SAND2020-0067PE

Sandia National Laboratories
NPC & Electronic Systems

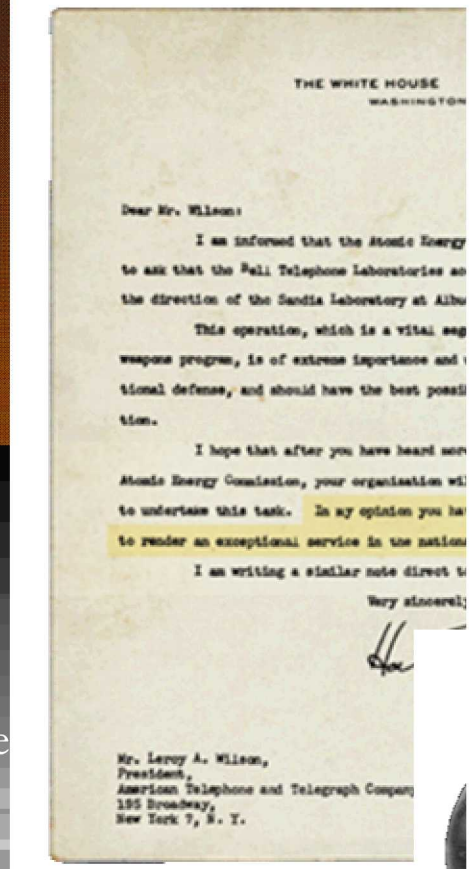
PRESENTED BY

Dan McMurtrey and Henry Coakley

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

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



THE WHITE HOUSE
WASHINGTON

Dear Mr. Wilson:

I am informed that the Atomic Energy
to ask that the Bell Telephone Laboratories ac
the direction of the Sandia Laboratory at Albu
This operation, which is a vital eng
weapons program, is of extreme importance and
tional defense, and should have the best possi
tion.

I hope that after you have heard more
Atomic Energy Commission, your organization wi
to undertake this task. In my opinion you ha
to render an exceptional service in the nation
I am writing a similar note direct t

Very sincerely

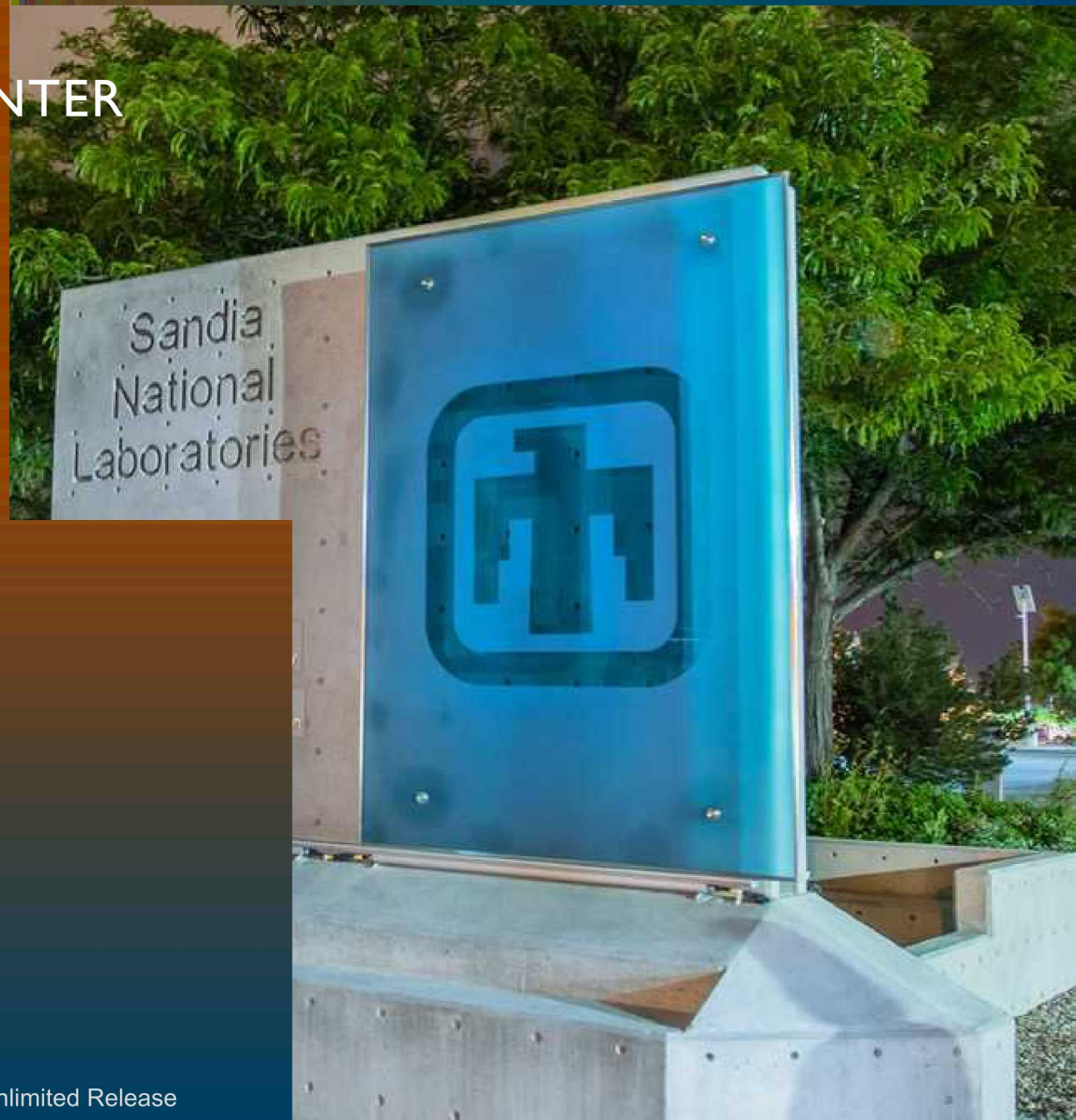
Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company
195 Broadway,
New York 7, N. Y.

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory is establishe
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present

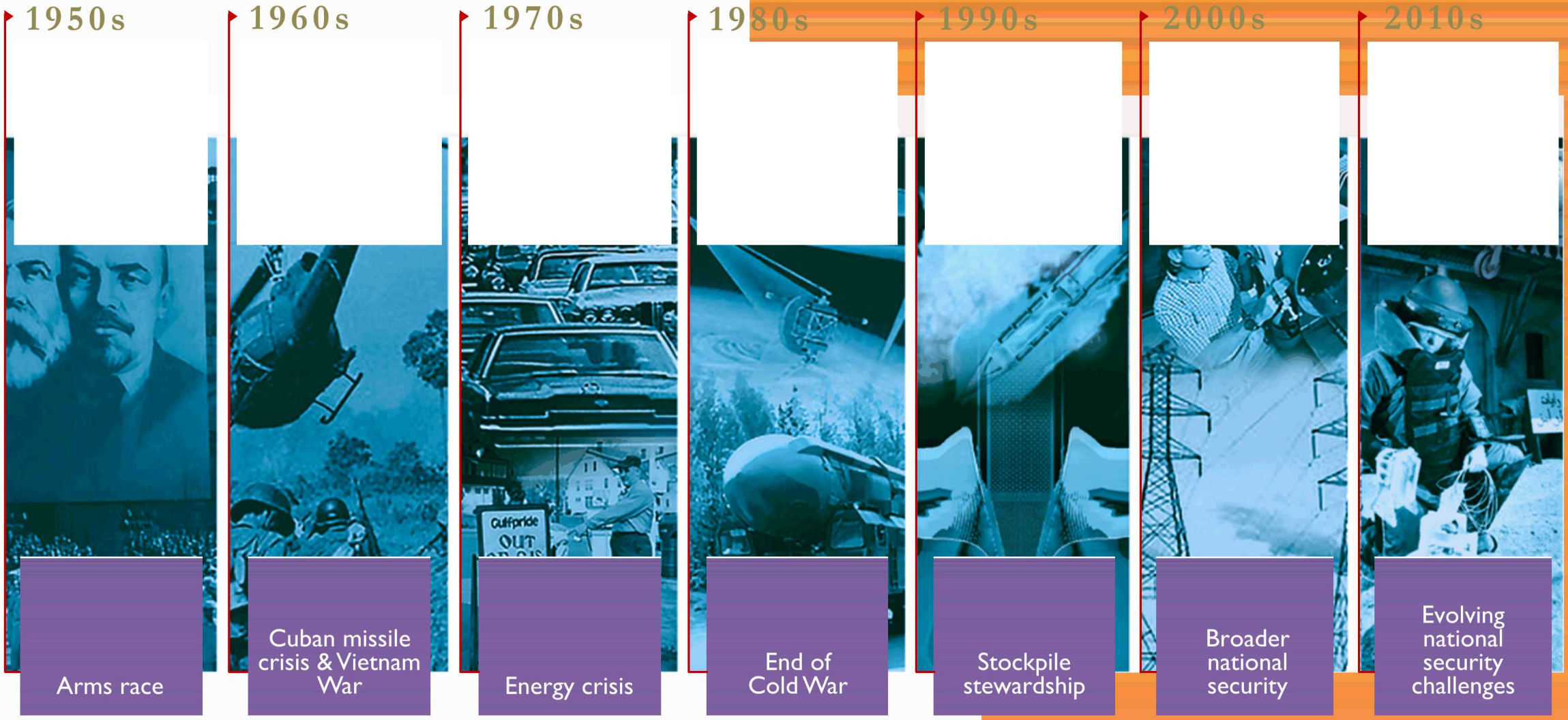
SANDIA IS A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER MANAGED AND OPERATED BY

National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc.: 2017 – present

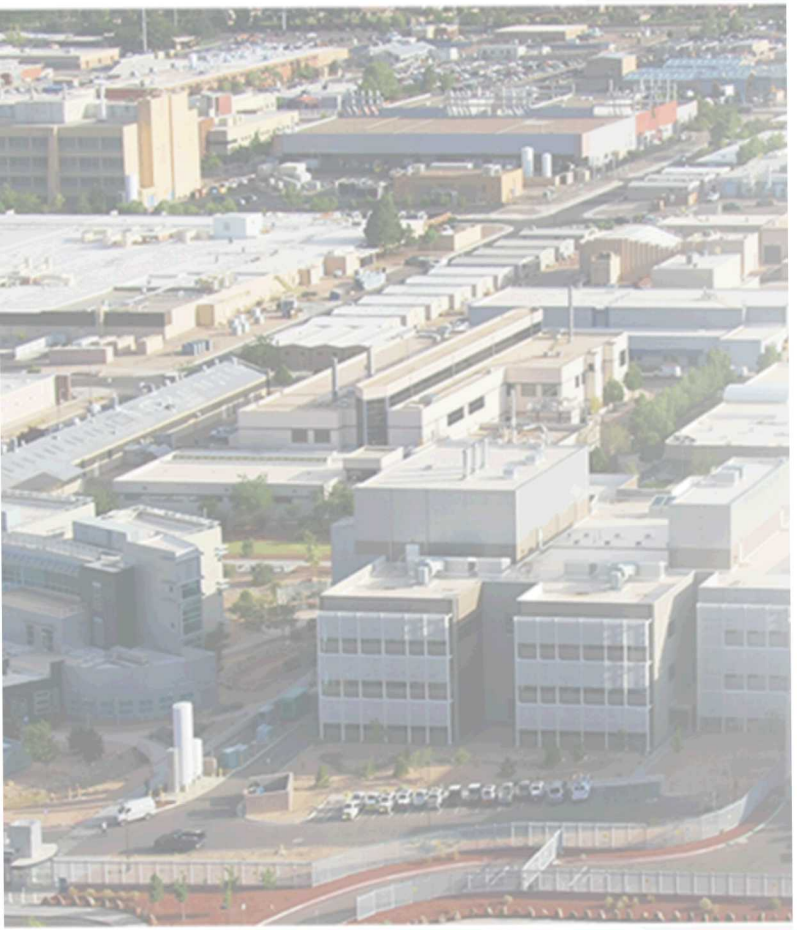
Government owned, contractor operated

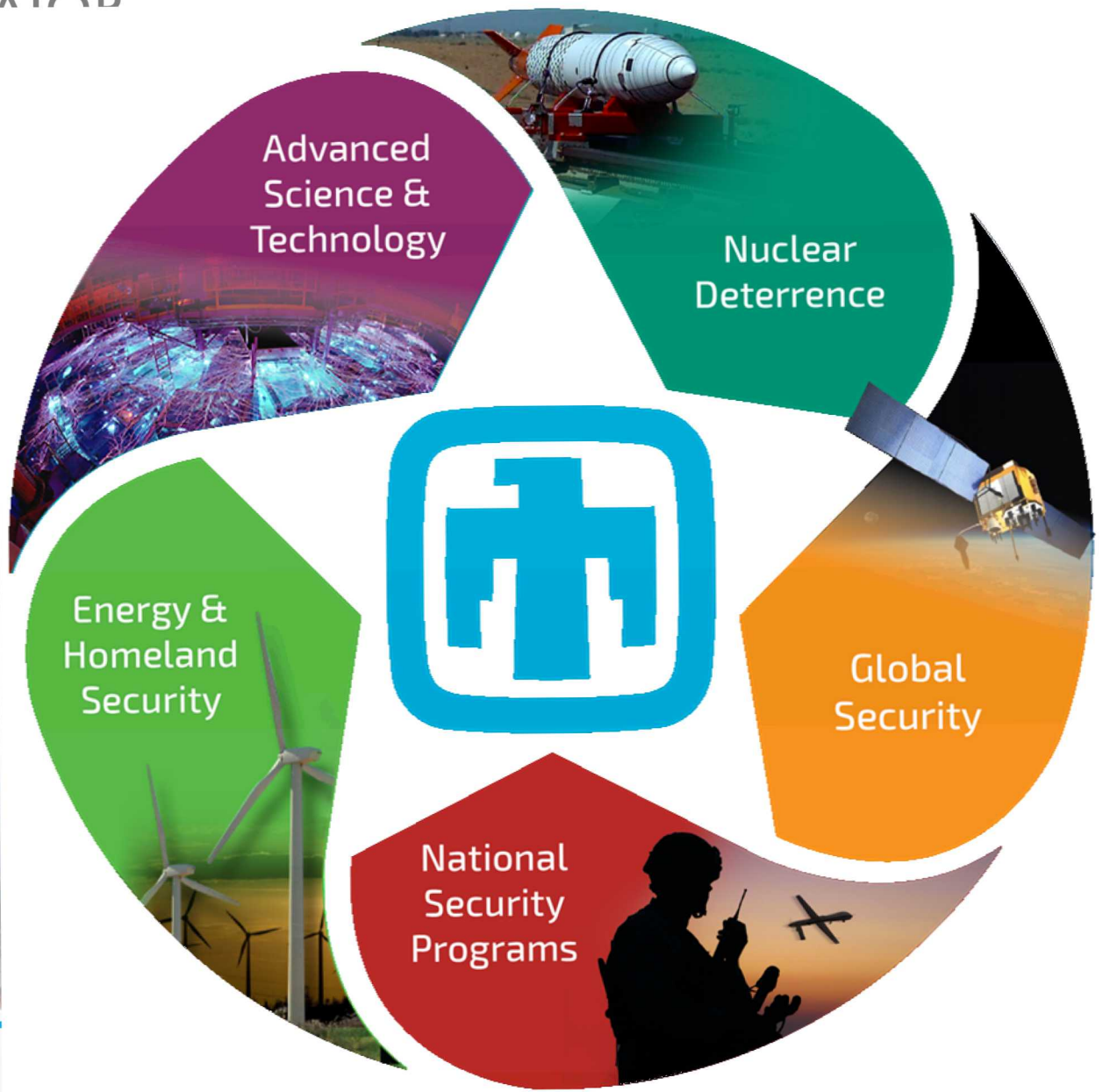


SANDIA ADDRESSES NATIONAL SECURITY CHALLENGES



SANDIA HAS FIVE MAJOR PROGRAM PORTFOLIOS





NUCLEAR DETERRENCE IMPERATIVES

Our primary mission drivers

Maintain the current U.S. nuclear weapons stockpile

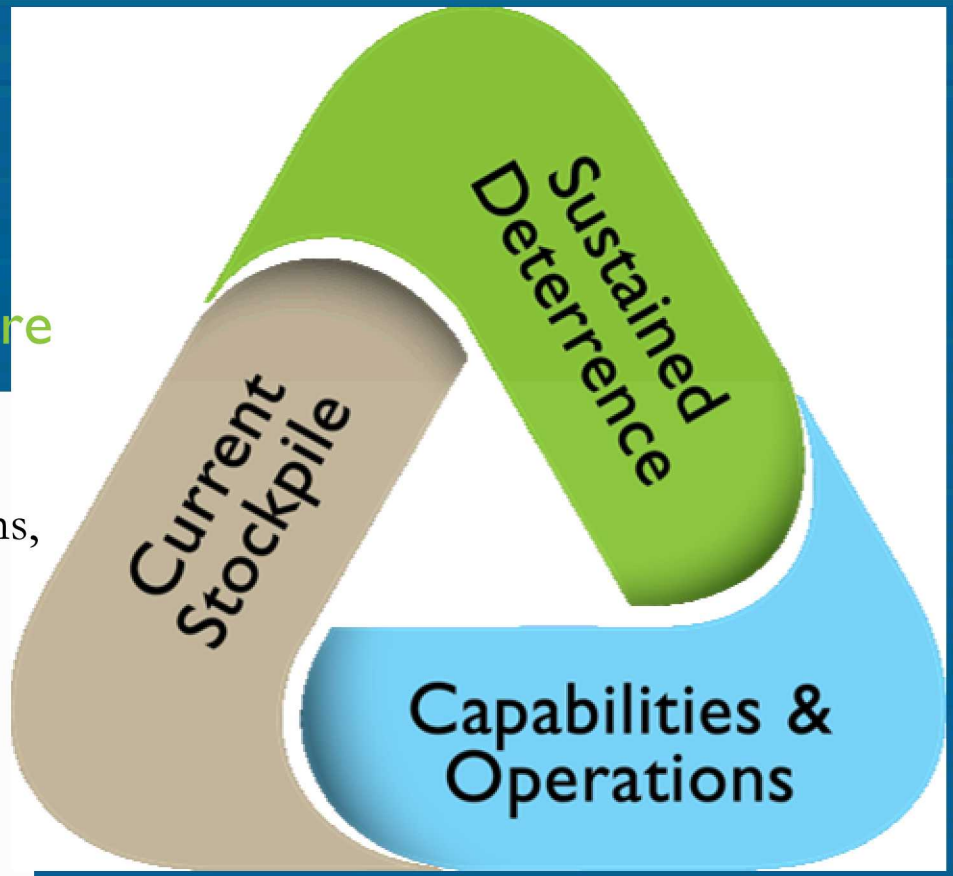
Continue the safety, security, and reliability of the current stockpile through Annual Assessment, surveillance, limited life component exchanges, significant finding investigations

Sustain a flexible and responsive stockpile into the future

Ensure U.S. nuclear deterrent effectiveness by extending warhead life and maintaining readiness to counter emerging and unconventional nuclear deterrent threats through Life Extension Programs, Alterations, Modifications, Technology Maturation, as well as Advanced & Exploratory work

Steward the long-term vitality of our capabilities, infrastructure, and operations

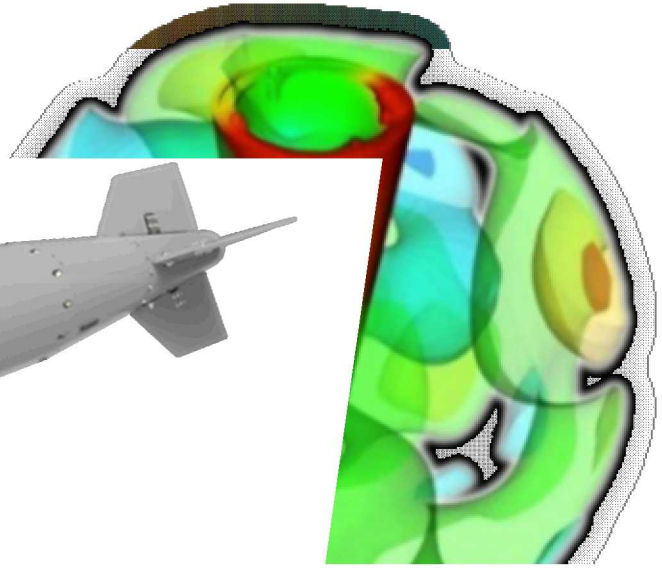
Continue the persistent commitment to world-class, multi-disciplinary staff, state-of-the-art labs, equipment, facilities, and safe/secure/quality/affordable operations



NUCLEAR DETERRENCE

Responsibilities form a critical mandate

Warhead systems engineering & integration

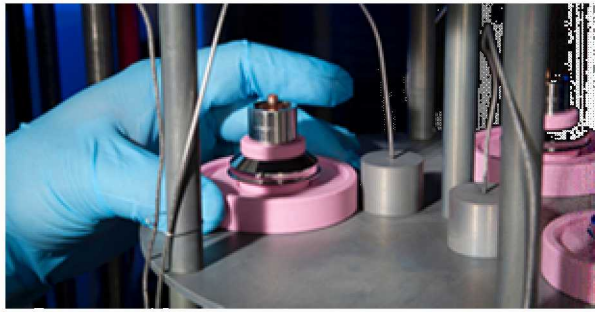


tidisciplinary
ıbilities

ired for design,
ication, production,
illance, computation/
imentation
ajor environmental test
ilities & diagnostics
aterials sciences
ght-initiated high explosives
mputational analytics

Design agency for nonnuclear components

- Gas transfer systems
- Radar
- Safety systems
- Arming, fuzing & firing systems
- Neutron generators



Production agency

- Neutron generators
- Sandia external production
- Microelectronics
- Thermal battery backup

GLOBAL SECURITY

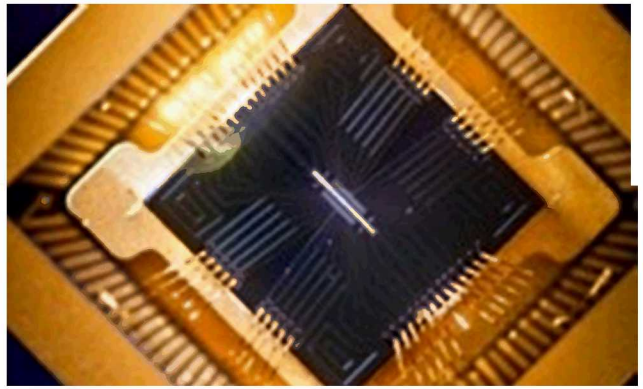
Protects the nation from threats at home and abroad

- Develop space- and ground-based sensor systems for monitoring emerging threats
- Supply technology, crisis response, and training to respond to a crisis associated with weapons of mass destruction
- Provide capabilities for protecting U.S. nuclear weapons and materials at fixed sites and in transit
- Produce systems that deter proliferation and verify compliance with international agreements using space-borne and ground-based sensing technology
- Lead global technical engagement to prevent the misuse of nuclear, chemical, biological, and radiological materials

NATIONAL SECURITY PROGRAMS

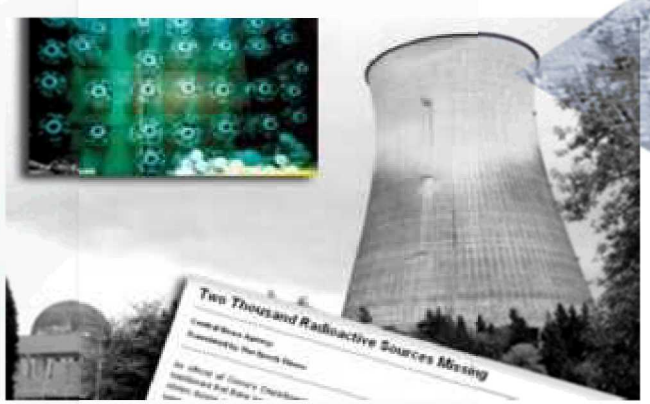
Strengthens our nation's defenders

Information operations



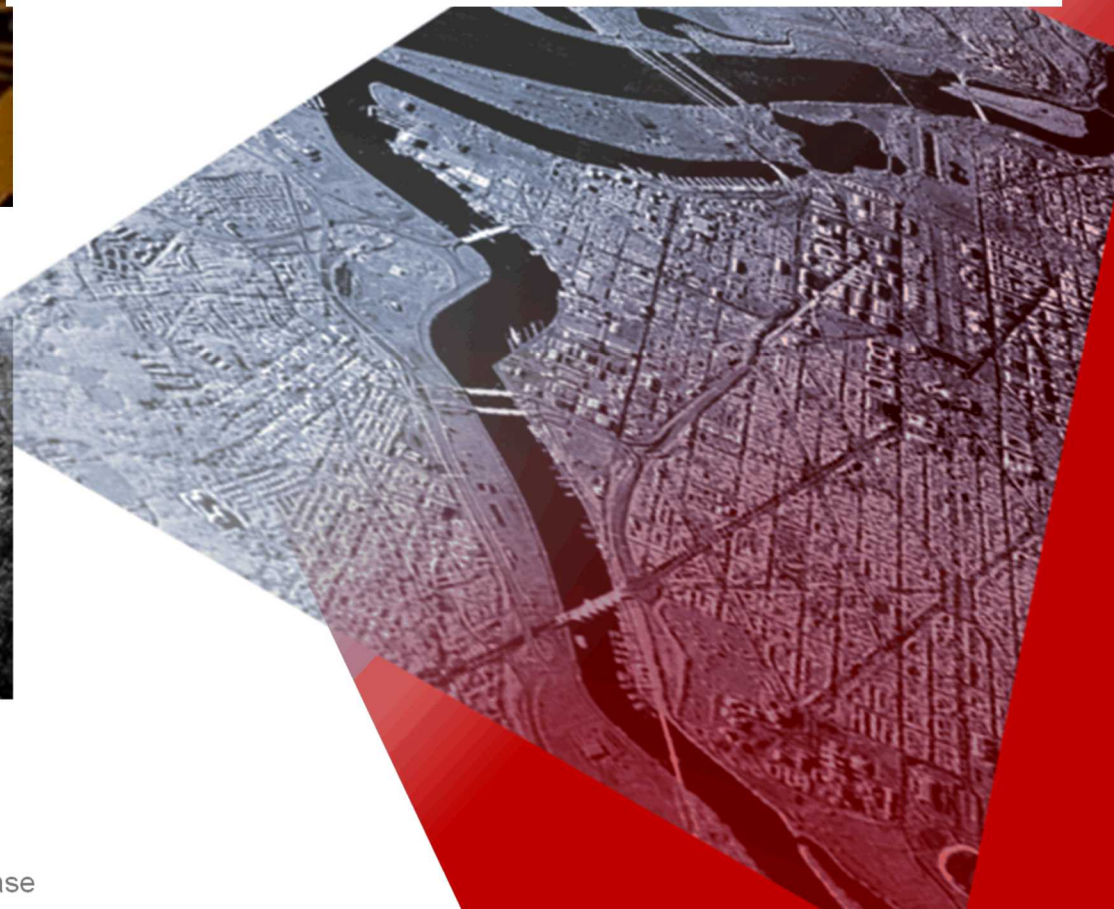
Science & technology products

Integrated military systems



Proliferation assessment

Surveillance &



ENERGY & HOMELAND SECURITY

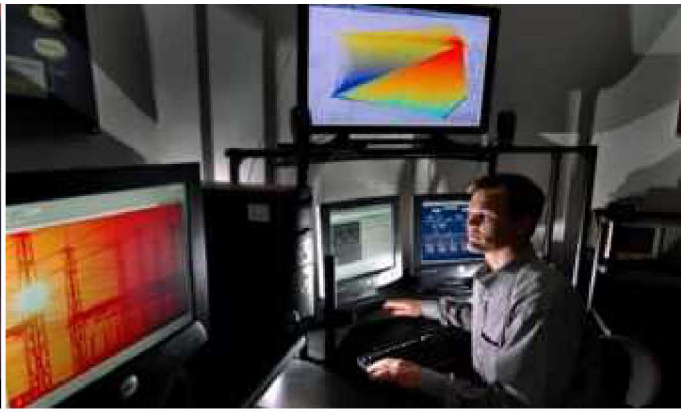
Innovates for a secure future

- Perform fundamental and applied R&D to support the resilience and security of the nation's energy system

Provide protection for our nation's digital and physical critical infrastructures

Reduce U.S. vulnerability to chemical, biological, radiological, and nuclear threats

Accelerate transformative innovations in the transportation sector through foundational physical and computational research

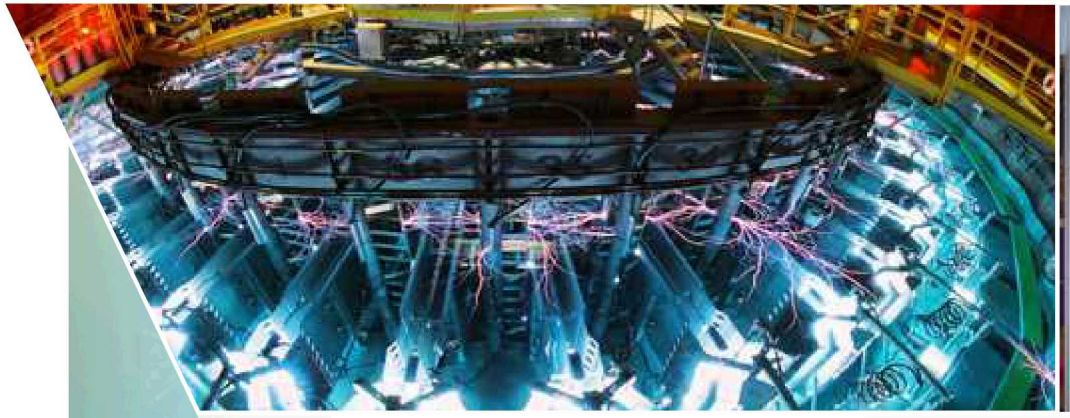


ADVANCED SCIENCE & TECHNOLOGY

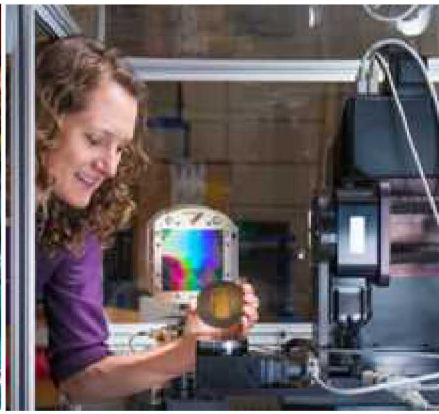
Researc[illegible]ral role in mission delivery

Nanodevices & Microsystems

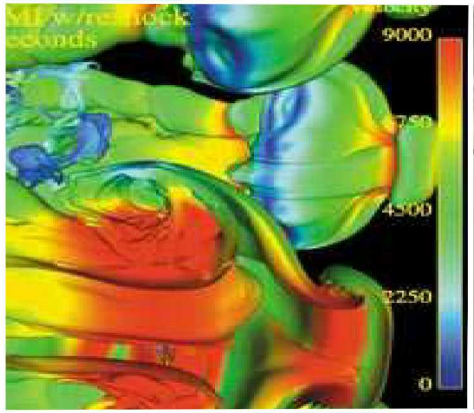
Computing & Informa[illegible]



Radiation Effects & High Energy Density Science

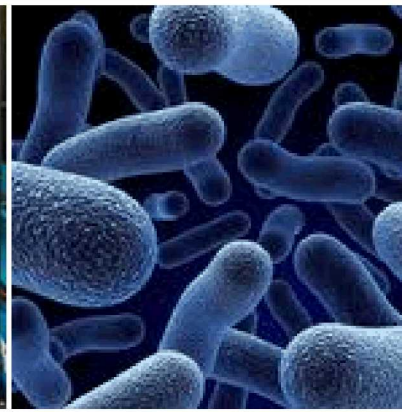


Materials Science



Engineering Science

Geoscienc[illegible]e

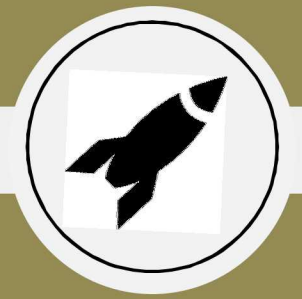


Bioscience

Navigation, Pointing, Controls & Electronics Systems

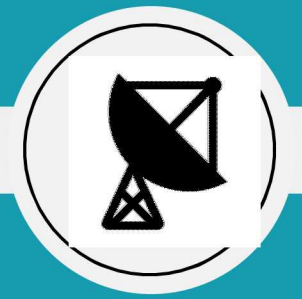
We Work in a Wide Variety of Program Portfolios

Reentry Systems & Rockets



- Computing & Processing
- Algorithms
- Inertial Navigation Systems

Contested, Degraded or Operationally-limited (CDO)

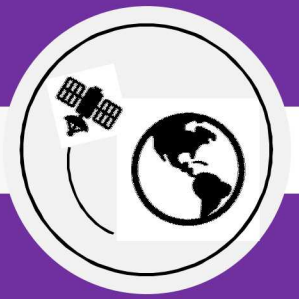


- GPS-Denied
- Alt-Nav
- Simulation & Analysis

Intelligence, Surveillance & Reconnaissance

- Synthetic Aperture Radar Expertise
- Algorithms & Software
- Hardware & Testing

Space Systems



- Satellites
- Software
- Hardware & Testing

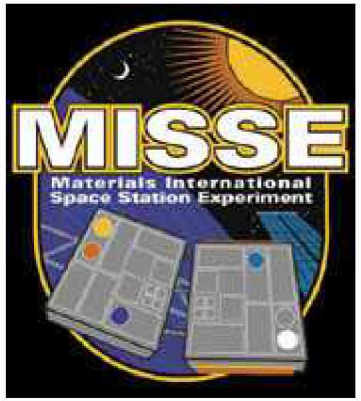
14 Space and Satellite Systems

Hardware, firmware, and software design, development, operations, and maintenance for space and satellite applications

Materials International Space Station Experiment (MISSE)

The purpose of the Materials International Space Station Experiment (MISSE) is to characterize the performance of new and prospective spacecraft materials and technologies when subjected to the combined effects of the space environment.

- The MISSE program has a rich history and benefits from six previous on-orbit payloads with substantial legacy hardware and design.
- MISSE 7 (launched Nov. 2009) is the first science payload for the Express Logistics Carrier (ELC) program and carries passive and actively powered experiments.
- One of two MISSE 7 Passive Experiment Containers (PECs) will be replaced by a MISSE 8 PEC (launch July 2010).

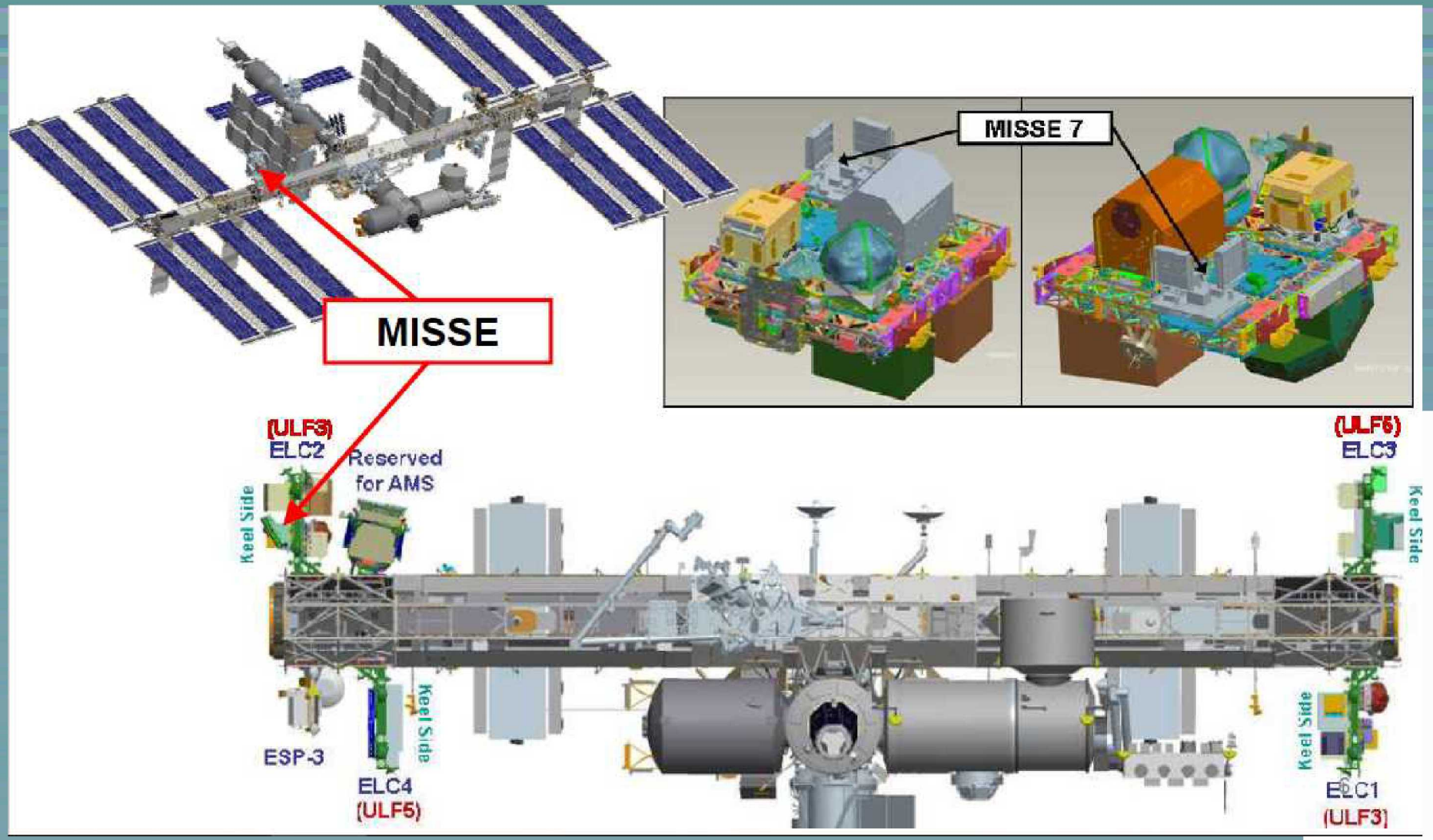


Sandia Contributions to MISSE

- **MISSE 6**
  - Piezoelectric polymer materials experiment
- **MISSE 7**
  - Single Events Upset Xilinx-Sandia Experiment (SEUXSE I)
  - Sandia Passive ISS Research Experiments (SPIRE)
- **MISSE 8**
  - Single Events Upset Xilinx-Sandia Experiment (SEUXSE II)

SEUXSE I & II are architecturally similar with differences highlighted in blue/red colors.

MISSE 7 & 8 Deployment Location



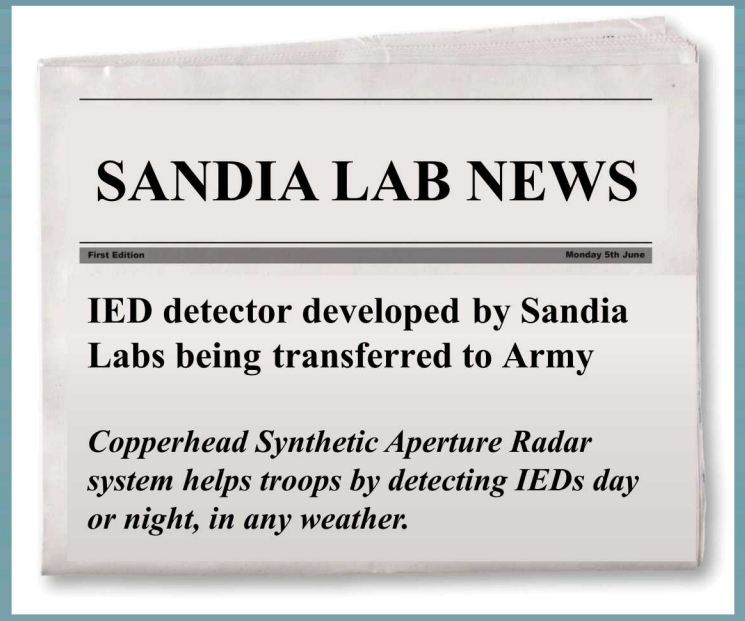
Single Event Upset Xilinx Sandia Experiment (SEUXSE) Objectives

- Single Event Upset (SEU) Detection and Characterization Using High Density Xilinx Field Programmable Gate Arrays (FPGA)
- Record Time and Bit Value of Each SEU Detected
  - Continuous scrubbing of Xilinx configuration bits
  - Continuous exercising and monitoring of most functional logic elements within each Xilinx Virtex FPGA
- Early design, delivery and deployment of technologies relevant to the DOE/NNSA's Joint Architecture Standard (JAS)
  - Xilinx Virtex-4 and Virtex-5 FPGAs
  - Point-of-Load (POL) power converters
  - Intellectual Property (IP)
  - Demonstrate in LEO space environment
- Develop Relationships with NRL, NASA, Xilinx, BYU and Many Other Academic and Industry Partners

Intelligence, Surveillance, and Reconnaissance (ISR)

3+ decades of experience delivering pathfinder ISR solutions for complex, critical and urgent national security problems

- All Weather, Day or Night
- High Resolution, Optical-like
- On-board and Real-time Processing
- Flexible platform and TPED configuration

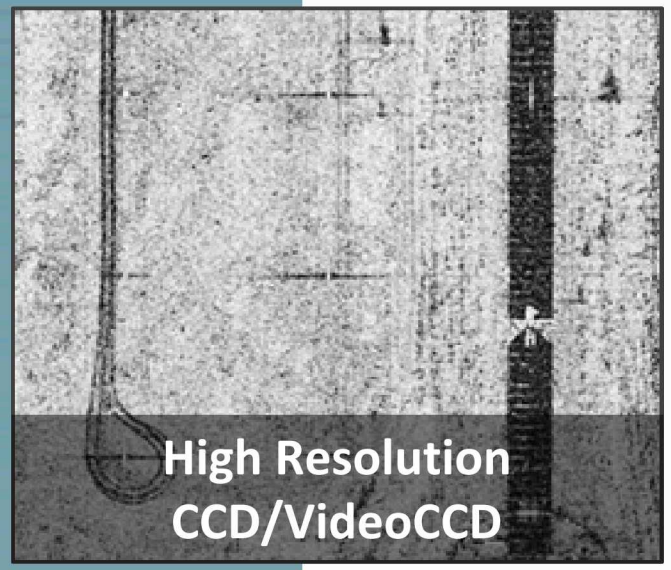


SANDIA LAB NEWS

First Edition Monday 5th June

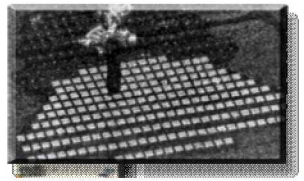
IED detector developed by Sandia Labs being transferred to Army

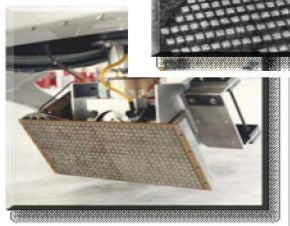
Copperhead Synthetic Aperture Radar system helps troops by detecting IEDs day or night, in any weather.



Sandia Synthetic Aperture Radar (SAR) Evolution

1987

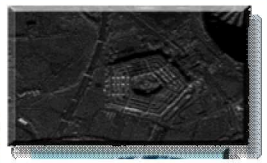




500 lbs

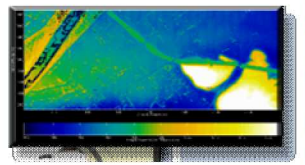
Terminal Fix System (TFS) SAR

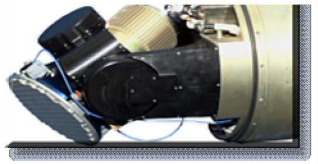
1991



SAR Target Recognition & Location System (STARLOS)

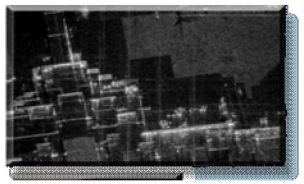
1997





Inertial Terrain Aided Guidance (ITAG)

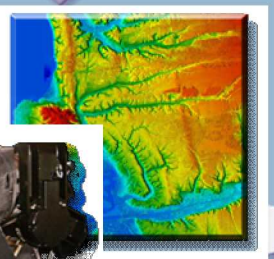
1998



120 lbs

Lynx Multi-Mode Radar CCD & GMTI

2001

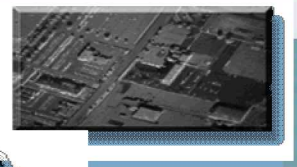


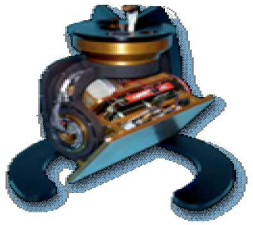
DTED III & IV

664 lbs

Rapid Terrain Visualization (RTV)

2004



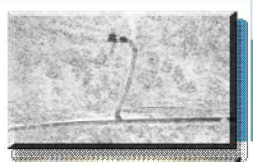


Developed for a Class III UAV

27 lbs

MiniSAR

2008

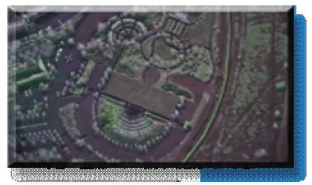


IED Detection

65 lbs

Copperhead

2010



FARAD

Multi-mode

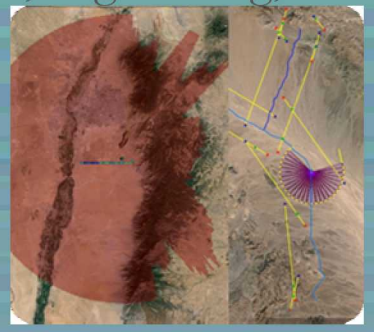
Variable Resolution & SWAP

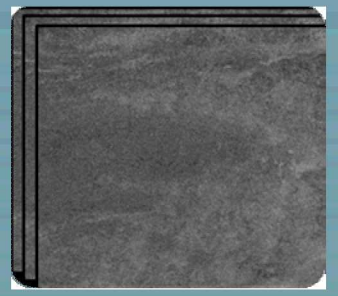
Improving radar performance & reducing SWAP for three decades

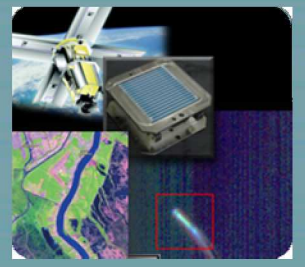
Complete Mission Solutions

Provider of end-to-end solutions that leverage physics, engineering, and data and information science to support national security decision making

- **Mission Engineering**
  - Pre-Mission Analysis & Flight Planning
  - Highly customized TTPs and CONOPs
  - Continuous performance assessments
  - Analyst Training in SAR phenomenology
- **Real-time Processing**
  - Real-time Delivery of Multiple Image Products to Analysts
  - Image Formation
  - Change Detection Products
  - Transmission of Real-time Products
- **Advanced Sensor Exploitation**
  - Predictive Intelligence
  - Human Factors
  - Advanced Exploitation Techniques
- **Analyst Training**

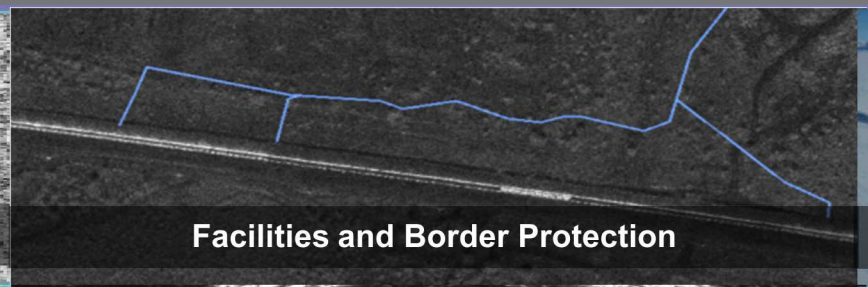


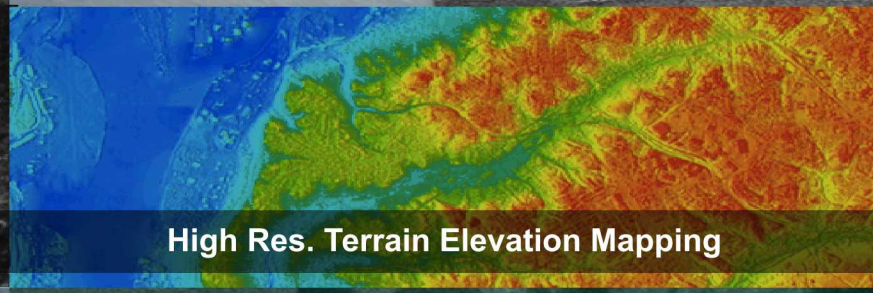


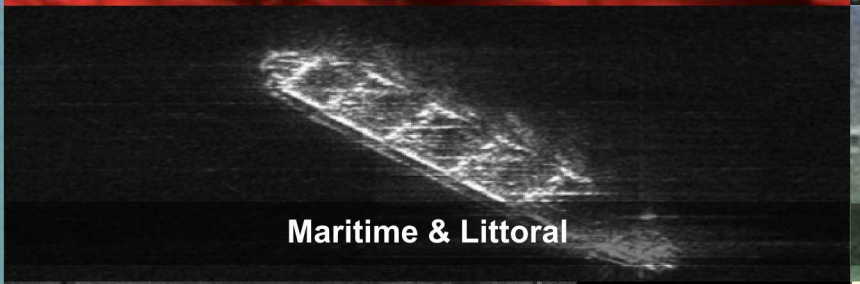



SAR imagery integration into PED cycle is difficult at best.

Real World Applications

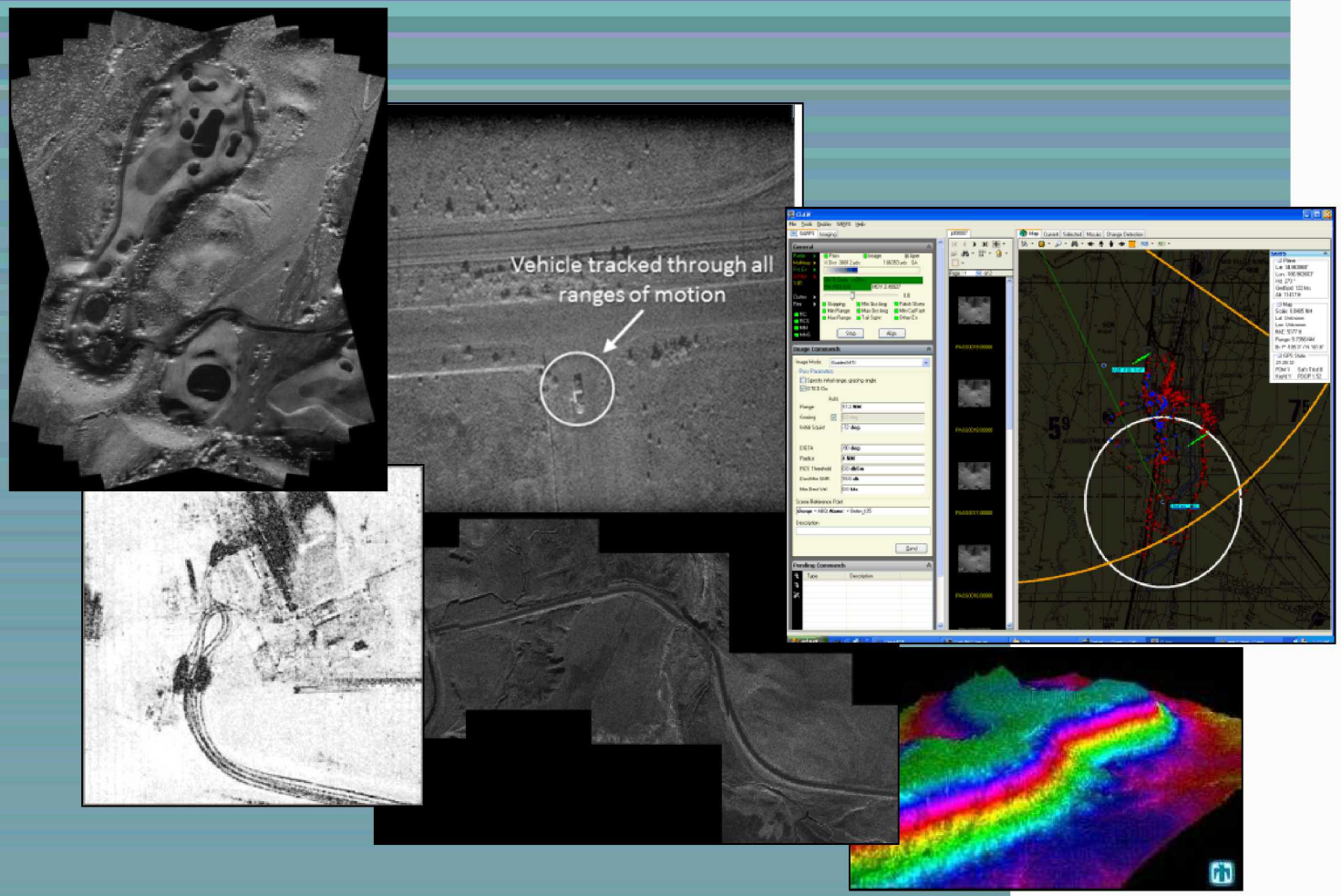






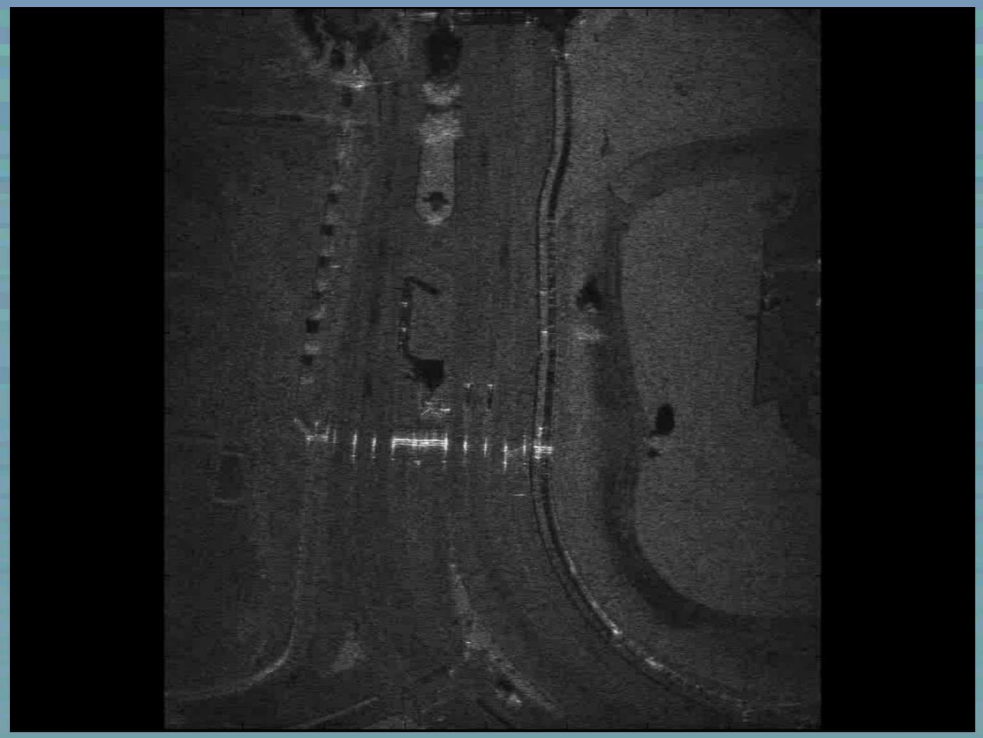
Multi-Mode Functionality

- Spotlight
- SpotDwell
- Circle
- Stripmap
- Arbitrary Stripmap
- CCD/NCP
- IFSAR
- VideoSAR/VICTR
- GMTI/DMTI
- Wide Area Search
- High Range Resolution



As new radar modes are developed they can be integrated into existing Sandia radars during product improvement phases without redeveloping the entire system

VideoSAR Vehicles Example



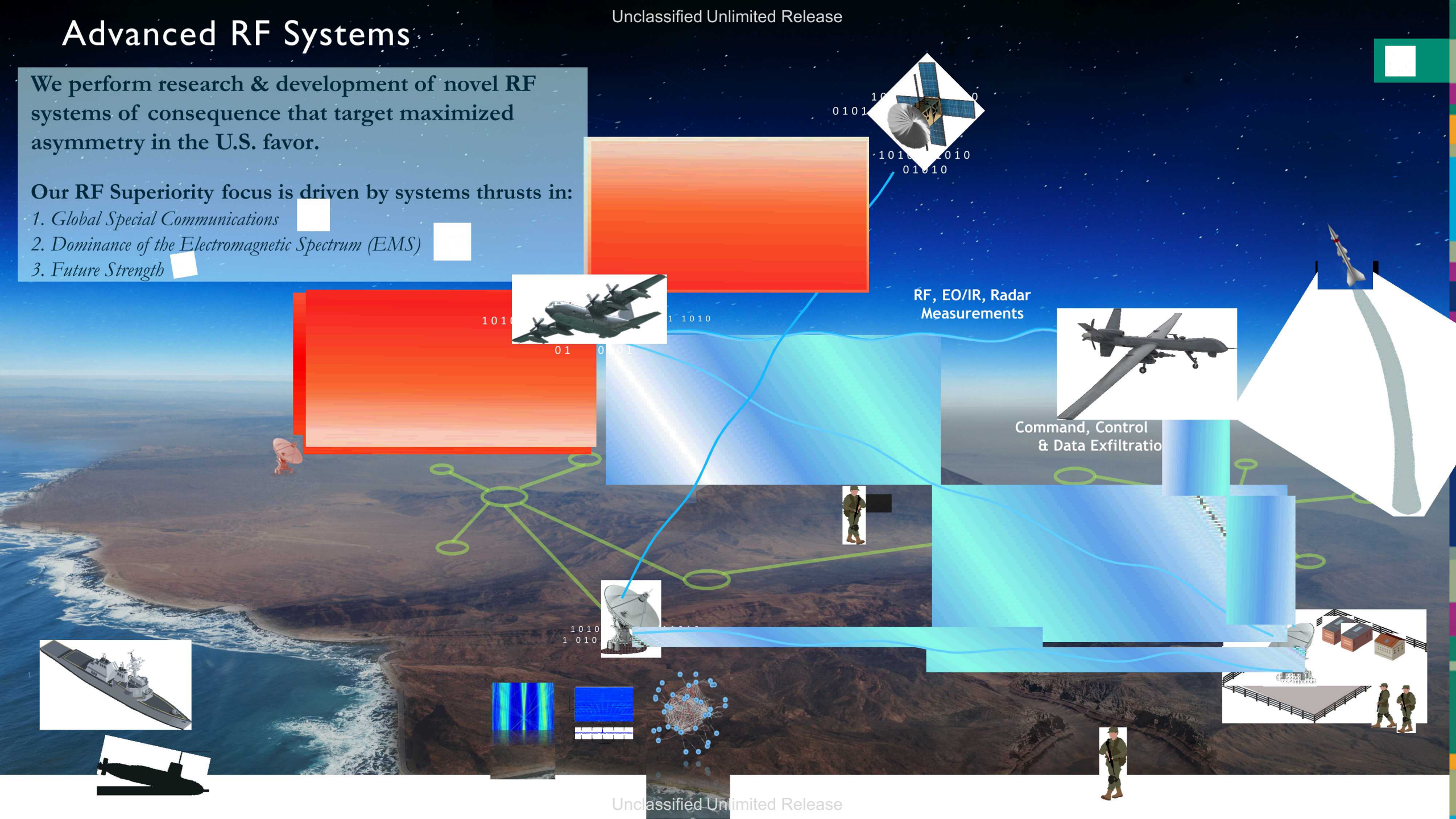
- This is VideoSAR footage of a gate at a facility. The video shows vehicle traffic moving through the gate. As the vehicles are in motion their location is indicated by a shadow. As the vehicles stop the reflected energy of the vehicles fall on top of the shadow. Once the vehicle continues in motion the shadow is again visible. The lines moving across the screen are Doppler shifts caused by the moving vehicles.

Advanced RF Systems

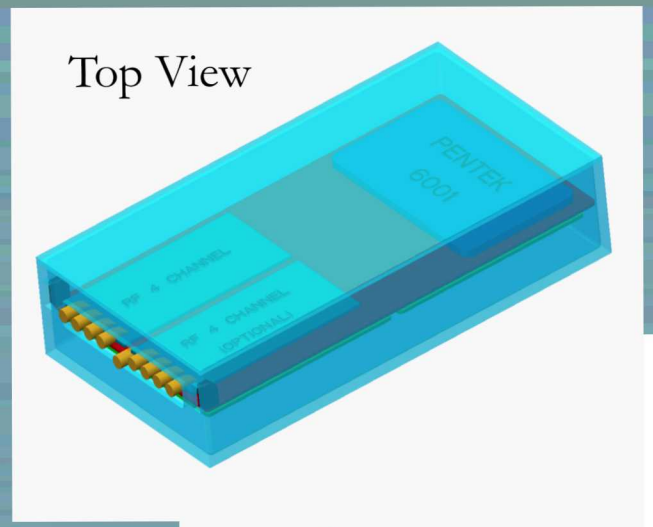
We perform research & development of novel RF systems of consequence that target maximized asymmetry in the U.S. favor.

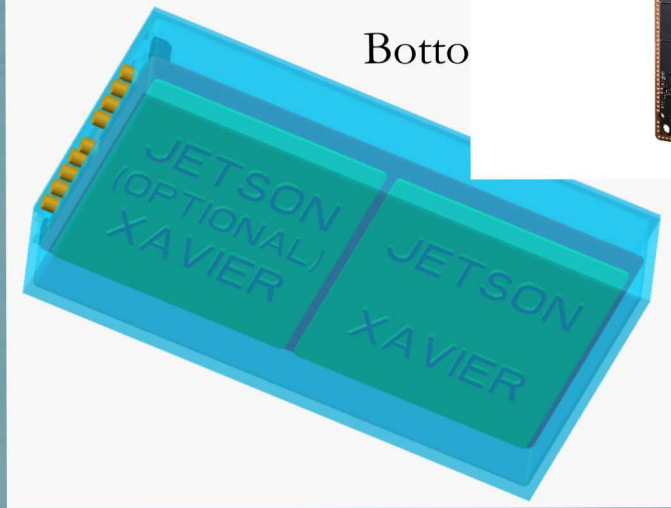
Our RF Superiority focus is driven by systems thrusts in:

1. *Global Special Communications*
2. *Dominance of the Electromagnetic Spectrum (EMS)*
3. *Future Strength*



Next Generation SDR Design





Hardware Architecture

- Commercial Pentek 6001 SOM
  - Xilinx Zynq UltraScale+ RFSoC FPGA
  - 8 high speed DACs/ADCs
  - 6-core ARM
- Commercial Jetson Xavier Mobile GPU:
  - 8-core ARM
  - 512-core Volta GPU
- Custom Interface Board:
  - Interfaces all the other boards
  - GPS Receiver
  - Network switch and WIFI
- Custom RF Board:
  - 4 RF channels
  - Multiple filter paths to allow different bands
  - Low Noise Amplifier for receive path
  - 2W PA on the transmit path

27 Reentry Systems and Rockets

We work on a variety of defensive and offensive programs, including hypersonics.

The NPC & Electronics systems organization are technical leaders in avionics, highly-complex electronics, software and algorithm and inertial navigation systems (INS) utilized across our aerial vehicle programs.

Hypersonic is defined as five times the speed of sound. The speed of sound is the basis for a unit called Mach Number.

- A mile is 5280 feet, so the threshold for hypersonic flight is about a mile per second, or Mach 5.

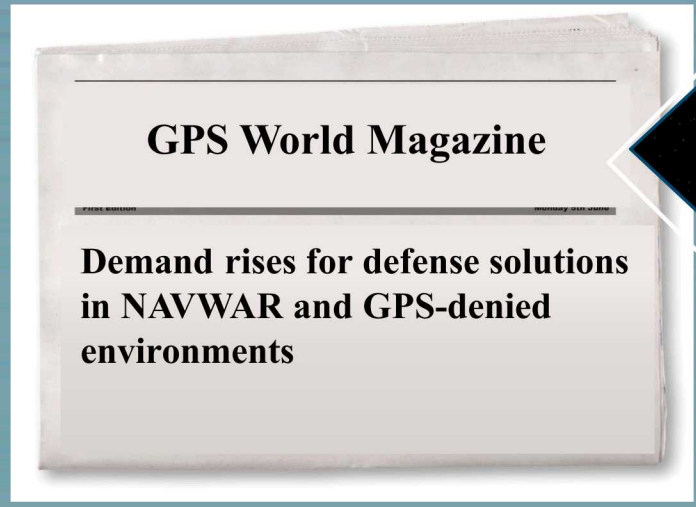
Engineering Challenges:

- Vehicle shape changes in hypersonic flight, creating challenges for flight control
- Difficult to simulate velocity, temperature, and Mach number on the ground
- Difficult to design sensors & actuators that can operate in a hypersonic flight environment
- Calculations are extremely time consuming

GPS-Denied

GPS-Denied (GPS-D)

An enormous issue with GPS is that the relatively weak GPS signals can be easily jammed, either intentionally or unintentionally. Consequently, in a military conflict GPS availability is threatened. Sandia is working to investigate, explore and develop conceptual designs that will allow strike and intelligence, surveillance and reconnaissance (ISR) systems to effectively operate in GPS-denied environments.



Ideal Prospective Employees

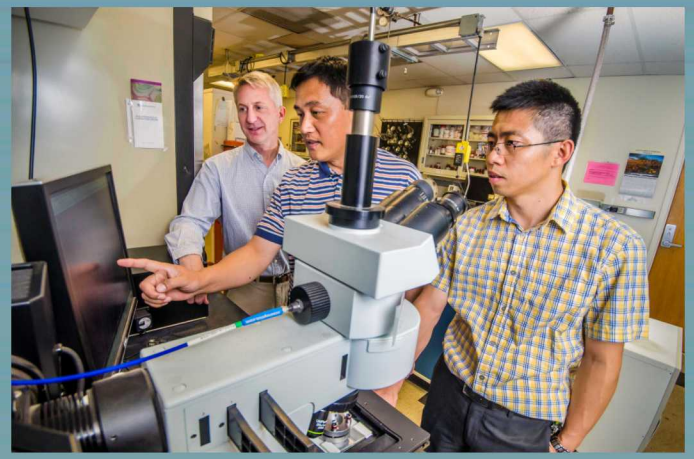
Must be able to obtain a security clearance.

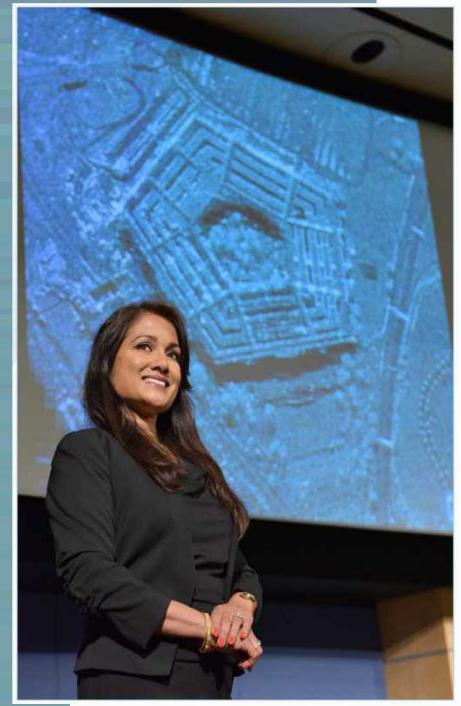
Proficient in technical areas: signal processing; algorithms; RF; inertial sensors; navigation, pointing, & controls; FPGA implementation; embedded and high-level software applications

Self motivated and innovative

Ability to work well on inter-disciplinary teams

Strong passion to see work come "alive" as solutions to national security problems

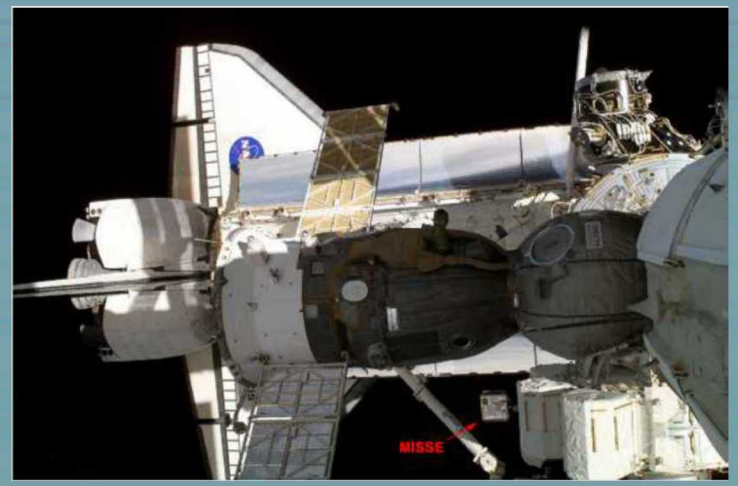




Backups

MISSE Background

- Experiments up to 2 years on the ISS
- Launched and returned by Shuttle.
- Initially passive experiments only – combined UV, AO, radiation.
- Active experiments connect to ISS for power, commanding, telemetry.



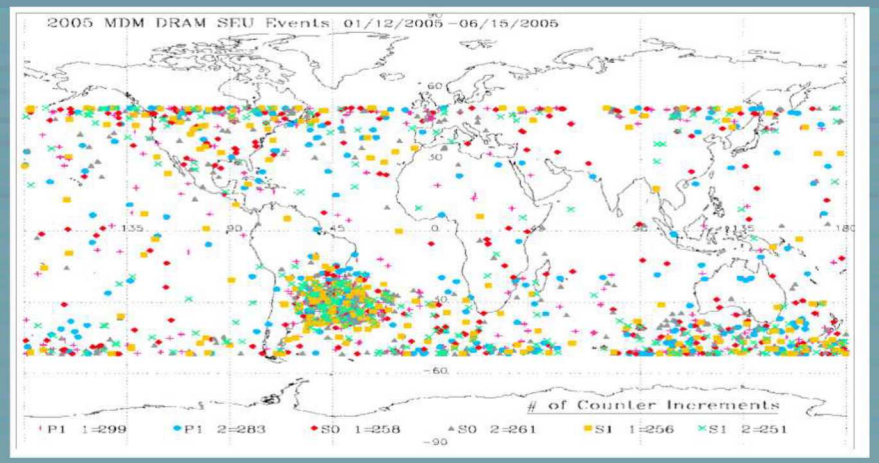
- **MISSE 1 & 2 (AFRL/ML)**
  - Passive material exposures
  - Launched 2001, returned 2005
- **MISSE 3 & 4 (AFRL/ML)**
  - Passive material exposures
  - Launched 2006, returned 2007
- **MISSE 5 (NRL)**
  - Self-powered with on-board, two-way comm
  - Active solar cell and passive material experiments
  - Launched Aug 2005, returned Sept 2006
- **MISSE 6 (AFOSR)**
  - Passive and active expts –data loggers
  - Launched March 2008, returned Sept 2009
- **MISSE 7 (NRL)**
  - Passive and Active experiments (NRL-0602)
  - Launched Nov 2009
- **MISSE 8 (NRL)**
  - Passive and Active experiments (NRL-0602)
  - Launch scheduled for July 2010

ISS Radiation Environment I

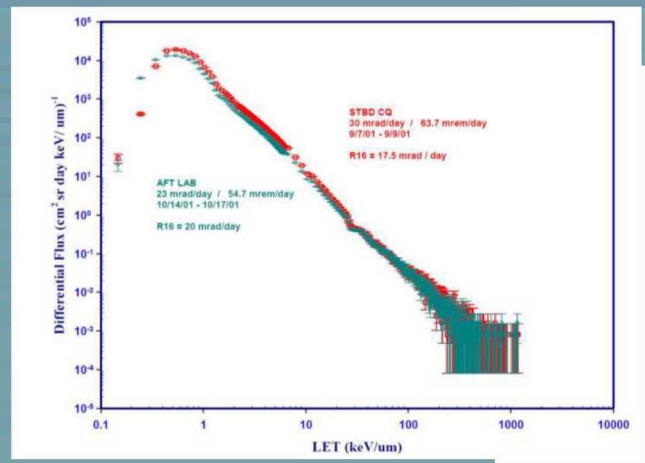
- ISS environment is suitable for a Single Event Effects experiment

– High inclination (51.5o) exposes ISS to higher fluence of trapped electrons and protons and solar and galactic cosmic rays than would be the case in a lower inclination orbit with the same altitude range, largely as a result of the overall shape and magnitude of the geomagnetic field.

– ISS passes through the South Atlantic Anomaly (SAA).



Aggregate MDM DRAM SEU Map
(155 days)



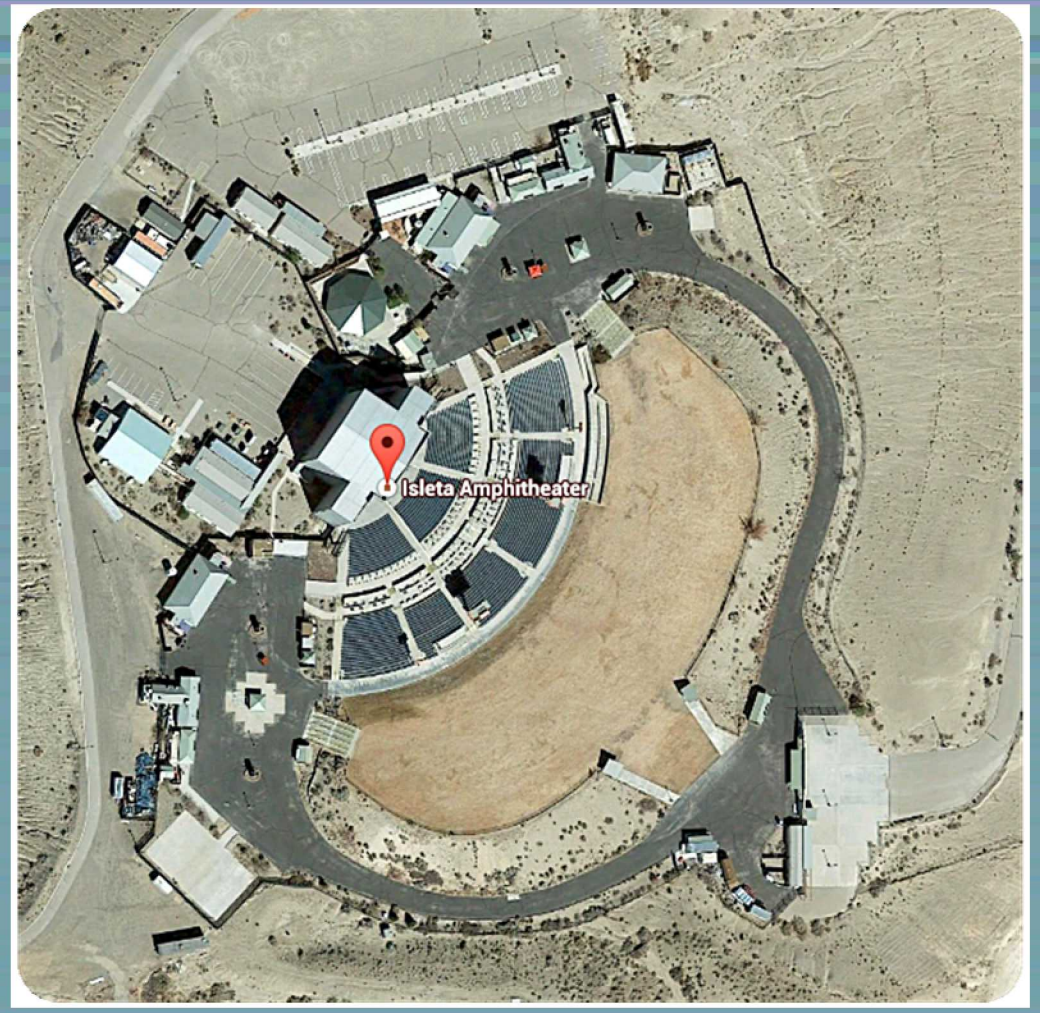
ISS Extra-Vehicular Charged Particle Spectrometer
(EV-CPDS)
Real-time LET measurements

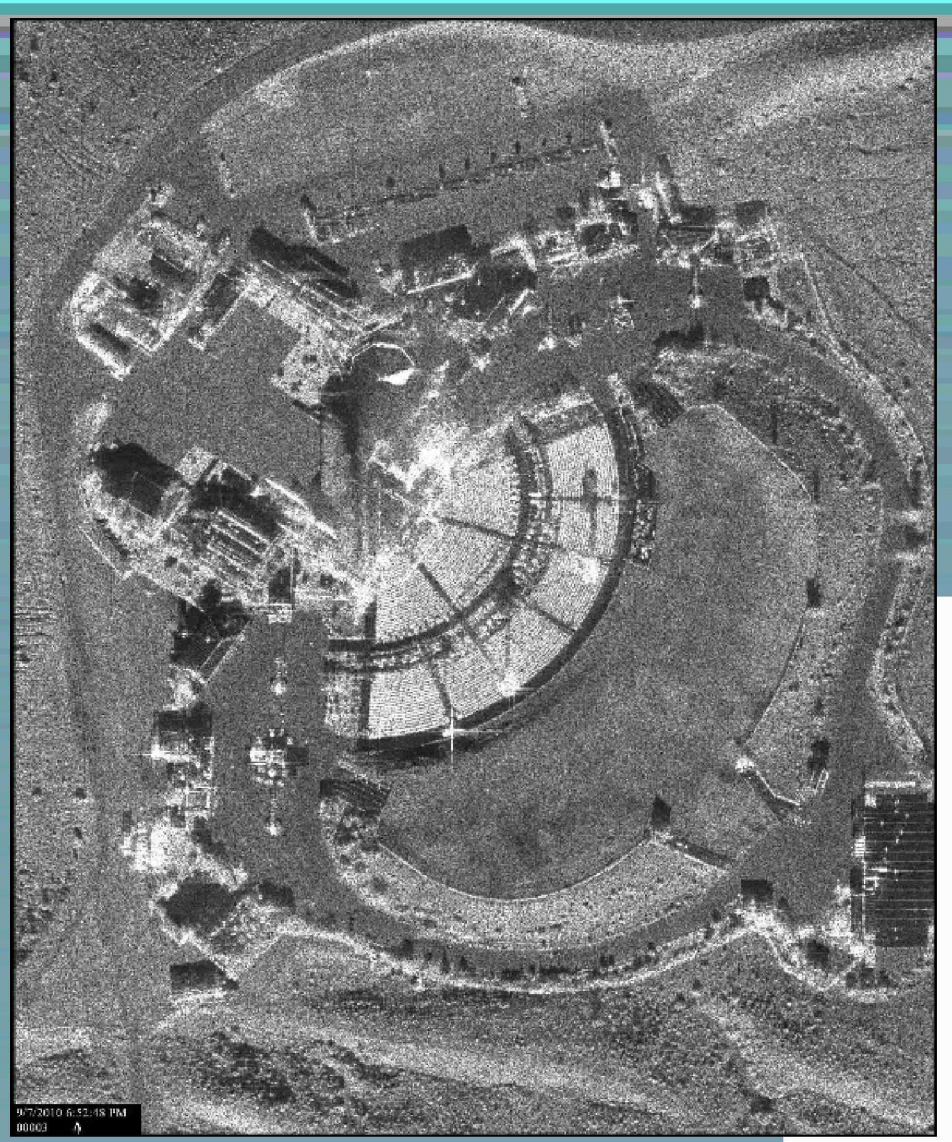
Detected SEUs will be correlated to ISS radiation and environmental monitored data.

ISS Radiation Environment II

- ISS Orbit: 336 km x 347 km, 51.6 deg. inclination
- Passive experiments TID (no shielding): ~30 krad/yr total dose at the surface.
- FPGA experiment TID (100 mil Al shield): ~30 rad/yr total dose.
- Predicted error rates:
  - Galactic cosmic rays to cause ~2 FPGA config bit errors/day and ~0.3 BRAM bit errors/day.
  - From LANL Cibola Flight Expt. SEU data (Virtex 1 FPGA's, similar orbit) ~4 errors/day.
  - About ½ of errors will be multiple bit upsets.
  - South Atlantic Anomaly will cause about 0.2 errors/day.
  - We predict about 7 flares/year with 4 errors/day and 1 flare/year with 20 errors/day.
  - Total errors/year expected to be about 1000.

VideoSAR Facility Example



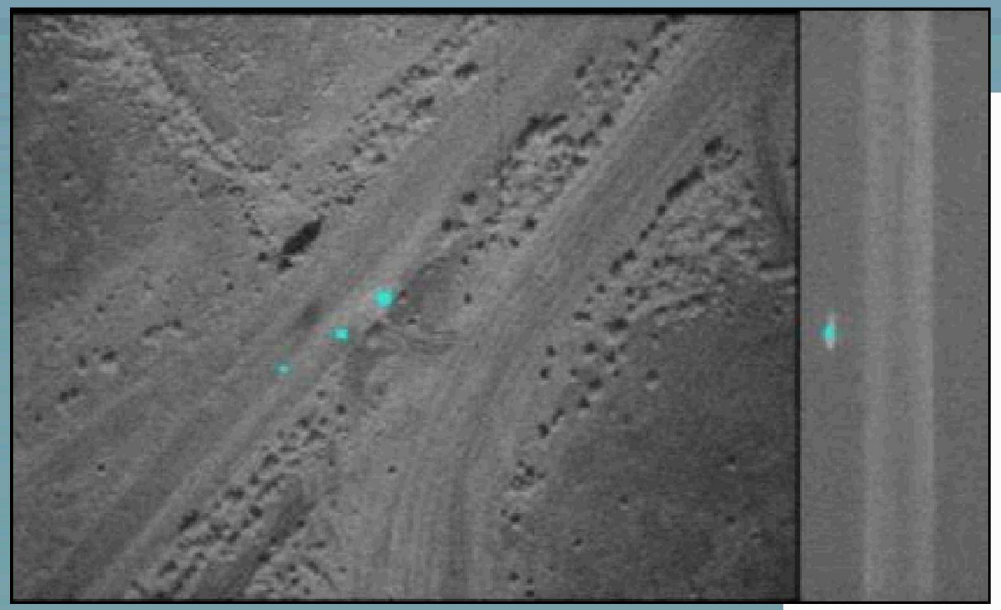


Advanced Capabilities

Multiple channels with the same instantaneous bandwidth.

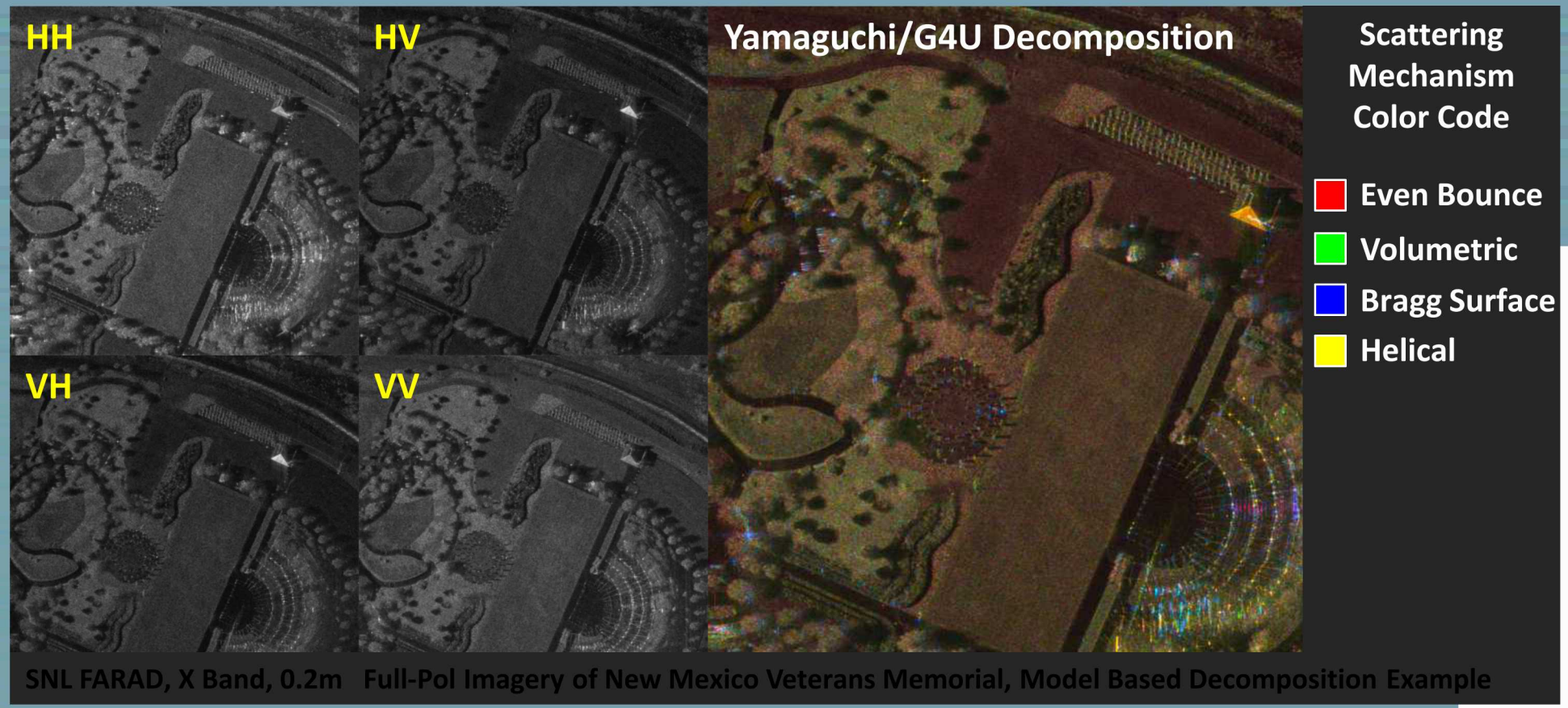
Multiple phase centers – sum and difference yield clutter suppression and increased ability to track targets.

Polarimetric (HH, VV, HV, VH) yields additional information around scattering phenomena.



High Resolution Polarimetric SAR

Value in polarimetric SAR is not in visual comparison of individual channel (HH, VV, HV) backscatter intensity maps, but rather in the inference of underlying scattering mechanisms from these independent phase coherent measures



The Purpose of FARAD

An in-house, high-performance, multi-mode airborne radar capability for the continued advancement of SAR ISR capabilities

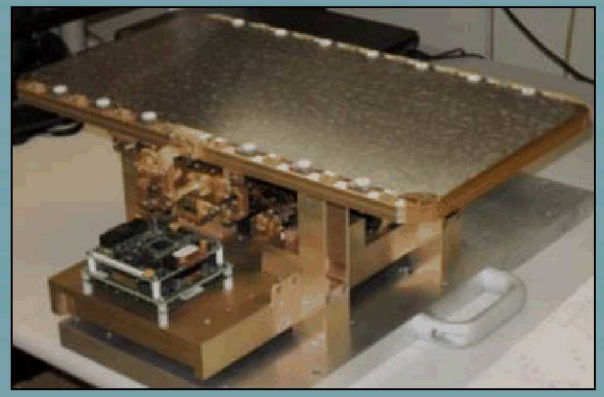
FARAD works in accord with R&D efforts, both internal and external, to provide advanced radar airborne data collection and exploitation assets to facilitate specific research goals

FARAD provides a "testbed laboratory"/research tool set that can be widely utilized in support of internal R&D, new program development, and collection of customer requested data products.

DeHavilland DHC-6 "Twin Otter" research aircraft operated for Sandia by Twin Otter International

FARAD SAR R&D Test-bed

- PhoeniX
  - X-band
  - Fully Polarmetric
- Ku-Band
  - Quad-phase center planar antenna
- Ka-Band
  - Dual-phase center planar antenna



Commercial Pentek 6001 QuartzXM eXpress Module

Unique QuartzXM eXpress Module enables deployment in custom form factors

Supports Xilinx Zynq UltraScale+ RFSoC FPGAs

Quad-core Arm® Cortex®-A53 MPCore up to 1.33GHz

Dual-core Arm Cortex-R5 MPCore up to 533MHz

8 * 12-bit ADCs at 4.096 GSPS

8 * 14-bit DACs at 6.554 GSPS

256KB On-Chip Memory w/ECC; External DDR4; DDR3; DDR3L; LPDDR4; LPDDR3; External Quad-SPI; NAND; eMMC

4 PS-GTR; PCIe Gen1/2; Serial ATA 3.1; DisplayPort 1.2a; USB 3.0; SGMII

214 PS I/O; UART; CAN; USB 2.0; I2C; SPI; 32b GPIO; Real Time Clock; Watchdog Timers; Triple Timer Counters

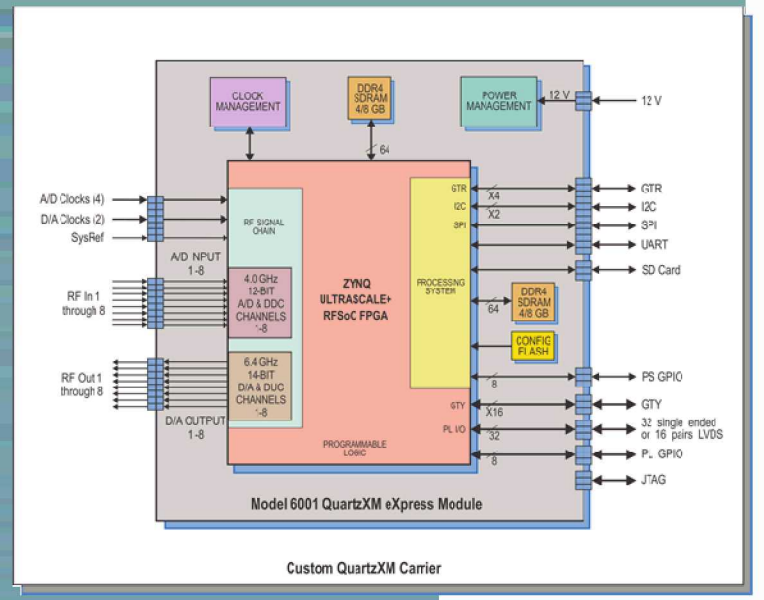
16 GB of DDR4 SDRAM

LVDS connections to the Zynq UltraScale+ FPGA for custom I/O

GTY connections for gigabit serial communication

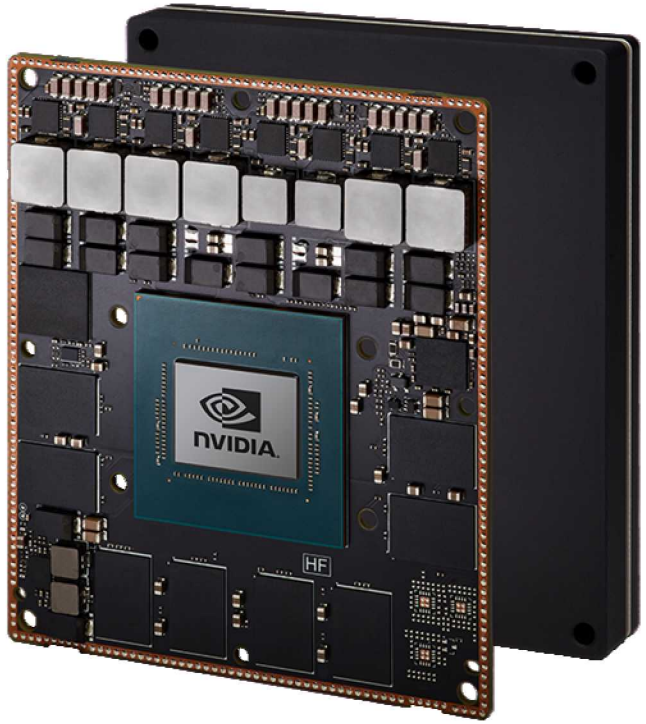
Ruggedized and conduction-cooled versions available

** https://www.pentek.com/products/detail.cfm?model=6001



40 Commercial Jetson AGX Xavier Mobile GPU

Technical Specifications	
GPU	NVIDIA Volta™ architecture with 384 NVIDIA CUDA cores and 48 Tensor cores 5.5 TFLOPS (FP16) 11.1 TOPS (INT8)
DL Accelerator	4.1 TFLOPS (FP16) 8.2 TOPS (INT8)
CPU	6-core Carmel ARM v8.2 64-bit CPU, 8MB L2 + 4MB L3
Memory	8GB 256-bit LPDDR4x - 1333 MHz - 85.3 GB/s
Display	Three multi-mode DP 1.2a/e DP 1.4/HDMI 2.0 a/b
Storage	32GB eMMC 5.1
Vision Accelerator	7-Way VLIW Vision Processor
Video Encode	2x464 MP/sec 2x 4K @ 30 (HEVC) 6x 1080p @ 60 (HEVC) 14x 1080p @ 30 (HEVC)
Video Decode	2x690 MP/sec 2x 4K @ 60 (HEVC) 4x 4K @ 30 (HEVC) 12x 1080p @ 60 (HEVC) 24x 1080p @ 30 (HEVC) 16x 1080p @ 30 (H.264)



** https://www.nvidia.com/en-us/autonomous-machines/embedded-systems/jetson-agx-xavier/

Development System

Built a 3U VPX development chassis to evaluate and develop SW/FW for the commercial Pentek and NVIDIA boards