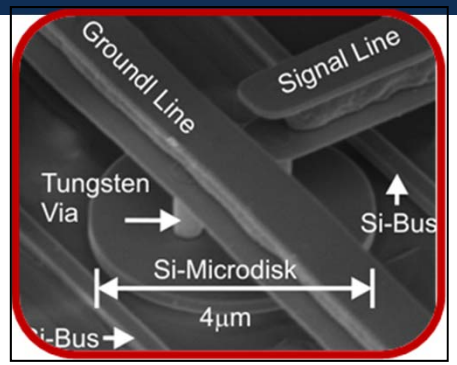
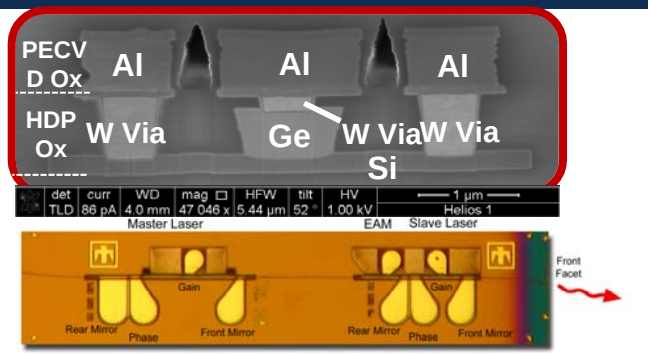
SAND2014-19920C

Exceptional service in the national interest

Sandia National Laboratories





Sandia National Laboratories and the Integrated Photonics Innovative Manufacturing Institute (IP-IMI)

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U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2011-0439P

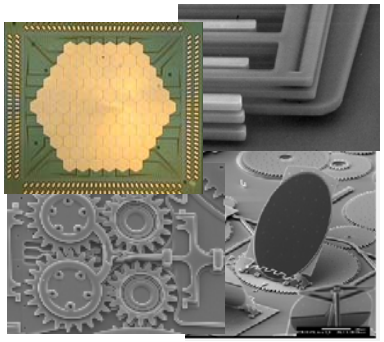
Why Sandia and the IP-IMI?

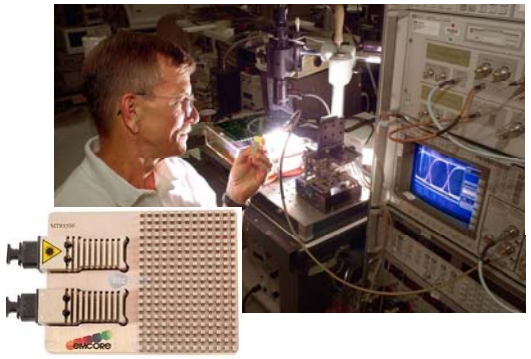
Sandia National Laboratories

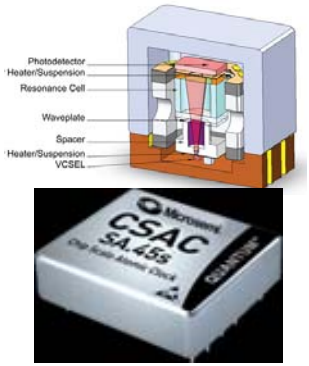
- **Expertise**: >20 years in III-V & Silicon Photonics R&D:
  - Toolboxes for internal and contract R&D
- **Capability**: Large flexible Si & III-V R&D Fab, Production rigor:
  - 65kft^2 fab, 10 epi reactors, >60 photonics staff, (60% Ph.D.)
  - Here today, here tomorrow…(NW IC deliveries)
  - Secure environment & staff, robust info-control (TRUST)
- **History of Technology Transfer to Industry**:

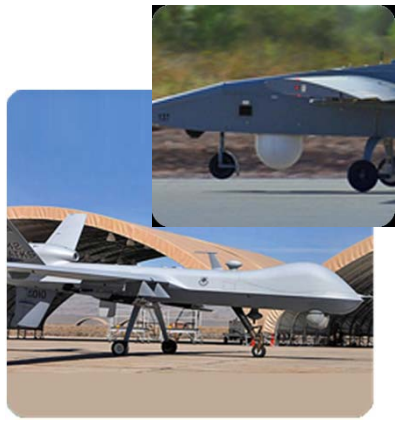
Processes → Devices → Subassemblies → Systems

MEMS (Fairchild)	**VCSEL/POM (EMCORE)**	**CSAC (Symetricon)**	**SAR (General Atomics)**
Transfer of Sandia's Summit IV™ MEMS technology. Network Photonics Optical MEMS	VCSEL/PD arrays Parallel Fiber Optic Module prototype development	Narrow λ temp-stable VCSEL for Chip-scale Atomic Clock (DARPA)	Copperhead & Lynx SAR (w/ GA Aero) on TigerShark & Predator UAVs (IED detector being transferred to Army)



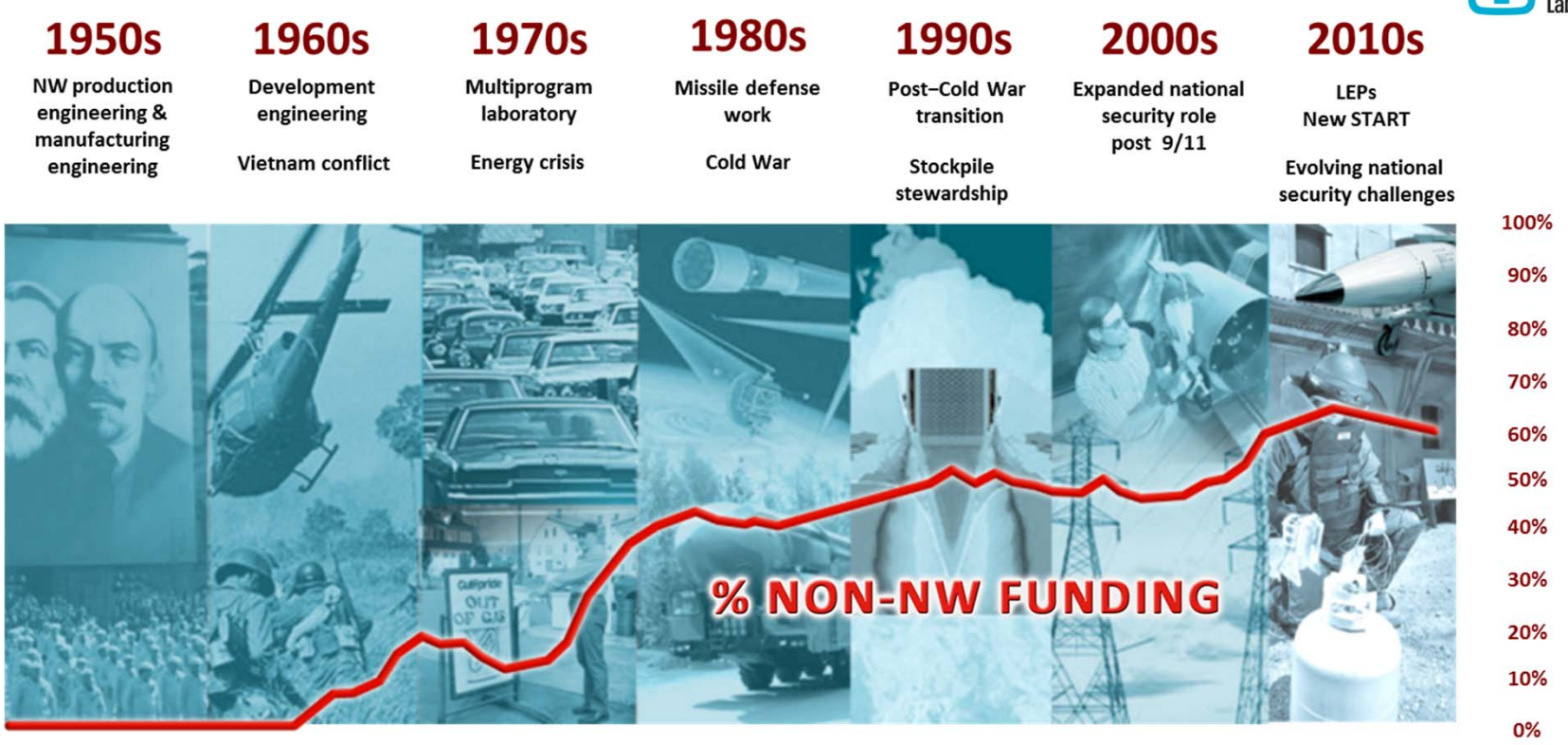






What is Sandia National Lab?

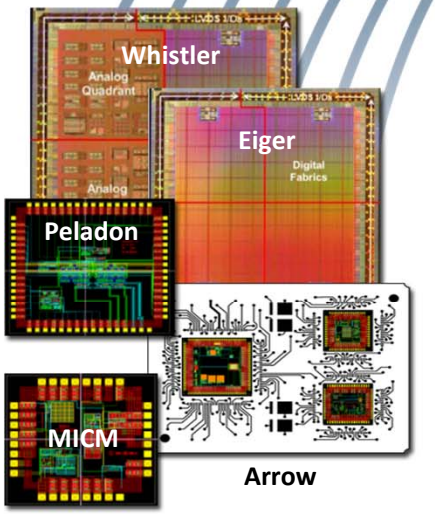
Sandia National Laboratories

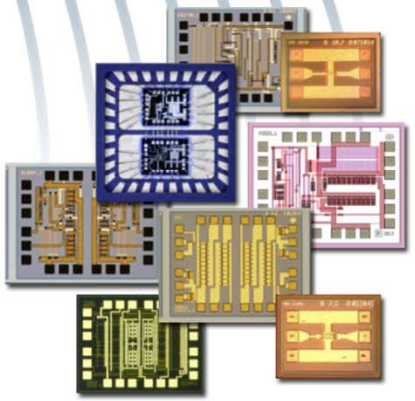


- DOE FFRDC: Initially Z-division of Manhattan Project (Non-nuclear Components, Weaponization of NEP)
- **National security tech transition**: Gov't Agencies (&/or Academia) ➔ SNL ➔ Industry
- Our Big 3: Non-compete with Industry, Fairness of Opportunity, No Organizational Conflict of Interest
- Managed by LMC, but see OCI above
- **CRADAs with many Defense Contractors, Many STTRs & SBIRs, BAA response teaming**
- **Experience handling sensitive & proprietary information**
- DOE supports our "Strategic Partnership Projects" (with Industry & other gov't agencies (OGAs))

MESA manufactures strategic radiation-hardened trusted components for Nuclear Weapons

Sandia National Laboratories





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

Radiation Hardened HBTs
- **>150,000 deliveries**

TRUST environment (NW, DMEA)

Strong Failure Analysis/Reliability

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

Sandia National Laboratories

- 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

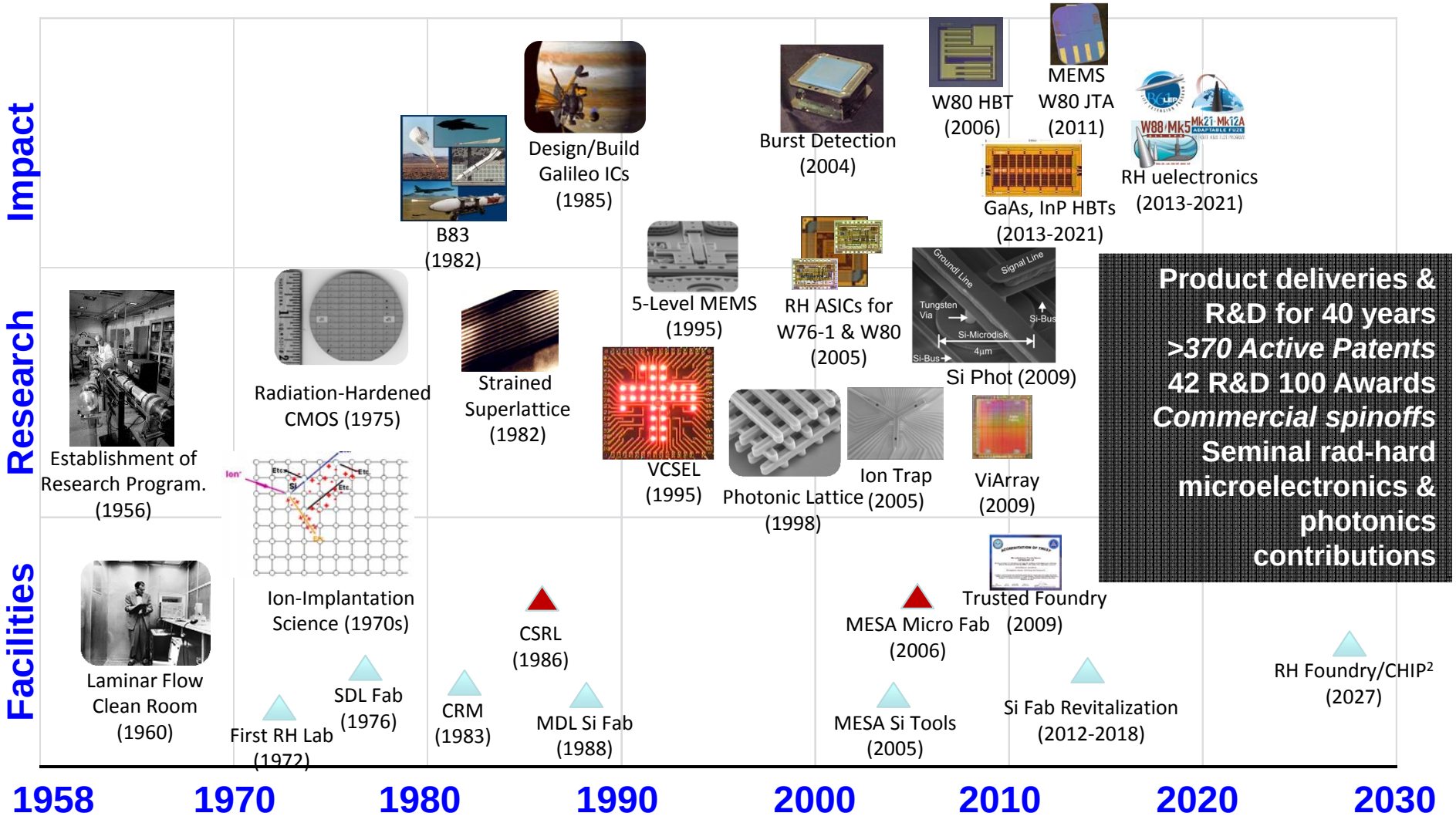
- Advanced Computation
- Modeling & Simulation
- COTS Qualification
- Advanced Packaging
- Custom Electronic Components
- System Design & Test

- 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

MESA is an FFRDC-based development and production facility for any microsystem component or technology that cannot or should not be obtained commercially.

R&D enables and sustains Sandia's Radiation-Hardened Microelectronics/Microsystems Capability

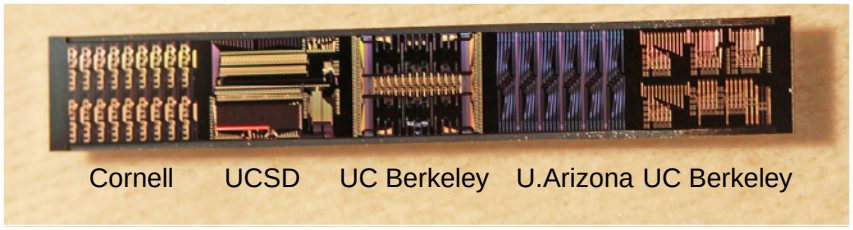
Sandia National Laboratories

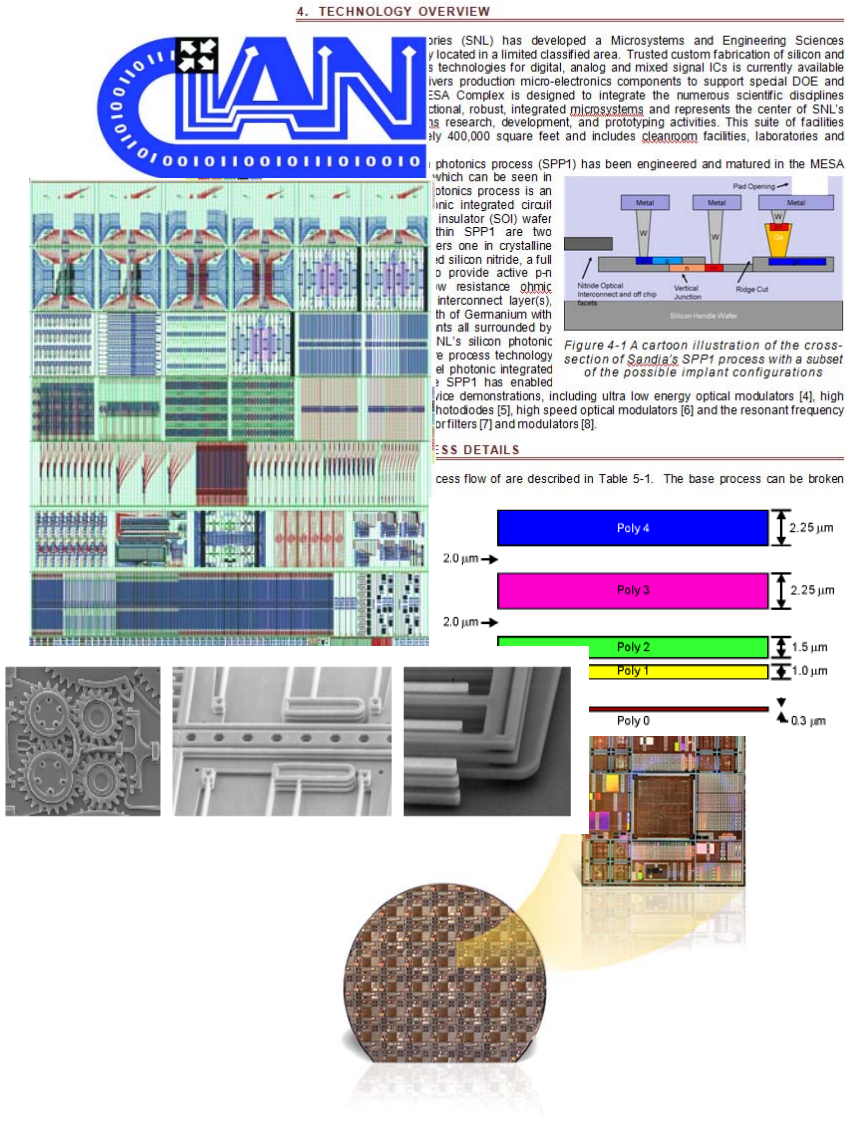


MISSION: Invent and mature integrated circuit and microsystems technologies that provide differentiation and impact for NW and other national security missions

Sandia and MPW Fabrication

- **SUMMIT V: 5 layer polysilicon MEMS process**
  - Developed design manual, DRC, many MPWs over the last decade
- **CMOS7 Electronics:** Rad-hard, mixed-signal ASIC/ViaArray: 0.35um, 3.3V core, 3.3V I/O, Cadence, MPWs since 2009
- **SPP1 Silicon Photonics Process:**
  - 250nm Si/3000nm BOx
  - fJ/bit mods, 45 GHz dets, filters, etc.
  - SiN 2-layer guides/xovers
  - Design manual, initial DRC, pilot MPW runs

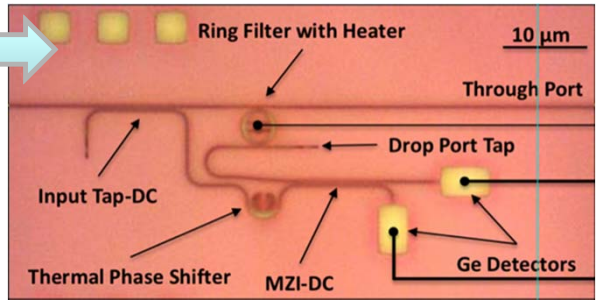


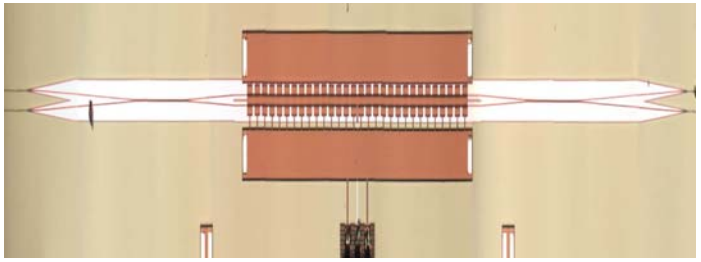


Trusted Advanced Pathfinder Products: Si Photonics

Sandia National Laboratories

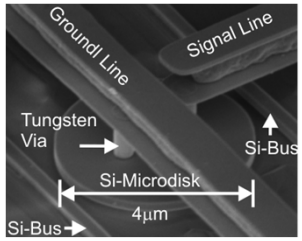
2014	*balanced homodyne resonant wavelength stabilization > 55C*
2013	*Si Photonics MPW (CIAN NSF ERC)*
2012	*24 GHz Si TW MZM*
2011	*45 GHz Ge Detector*
2010	*3 fJ/bit resonator modulator, 1V-cm MZM*
2009	*wavelength tunable rings over 35 nm*
2008	*2.4 ns Wavelength selective switch*
2007	*MicroDisk resonator infrared detector*
2005	*Si_3N_4 low-loss waveguides*
2000	*SiON / SiO2 (Clarendon Photonics)*
1990s	*Si PhC & Optical MEMS*



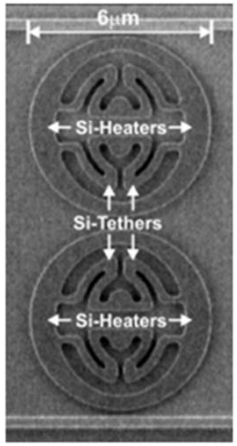


24 GHz 0.7V-cm Travelling Wave MZI Modulator

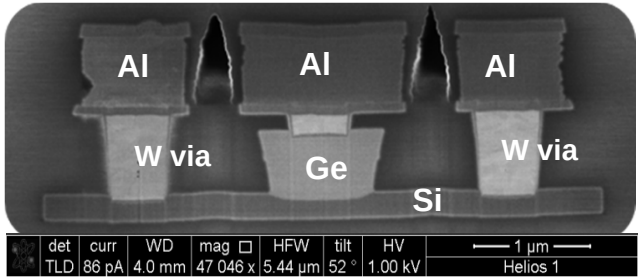
3.2fJ/bit at 12Gb/s



Resonant Optical Modulator/Filter

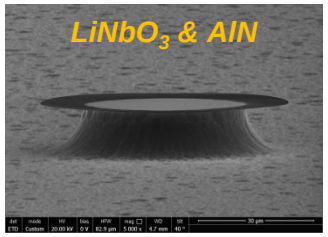


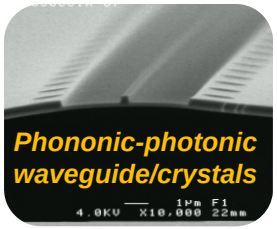
Tunable Resonant Filter



45 GHz High-speed Ge Detector on Si

MEMS process for additional capability

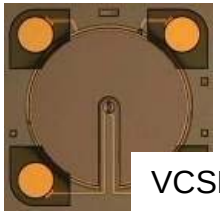




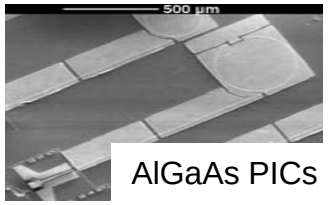
Trusted Advanced Pathfinder Products: III-V Photonics

2010s

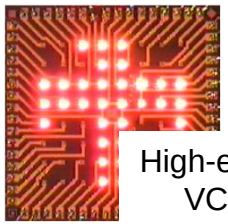
InGaAsP PICs



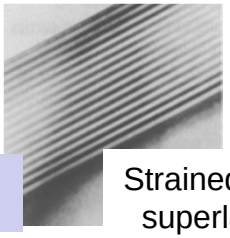
VCSEL+ PD



AlGaAs PICs



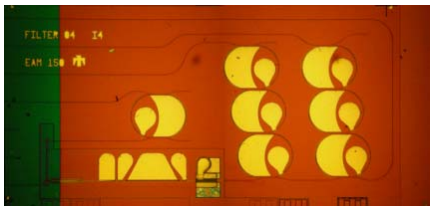
High-efficiency VCSELs



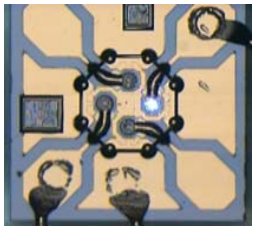
Strained-layer superlatices

1980s

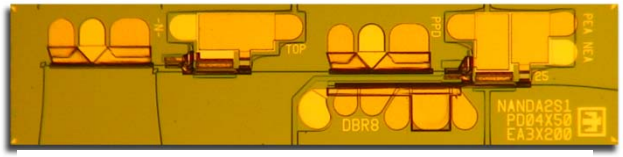
On-Chip Injection Locking
Enhanced Modulation > 50 GHz, C-Band



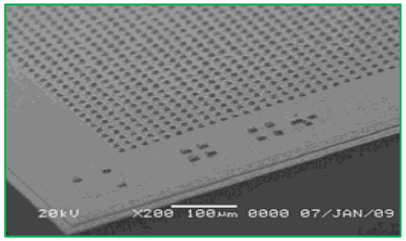
RF-Optical Channelizing Filter
1-20 GHz RF on C-Band Light



Single-Frequency Tunable VCSELs,
For atomic spectroscopy and sensors



All-Optical Logic at >40 Gb/s, C-Band



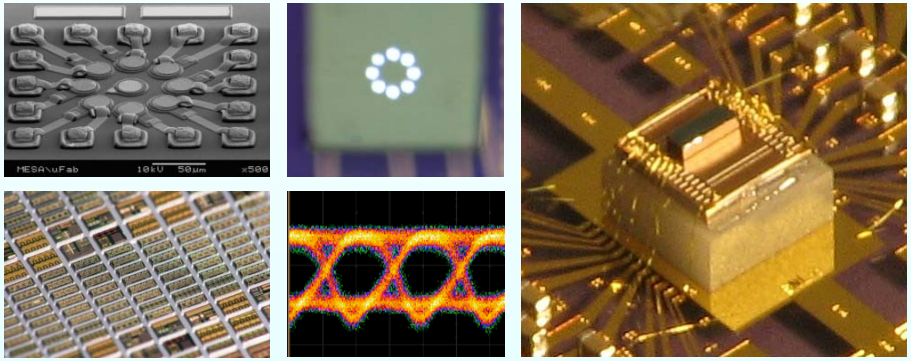
nBn FPAs in the SWIR, MWIR and LWIR,
leveraging novel III-P and III-Sb materials

- Foundational Capabilities
  - III-V compound semiconductor epitaxy, microfabrication, integration
  - Device physics, modeling, simulation
  - Microelectronics/optoelectronics, and complex mono/hetero-circuits
- Prove, Advance Technology Readiness Level, Productize
  - TRL1-6+: create, develop, prototype
  - NNSA QMS/QC-1-10; trusted
- Trusted, low-volume, high-reliability products for harsh environments

Trusted Advanced Pathfinder Products: Heterogeneous Integration

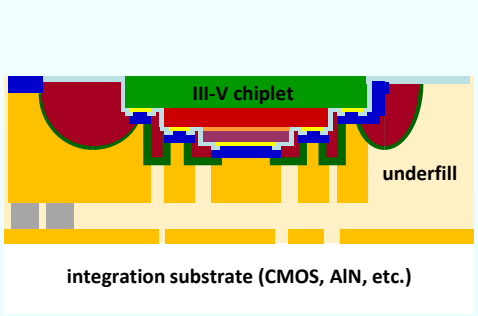
Sandia National Laboratories

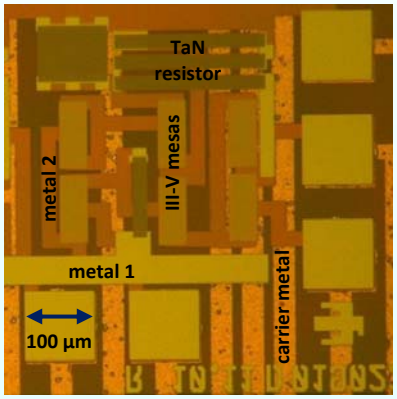
Optical Data Communications



- GaAs- and InP-based VCSELs, modulators, photodiodes
- dense integration onto 32-nm and 45-nm CMOS

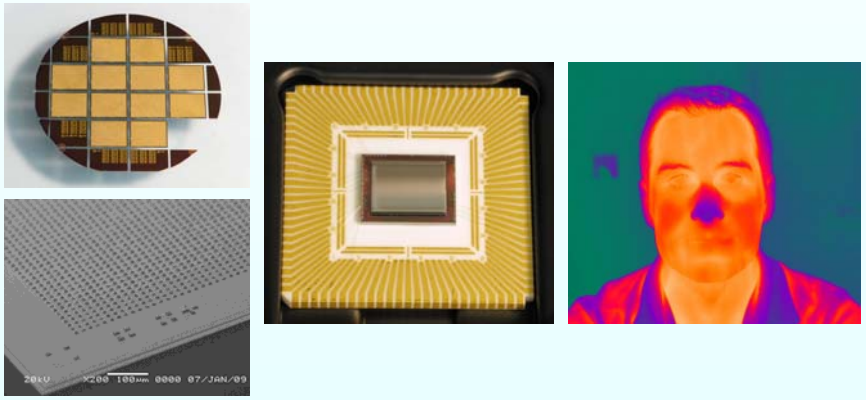
Heterogeneous III-V/CMOS Microelectronics





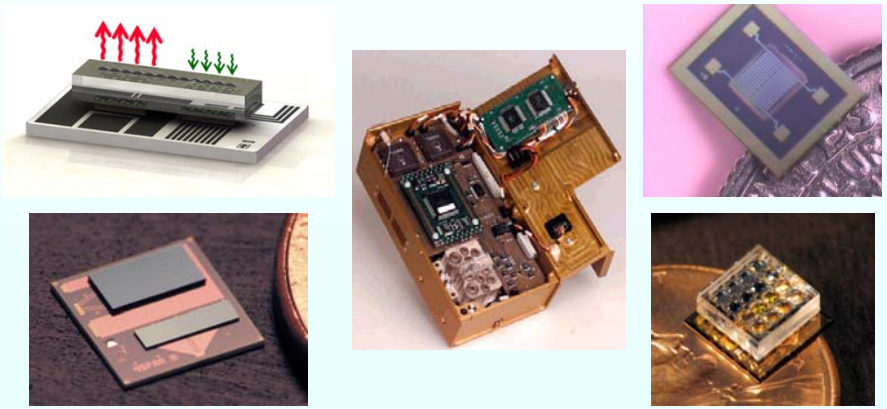
- complementary integration of GaAs and InP microelectronics
- III-V microelectronics circuitry on CMOS ASICs

IR Imagers for Remote Sensing



- nBn InAs/GaSb MWIR/LWIR detector arrays for large-format FPAs
- 10µm indium bump bonding, underfill, thinning, AR coating
- hybridization to silicon ROICs with >99.99% interconnect yield

Optical and MEMS-based Microsensors

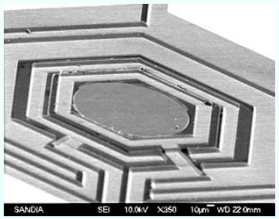
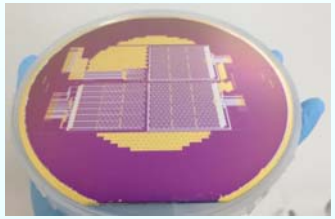
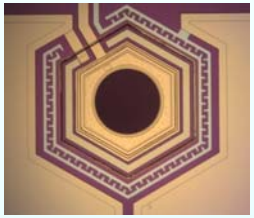


- chemical and bio sensors using MEMS and SAW devices
- g-hard optical microsensors with in-house photonics
- hybrid device integration with custom micro-optics

Trusted Advanced Pathfinder Product: Heterogeneous Integration

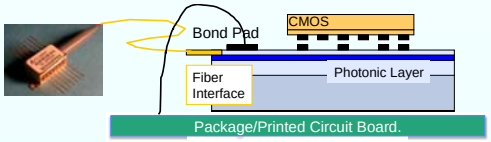
Sandia National Laboratories

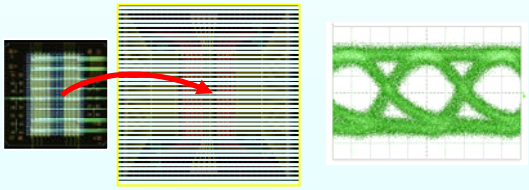
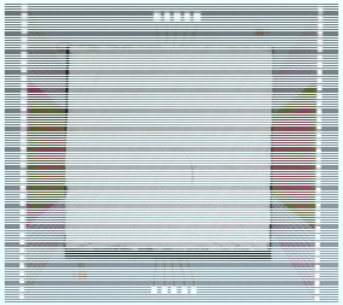
Microsystem-Enabled Photovoltaics

- wafer-level bonding for multi-junction solar cells
- InGaAsP/InP and InGaP/GaAs devices on silicon
- dielectric interfaces with III-V substrate removal
- integration with collection optics

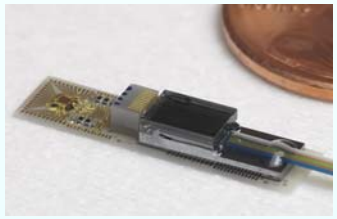
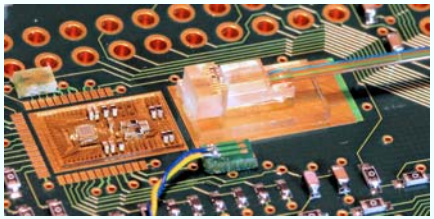
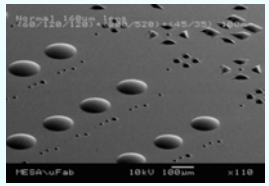
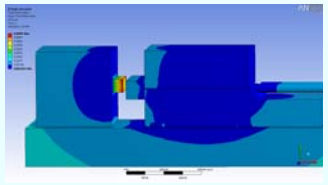
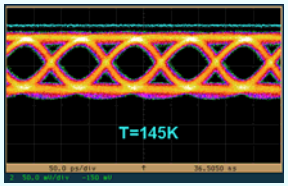
High Performance Computing



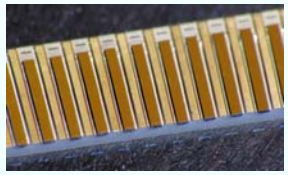
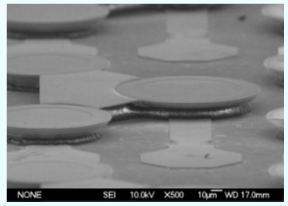
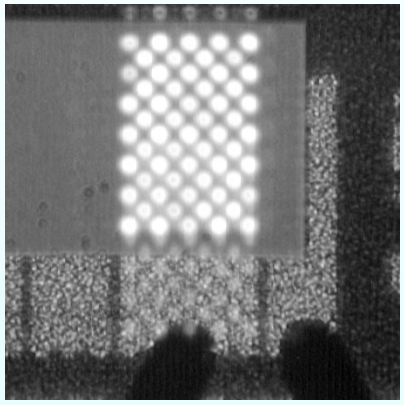
- silicon photonics on high-speed silicon ASIC
- independent optimization of electronics & photonics

Extreme Environment Applications

- custom photonics, optics, electronics for cryogenic interconnects
- advanced optoelectronics and integration for radiation hardness

High Performance Photonics

- high-power emitters on AlN and diamond
- RF packaging for high-speed test and measurement

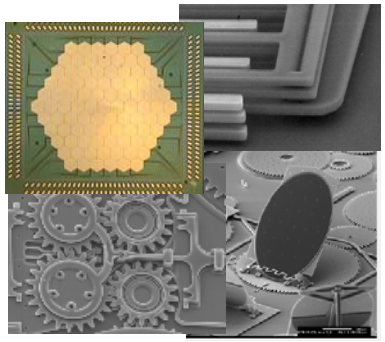
Why Sandia and the IP-IMI?

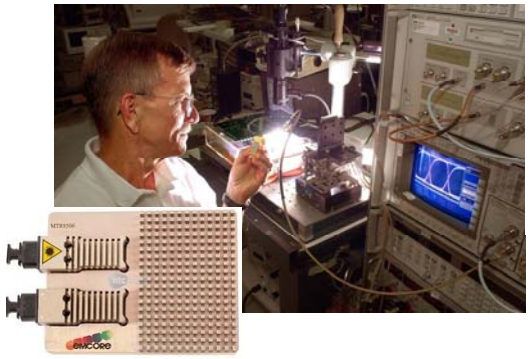
Sandia National Laboratories

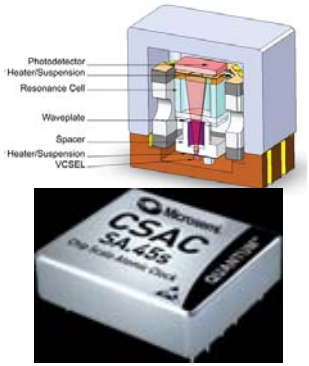
- **Expertise**: >20 years in III-V & Silicon Photonics R&D:
  - Toolboxes for internal and contract R&D
- **Capability**: Large flexible Si & III-V R&D Fab, Production rigor:
  - 65kft^2 fab, 10 epi reactors, >60 photonics staff, (60% Ph.D.)
  - Here today, here tomorrow…(NW IC deliveries)
  - Secure environment & staff, robust info-control (TRUST)
- **History of Technology Transfer to Industry**:

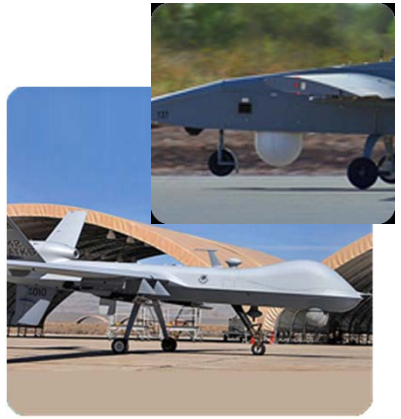
Processes → Devices → Subassemblies → Systems

MEMS (Fairchild)	**VCSEL/POM (EMCORE)**	**CSAC (Symetricon)**	**SAR (General Atomics)**
Transfer of Sandia's Summit IV™ MEMS technology. Network Photonics Optical MEMS	VCSEL/PD arrays Parallel Fiber Optic Module prototype development	Narrow λ temp-stable VCSEL for Chip-scale Atomic Clock (DARPA)	Copperhead & Lynx SAR (w/ GA Aero) on TigerShark & Predator UAVs (IED detector being transferred to Army)









Partnerships in Photonics

Sandia National Laboratories

Industry Partners

University Partners

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Sandia National Laboratories

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