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Exceptional service in the national interest

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

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UNCLASSIFIED UNLIMITED RELEASE
Why Sandia and the IP-IMI?

- **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**:

<table>
<thead>
<tr>
<th>Processes</th>
<th>Devices</th>
<th>Subassemblies</th>
<th>Systems</th>
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<tbody>
<tr>
<td>MEMS (Fairchild)</td>
<td>VCSEL CSAC (Microsemi)</td>
<td>POM (EMCORE)</td>
<td>SAR (General Atomics)</td>
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<tr>
<td>Transfer of Sandia’s Summit IV™ MEMS technology. Network Photonics Optical MEMS</td>
<td>Narrow λ temp-stable VCSEL for Chip-scale Atomic Clock (DARPA)</td>
<td>OC-192 Transponder Parallel Fiber Optic Module prototype development using VCSEL &amp; PD arrays</td>
<td>Copperhead &amp; Lynx SAR (w/ GA Aero) on TigerShark &amp; Predator UAVs (IED detector being transferred to Army)</td>
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What is Sandia National Lab?

- 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
- DOE supports our “Strategic Partnership Projects” (with Industry & other gov’t agencies (OGAs))
- 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
Microsystems and Engineering Sciences Applications (MESA): 400,000 Sq-ft Complex with >650 Employees in Secure Facility

**Si**

**III-V**

- Compound Semiconductor
  - 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
    - Rad-Hard μElectronics
    - Rad-hard Optical Links
    - Solid-State RF Devices
    - GaN Power Electronics

- Materials Research
  - 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

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

**MESA** is an FFRDC-based development and production facility for any microsystem component or technology that cannot or should not be obtained commercially.
MESA manufactures strategic radiation-hardened trusted components for Nuclear Weapons

TRUST environment (NW, DMEA)
R&D enables and sustains Sandia’s Radiation-Hardened Microelectronics/Microsystems Capability

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Research</th>
<th>Impact</th>
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<tr>
<td>MESA Si Tools (2005)</td>
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<td>Si Fab Revitalization (2012-2018)</td>
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<td>Trusted Foundry (2009)</td>
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<td>RH Foundry/CHIP² (2027)</td>
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Product deliveries & R&D for 40 years
>370 Active Patents
42 R&D 100 Awards
Commercial spinoffs
Seminal rad-hard microelectronics & photonics contributions

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

- 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$_3$N$_4$ low-loss waveguides
- 2000: SiON / SiO2 (Clarendon Photonics)
- 1990s: Si PhC & Optical MEMS

MEMS process for additional capability

LiNbO$_3$ & AlN

Phononic-photonic waveguide/crystals

Suspended SiSiN resonators

24 GHz 0.7V-cm Travelling Wave MZI Modulator

45 GHz High-speed Ge Detector on Si
Trusted Advanced Pathfinder Products: III-V Photonics

### 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

Optical Data Communications

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

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

Heterogeneous III-V/CMOS Microelectronics

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

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
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
Potential Roles and Engagement within The IP-IMI

- **Trusted Tech Transition:** ITAR, sensitive projects
- **Novel Materials, Devices, or process integration:**
  - Items outside primary scope of Institute?
- **Extra Fab/MPW and Test capacity**
  - Unique failure analysis and reliability tools also available

**Engagement**

- DOE supporting National Lab involvement in strategy and project development for ALL teams.
- We are available for:
  - Telecons & briefings at team meetings
  - Hosting visits to Sandia

*Very strong teams have formed: What gaps can we help fill?*

http://www.sandia.gov/mstc/IPIMI