Great Lakes Symposium on VLSI

Keynote

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Future Defense Systems
Advanced Microelectronics Needs

System of Systems

Cyber and Social

Human and Robot Collaboration

Cyber and Social

Big Data and AI Systems
- Artificial Intelligence (AI) and Graph Processors
  - 100B-1T node graphs
  - Need 1000x performance and efficiency for real-time

Decentralized Systems
- Open and Distributed Architecture & Processing
  - Local processing raw data
  - Rapid tech. insertion & upgrades using SotA

Human and Robot Systems
- Vision, Semantic and Navigation Processing
  - High performance imagers & local processing circuits
  - Robust Navigation & local semantic processing

Diverse Protected Links
- Frequency and Antenna Diversity Signal Proc.
  - Multi-antenna & frequencies
  - Adaptive processing (Trillion Ops/sec/watt) for robust comm. & radar systems

Global Tech and Infrastructure
- Leverage & Assure Access to the best Technology
  - Use best global tech where it exists
  - Assure domestic sources for state-of-art

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Artificial Intelligence (AI) and Graph Processors
- 100B-1T node graphs
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## Current Global Microelectronics Leadership

### U.S. Ecosystem
- Strong domestic fabless semiconductor industry
  - Apple, Qualcomm, others dominate profits
  - Hardware startups falling behind foreigners
- Integrated Device Manufacturers at risk
- R&D from top universities migrates to Europe & Asia

### Asia
- Significant increase in # of fabless firms
  - 3,000 new in 2017
- Multiple Joint Ventures and acquisitions
- Investments of $150B+ in advanced microelectronics and $60B+ in STEM and universities
- TSMC offers $200M a year in free silicon to universities

## Possible Future Global Microelectronics Leadership

### U.S. Ecosystem
- Strong global fabless semiconductor industry
  - U.S. companies invest in Asian production
- Integrated Device Manufacturers diversify
- Overproduction globally forces domestic fabrication closure
- Best R&D from Asia

### Asia
- Leading world-class microelectronics design and production capability
  - 7 new (≤14nm) foundries
- Trade policies:
  - Increase domestic market share
  - Acquisitions and startups funded by government
Past and Current Analogous Situations

Japan
- Trade and industrial actions in ‘70s & ’80s to increase semiconductor market share
  - Largely successful, U.S. lost significant market share and fab capacity.

U.S. Government Response
- VHISC ($918M) was DoD program to develop two new generations of IC tech
- MIMIC ($570M) was DoD program to accelerate GaAs technology

Taiwan
- Created ITRI in ‘70s, a government funded R&D Institute. Spun off multiple companies, including TSMC
- Today, 4th in global market share
- TSMC is world’s largest pure-play foundry

US Gov. & Industry Response
- SEMATECH ($870M + industry match) partnership of 14 U.S. companies
  - Transitioned from government to private funding only and international partners joined

China
- In 2015, stated plan to reach “advanced world-level in all major semiconductor industry segments by 2030.”
  - Subsidies: ($150B over 10 years), direct funding by state-owned companies, & foreign company and IP purchase
  - Zero-sum trade policies
- Current status:
  - Foundries now 2-3 generations behind
  - Seven (7) state-of-the-art fabrication starts planned
  - No domestically owned memory, but major memory investments
  - Significant increase in # of fabless firms

Technology slow down due to scaling physical limitations could result in leadership transition
Electronics as a Strategic Issue

DoD Assured Electronics Issue

COTS Electronics Assurance (DoD & Beyond)

Larger Strategic Issue

Tactical Issue

Assured access to domestic semiconductors (CMOS, analog, compound semiconductor, memory, design tools, intellectual property, manufacturing tools, processors and applications) to ensure national security & economic competitiveness

FY03-16
Trusted Foundry Program

FY 17-23:
Trusted & Assured Micro-electronics

FY 19-23 and beyond:
DoD Micro-electronics Innovation for National Security (MINSEC)
Elements of a Strategy for Ensuring Access to Assured Microelectronics

- **Revised trust and assurance policy** to address state-of-the-art (SOTA) technology applications, use of commercial parts in DoD systems, and full life cycle vulnerability protection, beginning with secure design and protection of intellectual property (IP)

- **Healthy microelectronics verification and validation (V&V) capability**

- **Access to DoD/Government-unique needs**, radiation-hardened by process and radiation-hardened by design technologies, in support of space and nuclear modernization, including Diminishing Manufacturing Sources and Material Shortages (DMSMS) foundry-of-last-resort capability

- **Adequate workforce expertise** and engagement with academia, Defense Industrial Base (DIB), and DoD user communities in prototyping, and development activities to build a domestic knowledge base for design and manufacturing of advanced microelectronics

- **Research and Development (R&D) investment** to lead development of the next generation microelectronics and protect domestic leadership

- **Modernization** to deliver modern application-specific integrated circuits (ASICs) and systems-on-chips (SOCs), **reduced reliance on legacy parts** and replace obsolete systems, and enactment of acquisition policies that promote rapid modernization, standards and best practices to facilitate V&V, supply chain risk assessment, and counterfeit detection

- **Availability, Access and Assurance** at multiple domestic State-of-the-Art (SOTA) Foundries and business models to sustain growth and commercial competitiveness
DoD Strategy and Actions

Policy
- Program Protection Plan (PPP), 5200.44, ITAR, DPA Title III updates
- Strategy/Directive for Assured Microelectronics
- National Security Strategy priority

DMEA
- Maintain and expand the number of trusted suppliers
- Provide access to state-of-the-art trusted flow (TAPO)
- Support sensitive needs and operations

Trusted & Assured Microelectronics
- Assured Access to state-of-the-art foundries through modern trust and assurance methods and demonstration
- Industrial standards for assurance
- Joint Federated Assurance Center Enhancement

DoD MINSEC
- Next generation R&D DARPA (ERI) captured in US
- Modernization & assurance for DoD & nation through Innovation ecosystems
- Radiation hardened micro-electronics for nuclear and space

Domestic Foundry & Packaging
- Multiple competitive State of the Art Foundries on shore
- Leadership in R&D and production
- Strong commercial business models
- Government business model for innovation & assurance
• DoD Trusted Foundry Program management has been consolidated at Defense Microelectronics Activity (DMEA) to include the TAPO
  – Offers a range of processes from CMOS (>28nm), NVRAM CMOS, Mixed Signal CMOS, Rad-Hard CMOS, RF CMOS, SOI CMOS and an assortment of compound semiconductor processes
    o Working on access and accreditation for 14nm CMOS at GlobalFoundries
  – Trusted Suppliers offer microelectronics design, fabrication and packaging services from 75 sources

TAPO Process Offerings

Trusted Suppliers (75)
T&AM
Domains & Technical Challenges

Availability
- Assured and expanded supply chain for specialized microelectronics for DoD systems
- Increased assurance and expanded supply options for Legacy parts

Access
- Lower barriers to safely access and develop advanced semiconductor-based systems to address new threats
- Robust design & validation tool access

Assurance
- Leverage an assured global supply and partners in U.S. semiconductor industry
- Competitive advantage for new markets through enhanced assurance practices

ASIC
- Dense Digital CMOS
- RF & Mixed Signal
- Compound Semiconductors

FPGA
- Commercial SoC w/FGPA
- Rad-hardened
- Low-power

COTS
- Microcontrollers
- Analog components
- PCB assemblies

Assurance Tools

Assurance Level
Base Assurance for all DoD

% Programs supported
Systems Engineering Approach

Threats

Program development and capabilities
PPP/ CPI
Design
Verify
Mask
Fabrication
Pack. and test
Verify and validate
Config. prog. SW
Integrate and test
Operation and maint.

Mitigations

PPP
System Security Architecture
Assured Design
Trusted Mask

Mitigation

Efficacy

JFAC & Industry

Impact

Innovators and Developers
System architects
R&D engineers
Acquisition experts
Manufacturing experts

Adopters & Improvers
System Integrators
Test and validation Operators and Maintainers
Joint Federated Assurance Center (JFAC)

• Federation of DoD software and hardware assurance (SwA/HwA) capabilities and capacities
  – Support programs in addressing current and emerging threats and vulnerabilities
  – Facilitate collaboration across the Department and throughout the lifecycle of acquisition programs
  – Maximize use of available resources
  – Assess and recommend capability and capacity gaps to resource

• Innovation of SW and HW inspection, detection, analysis, risk assessment, and remediation tools and techniques to mitigate risk of malicious insertion
  – R&D is key component of JFAC operations
  – Focus on improving tools, techniques, and procedures for SwA and HwA to support programs

• Federated Organizations
  – Army, Navy, Air Force, National Security Agency (NSA), Defense MicroElectronics Activity (DMEA), Defense Information Systems Agency (DISA), National Reconnaissance Office (NRO), and Missile Defense Agency (MDA) laboratories and engineering support organizations; Intelligence Community and Department of Energy

Portal: https://jfac.navy.mil

JFAC Mission is to support programs with SwA and HwA needs
T&AM New Trust and Assurance Approaches

Design for trust
- Designing techniques to limit full use/functionality to trusted operation

IP protection
- Preventing exploitation, including control of use, concealment, reconfiguring, partitioning, or employment

Low-volume/high-mix production
- Innovative methods to permit cost-effective, Trusted and assured low volume manufacturing of state-of-the-art ICs

Electronic component markers
- Tagging/marking ICs and subassemblies to authenticate and track supply chain movements

Imaging technologies and forensics
- Advanced capabilities to efficiently evaluate dense, state-of-the-art commercial components

Implement and demonstrate assurance capability with transition partners
1. Define the various levels of trust required by DoD systems
2. Identify means of classifying DoD systems based on the required level of trust for microelectronics within the system
3. Identify means by which trust in microelectronics can be assured
4. Identify a means to increase the supplier base for assured microelectronics to ensure multiple supply pathways
5. Provide an assessment of the microelectronics needs of the DoD in future years, including the need for trusted, radiation-hardened microelectronics
6. Provide an assessment of the microelectronics needs of the DoD that may not be fulfilled by entities outside the DoD
7. Identify the resources required to assure access to trusted microelectronics, including infrastructure workforce, and investments in science and technology
8. Develop a research and development strategy to ensure the DoD can, to the maximum extent practicable, use state of the art commercial microelectronics capabilities or their equivalent, while satisfying the needs for trust
9. Develop recommendations for changes in authorities, regulations, and practices, including acquisition policies, financial management, public-private partnership policies, or in any other relevant areas, that would support the achievement of goals of the strategy

(* DoD currently addressing 1-6, MINSEC funding will address 7, 8, & 9)
Microelectronics (ME) Assurance Process Flow

CONOPS
Capabilities
Needs

Analyses
Criticality
Threats
Vulnerabilities

Risk Assessment
Consequence
Likelihood

Assurance Required

Mitigations
Designer, Supplier

Manufacture

Systems of Systems
Systems Boards
Components

COTS, 8
Display Logic, 2.7
Interface, 30.3
Logic ASSPs, 2.8
Data Converters, 29.4
DSP, 6
Microprocessors, 0.261
Microcontrollers, 23.2
Analog ASSPs, 76.8
SRAM, 3.4
DRAM, 85.8
Flash, 33.2
Power, 167
Amplifiers and Comparators, 33.8

Quantities (M), Total 596M

IDA Data: Based on dataBeans 2017, quantities in millions
Microelectronics Assurance Paths
Microelectronics Assurance Paths
A Potential New Approach for Achieving ME Assurance

Current Approach

Cyber-Physical Approach

Sensors

Hashed Crypto Records

Keychain

Action

World

Policy

World Data
Microelectronics Innovation for National Security and Economic Competitiveness (MINSEC)

Strategic National Security Applications
- Secure IoT
- Financial & Data Analytics
- Autonomous Systems + AI
- Robust + Agile Communicators
- Commercial Space
- Biomedical

Strategic National Economic Competitiveness Applications
- Proactive Awareness & Security
  - Supply Chain track
  - Proactive Authorities
  - Intelligence & CI
  - Standards
- Access & Assurance
  - Secure Design
  - IP, EDA, experts
  - Foundry assured Access
  - Modernization & co-development
- Enhanced Manufacturing
  - SOTP Back-end parity with SOTA
  - SOTA on 200mm tools at SOTP
  - High-mix low vol. fabrication
- Incentives & Market Growth
  - Acquisition reform and incentives
  - Tax, policy, regulation reform
  - R&D and domestic fab incentives
- Strategic Alliances
  - Cooperative R&D
  - Trade and Foreign Military Sales (FMS)
  - Americas
  - Europe
  - Asia partners

Disruptive Research & Development
- Materials, Devices, Circuits
- Architectures
- Design Tools for Complexity
- Experts, Infrastructure, Venture Capital
- Innovation, Science & Technology, R&D
### DoD MINSEC Highlights

#### Develop the Next Generation Technology
DARPA Electronic Resurgence Initiative R&D Programs with matching from industry

#### Capture & Secure R&D in US Ecosystem
Secure design environments, foundry access and enhancement, security support

#### New Capability Development w/ Assurance & Insertion into DoD, dual use products (1000x COTS)
Assured COTS Programmable Co-Development

#### Modernization & Security
Obsolescence & Replacement

#### Workforce Development

#### Specialty Needs
Rad-Hard Microelectronics
Deliver future nuclear and space modernization

RF & Optical Technologies
Deliver unique RF and optical technologies for DoD systems

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### Results & Deliverables

**$2.2B FY19-23**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Devices</th>
<th>Design tools</th>
<th>Architectures</th>
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<tbody>
<tr>
<td>Secure design environments</td>
<td>Intelligence &amp; counter intelligence</td>
<td>Domestic enhanced R&amp;D fabs</td>
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<tr>
<th>Most Advanced Digital Imagers</th>
<th>EW Array SoC</th>
<th>Secure PNT SoC</th>
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<tbody>
<tr>
<td>Assured FPGA from 2 vendors</td>
<td>ML/AI SoC 2 Chips = 8 Peta FLOPS 400,000 FPS, 240W</td>
<td>10k X GPU</td>
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**Preserve access to legacy IP and processes**
Future obsolescence replacement of boards by SoCs

**100 STEM scholarships including microelectronics specialization**

- Domestic USG fab enhanced from 90nm AL to 65nm copper back-end process developed in partnership with NNSA
- Rad-hard by design developed for 1-2 SOTA foundry offerings with limited testing and qualification (strat-RH)
- Secure design and development of radio frequency and optoelectronic IP and test articles
- JFAC and NSA evaluation and qualification using SOTP and SOTA foundries
Create Microelectronics Innovation Throughout the United States
Teaming and Partnerships Are Key to Success

• **Many stakeholders are involved in the success of the long-term strategy:**
  
  – Leadership from OSD, Services, and Agencies
  
  – Performers including Services, DMEA, DARPA, IARPA and other S&T organizations and laboratories
  
  – Integration and support of functions of:
    
    o DoD Trusted Foundry Program
    
    o DMEA Trusted Supplier Accreditation Program
    
    o Joint Federated Assurance Center
    
    o Microelectronics Assurance S&T and transition activities
  
  – Building and leveraging partnerships with Defense and commercial industry and academia for National Security and Economic Competitiveness
  
  – Coordination with other U.S. Government agency partners

• **Overall Bottom Line – structuring activities to meet acquisition program needs for trust and access to state of the art microelectronics**
Defense Innovation Marketplace
http://www.defenseinnovationmarketplace.mil

DASD, Systems Engineering
http://www.acq.osd.mil/se