sweet spot identified by customers for both analog and digital
    - Tradeoffs in cost, yield, and performance need addressed
  - CMOS fab, advanced packaging, design, and test/BI
  - 300mm advanced nodes for split-fab back-end-of-line?
  - Expanded R&D capabilities
  - Heterogeneous Integration



Next Generation Facility




Stacking & Heterogeneous Integration

MESA Complex

# Rad-Hard Trustworthy Microelectronics

Sandia National Laboratories

An ecosystem of co-located resources

**Radiation Physics**
RHBP/RHBD
Models/Test
Characterization

Assessments
Vulnerability Analysis

**Cradle** — **Grave**

Fortification
Policy/TF
Pedigree

Assurance
Verification
Validation

Deterrence
Attribution

Resiliency:
Detect, Decide,
Deter

**NW *Safe & Secure***

Assessments

Cyber

**Counterfeit Detection Center**

Red team, Software Eng.

Microsystems

Nano-electronics

**SNL Future Fab**
Design, Production, Packaging

Testing, Burn-In

Hetergeneous Integration

State of the Art Tools

**Foundational Capability**
Facilities, Tools, People, Research

Data Processing, HPC

Collaboration across DOE/DOD labs

HPC: High Performance Computing



Anticipating and Resolving DMS for trustworthy strategic rad-hard parts

# Summary

- Rad-hard Trusted solutions exist today and will continue to be available in the near future
- Access to trustworthy rad-hard microelectronics will become more difficult due to DMS: consolidation, movement off-shore, closing of factories
- Measuring Trust and engineering Trust present difficult research problems with national-scale impact
- Sandia is addressing these complexities by developing the capabilities, tools, people, research programs, and facilities required to help secure trusted rad-hard microelectronics in the future