DARPA Next-Generation Microelectronics Manufacturing (NGMM)

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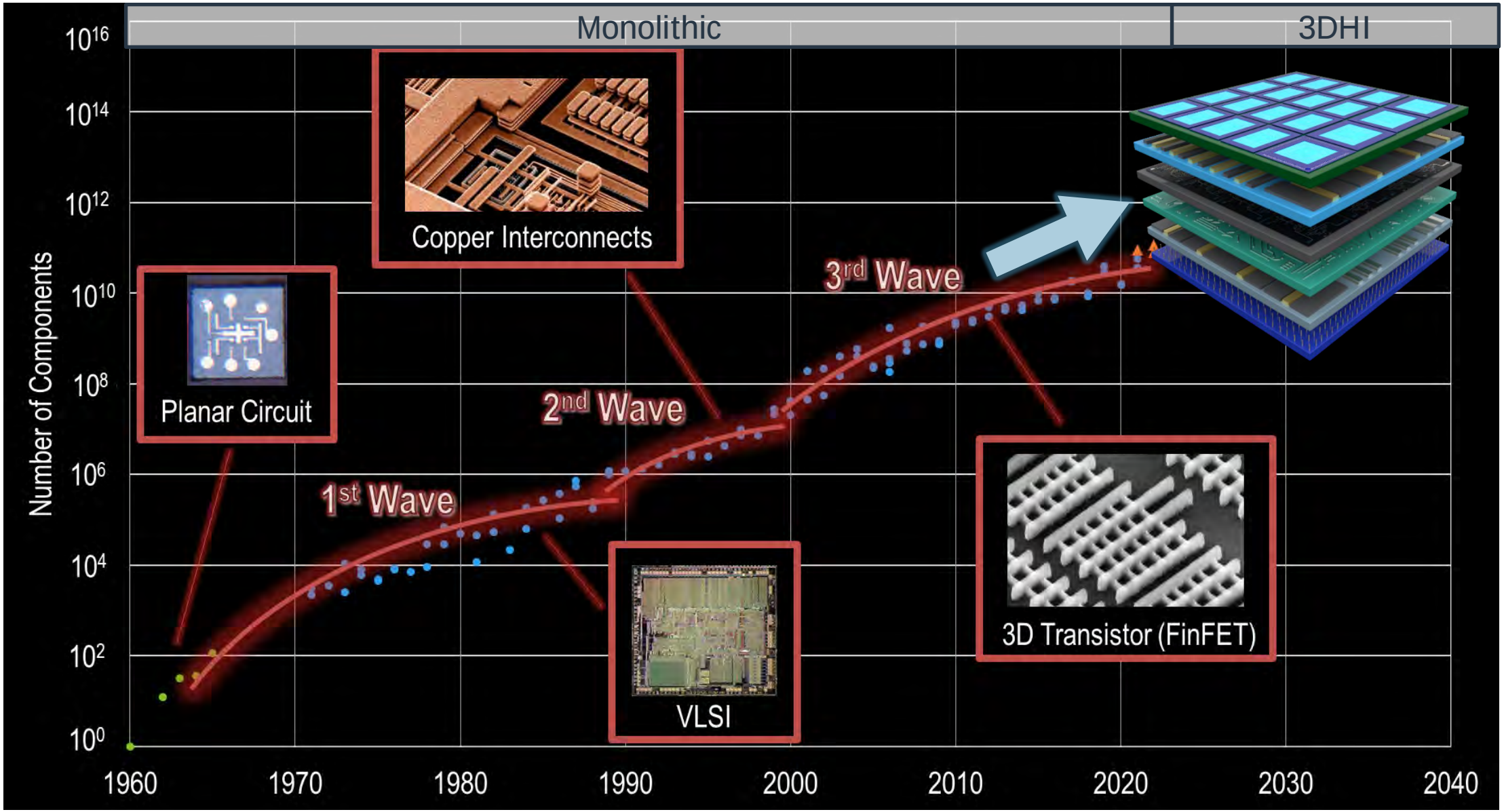
DARPA Microsystems Technology Office (MTO)

July 25, 2025

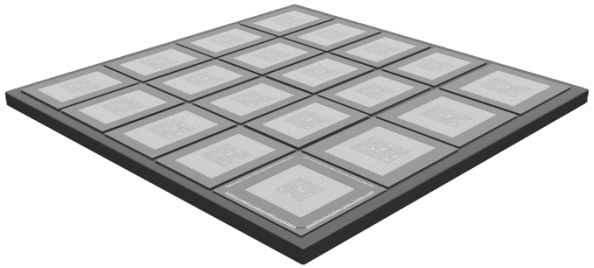

NEXT-GENERATION
MICROELECTRONICS
MANUFACTURING
NGMM

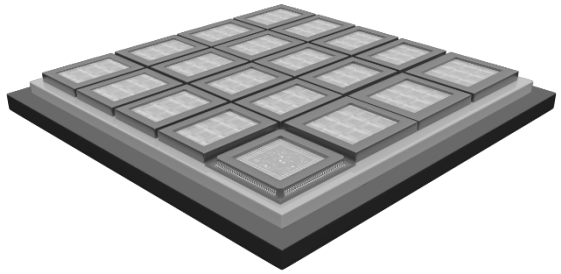
The Next Wave of Performance Enabled by **3D Heterogeneous Integration (3DHI)**

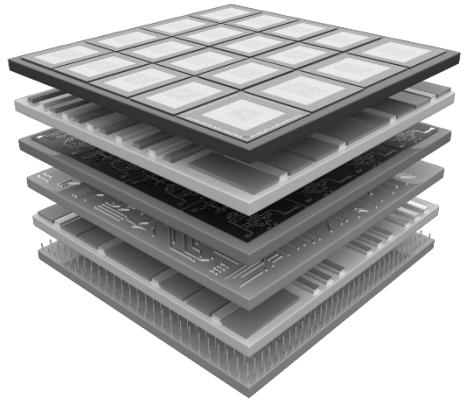


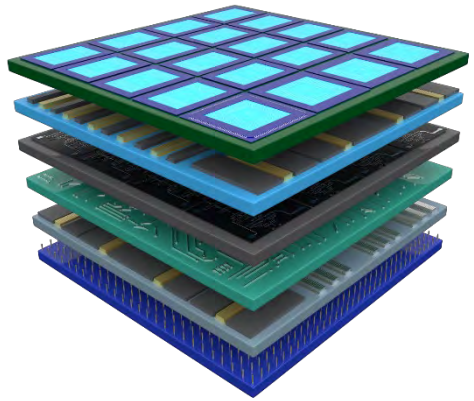
Levels of Integration

2D | 2.5D | 3D | 3DHI









DARPA NGMM

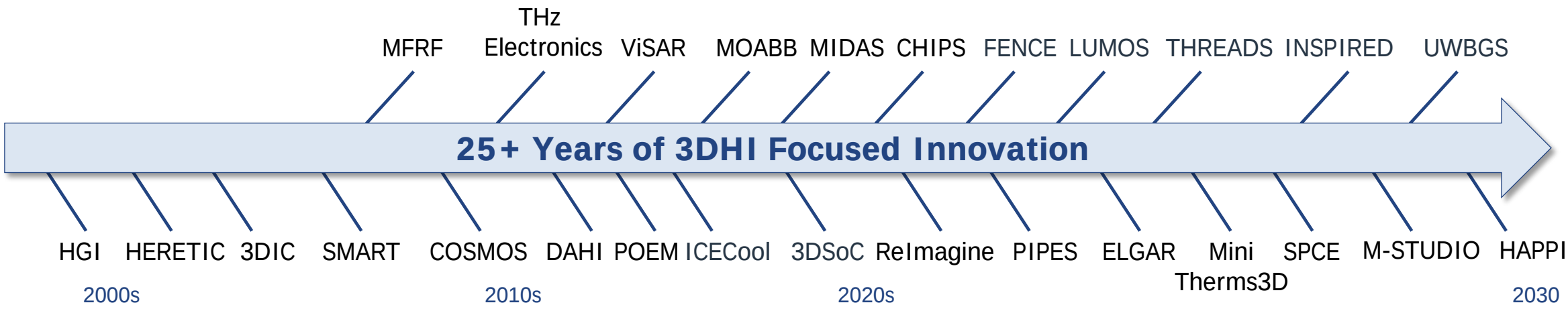
Silicon → Mixed Materials

Performance

1x | 3x | 30x | 100x

3DHI: Three-dimensional heterogeneous integration

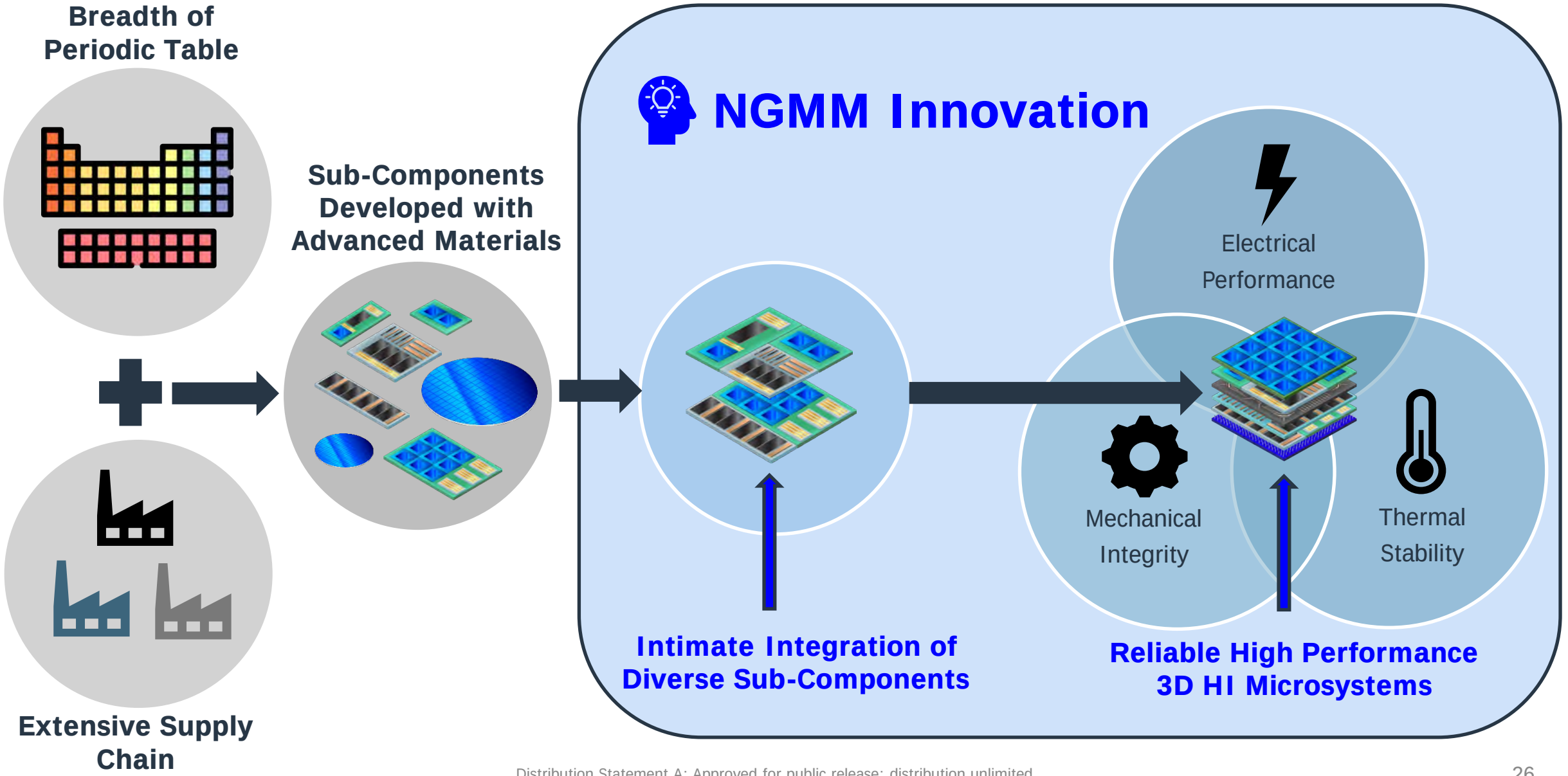
NGMM Is the Capstone of Many DARPA Efforts in 3DHI



- **Process Development Focus**
  - ✓ **Materials**
  - ✓ **Integration Technologies**
  - ✓ **Thermal Management & Analysis**
  - ✓ **High Speed Interconnects**

- **Product Development Focus**
  - ✓ **Arrays/Sensors**
  - ✓ **Optical**
  - ✓ **Advanced Devices (THz, UWBG)**
  - ✓ **Standards**

DARPA Next-Generation Microelectronics Manufacturing (NGMM) Innovation



Icon Source: FLATICON

NGMM: National Capability for **3DHI** R&D and Manufacturing

Research

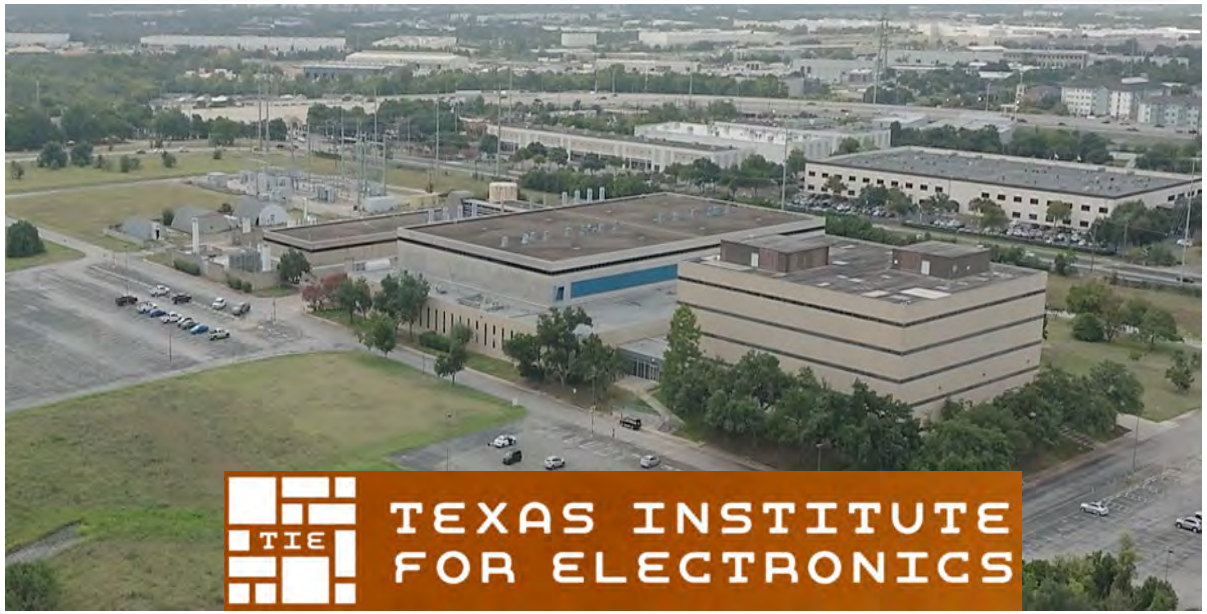
Prototyping

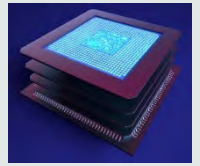
Pilot Production

Industry

Academia

Government



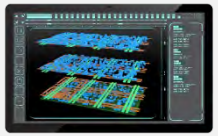


High Performance 3DHI Microsystems

Source: Adobe

Digital Twin

Integration Processes

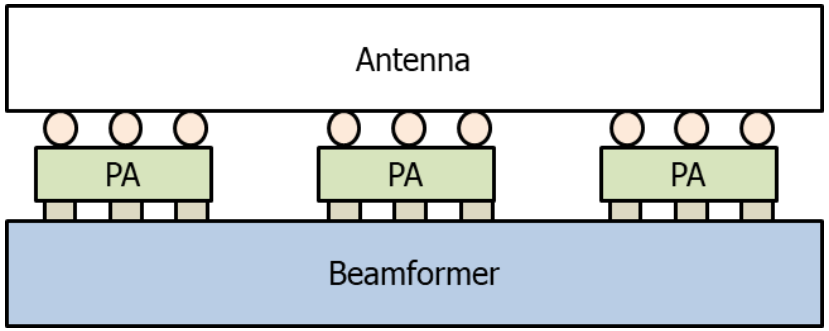


3DHI Assembly Design Kit (ADK)

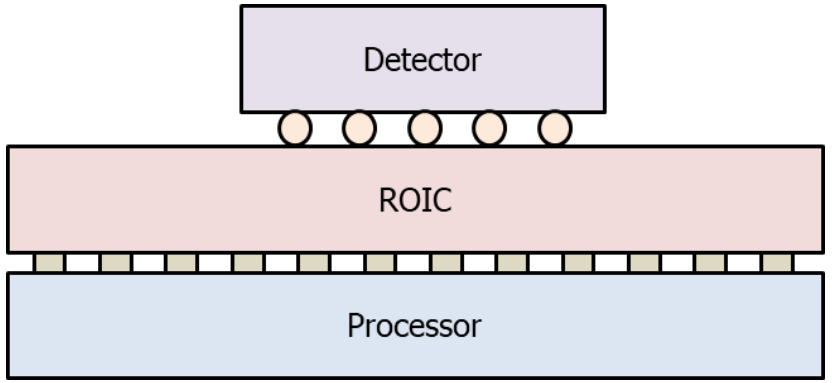
Self-Sustaining National Capability for 3DHI R&D and Manufacturing

3DHI: Three-dimensional heterogeneous integration
NGMM: Next-Generation Microelectronics Manufacturing program

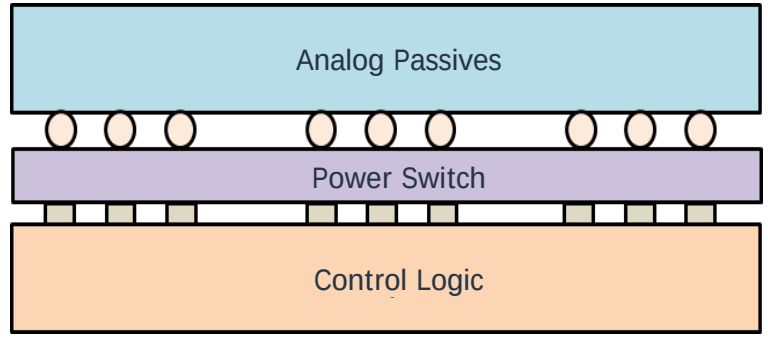
Three Exemplar 3DHI Microsystems Focus NGMM Capability Development



1. RF Phased Array Radar



2. Focal Plane Array Imager



3. Compact Power Converter

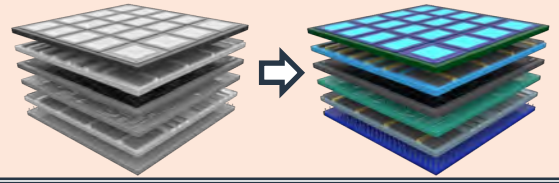
- Define the EDA, process modules, and ADK requirements to fabricate and model devices
- Define specific configuration of integrated tiers
- Develop common integration modules to support diversity of chips and materials

Establish initial process capability supporting a wide variety of customer 3DHI microsystems

3DHI: Three-dimensional heterogenous integration
ADK: Assembly design kit
EDA: Electronic design automation
FPA: Focal plane array
RF: Radio frequency

NGMM Baseline Process Capability Development Plan

Overall Goal: Development & Fabrication of Mixed-Materials 3DHI Microsystems Built on 3D Si Baseline
(Si, Glass, GaN, InP, GaAs, SiC, Ferrite, HgCdTe)



Planned Capabilities:

1. Bonding

Die-To-Wafer	Wafer-To-Wafer
Thermocompression *Cu-Cu Cu-Sn In-In*	**Hybrid** *Cu-Cu*

2. Through Substrate Via (TSV) Processes

Silicon	Glass
Compound Semiconductor	Polymer

3. Enabling Capabilities

- **Cu Routing Layers (200mm/300mm)** *Cu Damascene, RDL/Bump*
- **Sub-200mm Wafer Processing Enabled by Reconstitution**
- **Substrate FOWLP** | **Thermal Interposer**

4. Tool and Process R&D

5. 3D Assembly Development Kit (3D-ADK)

- Mixed materials Heterogeneous Integration (3DHI) built on a silicon advanced packaging baseline
- Support many wafer sizes and formats
- All bonding completed at 200mm/300mm using reconstitution or related methods
- Standardized planar Cu interface. Common Cu Damascene processing to enable diverse materials integration.
- 3D Assembly Design Kit and support of EDA vendors
- Digital Twin representation to support modeling
- Domestic open access to SoA HI capability
- ITAR/EAR compliant operations
- Strategic domestic partnerships being explored

NGMM Program Plan Summary

Phase 1
Establish Baseline Process

Phase 1 Deliverables
1. Initial Process Capability
2. Alpha ADK

- **Facility Preparation and Equipment Installation**
  - Facility Refurbishment
  - Equipment Procurement and Installation
- **Process Development**
  - Initial Process Capability Development
- **Electronic Design Automation**
  - Workflows and Simulation
  - 3D-Assembly Design Kit (ADK)

30 Months: Q4FY24-Q1FY27

Design Challenge Solicitation

NGMM Program Plan Summary

Phase 1
Establish Baseline Process

Phase 1 Deliverables
1. Initial Process Capability
2. Alpha ADK

Phase 2
Qualify / Operationalize

Phase 2 Deliverables
1. Qualified Process Capability
2. Beta ADK

- **Facility Preparation and Equipment Installation**
  - Facility Refurbishment
  - Equipment Procurement and Installation
- **Process Development**
  - Initial Process Capability Development
- **Electronic Design Automation**
  - Workflows and Simulation
  - 3D-Assembly Design Kit (ADK)

- **3DHI Prototyping**
  - Exemplar Microsystems and Design Challenge Prototypes to Exercise Process Capability
- **Process Improvement**
  - Automation of Fabrication, Assembly, and Test Processes
- **Emulation/Digital Twin Capability Development**

30 Months: Q4FY24-Q1FY27

30 Months: Q2FY27-Q3FY29

Design Challenge Solicitation

Design Challenge

NGMM Program Plan Summary

Phase 1	Phase 1 Deliverables	Phase 2	Phase 2 Deliverables	End Goal
Establish Baseline Process	1. Initial Process Capability 2. Alpha ADK	**Qualify / Operationalize**	1. Qualified Process Capability 2. Beta ADK	**Ready for Customers**

- **Facility Preparation and Equipment Installation**
  - Facility Refurbishment
  - Equipment Procurement and Installation
- **Process Development**
  - Initial Process Capability Development
- **Electronic Design Automation**
  - Workflows and Simulation
  - 3D-Assembly Design Kit (ADK)

- **3DHI Prototyping**
  - Exemplar Microsystems and Design Challenge Prototypes to Exercise Process Capability
- **Process Improvement**
  - Automation of Fabrication, Assembly, and Test Processes
- **Emulation/Digital Twin Capability Development**

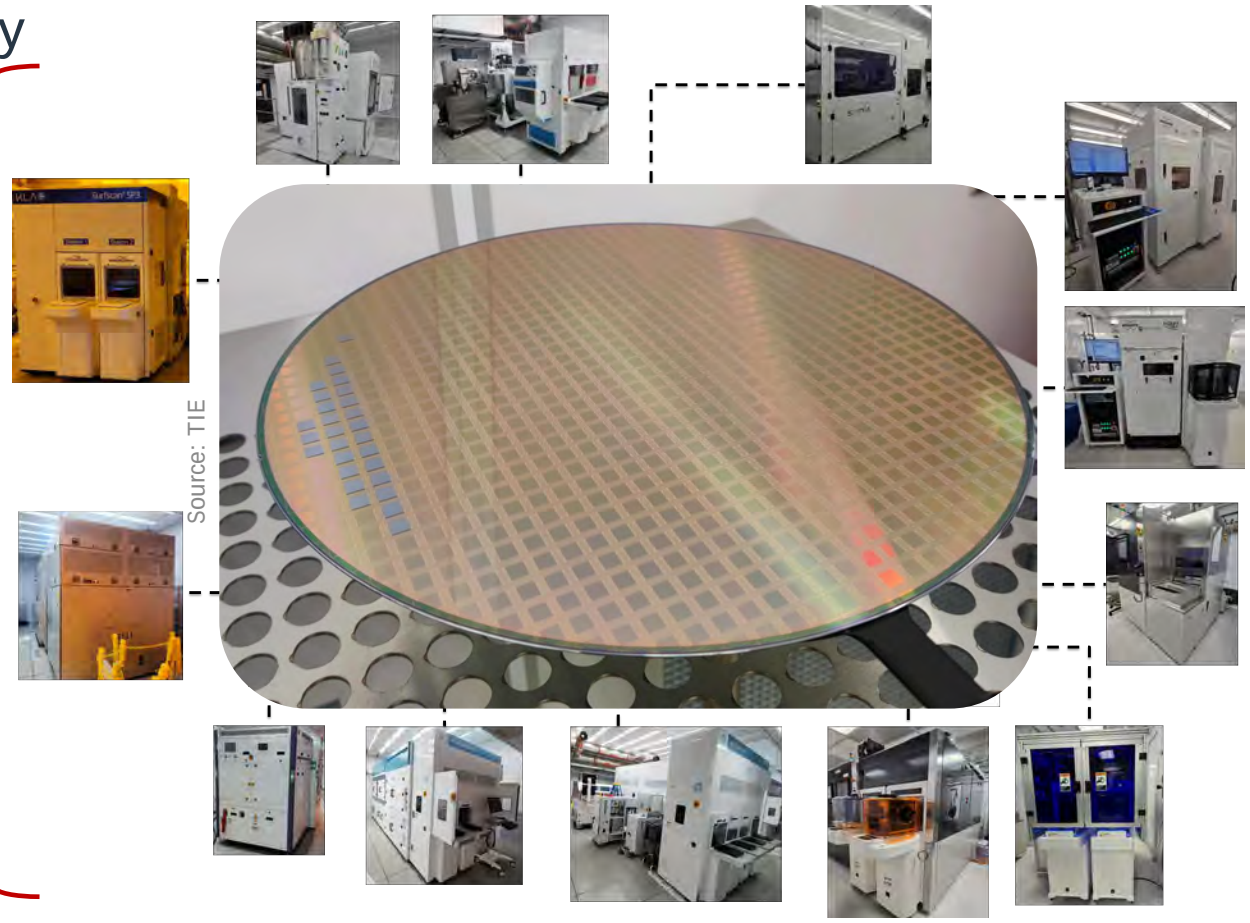
- **3DHI Capability**
  - ✓ **High Performance HI Microsystems**
  - ✓ **Research, Prototyping, & Pilot Production**
  - ✓ **Fast Paced Research**
  - ✓ **Open Access**
  - ✓ **ITAR/EAR Compliant**
  - ✓ **Self-Sustaining**
  - ✓ **Cost Effective**

30 Months: Q4FY24-Q1FY27 → **30 Months: Q2FY27-Q3FY29** → **Open-Access 3DHI Capability**

Design Challenge Solicitation → **Design Challenge**

NGMM Recent Accomplishments

- Doubled cleanroom space at TIE research facility
- All D2W hybrid bonding equipment installed
- Critical infrastructure refurbishment at TIE Montopolis facility completed
  - Nitrogen Plant
  - Acid Waste Neutralization
  - Grid Power
  - Fire Suppression
- Hired key leadership in process integration, thermal management, facilities, and operations



Source: TIE

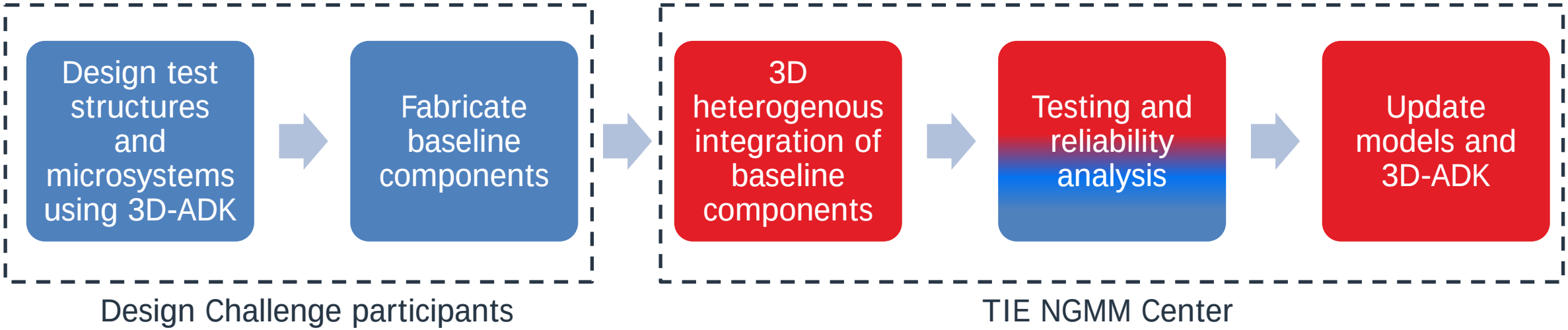
First D2W Bonding (Si-Si) Completed In May!!

NGMM Design Challenge Program

Goal

- Support long term sustainability and technical roadmap of the TIE NGMM Center
  - Exercise business, design, and fabrication processes aligned with TIE's existing capability
- Allow stakeholders to demonstrate additional microsystems showing unprecedented performance of 3DHI technology
- Opportunity for early engagement with NGMM center to demonstrate novel, next generation prototypes

Program Structure



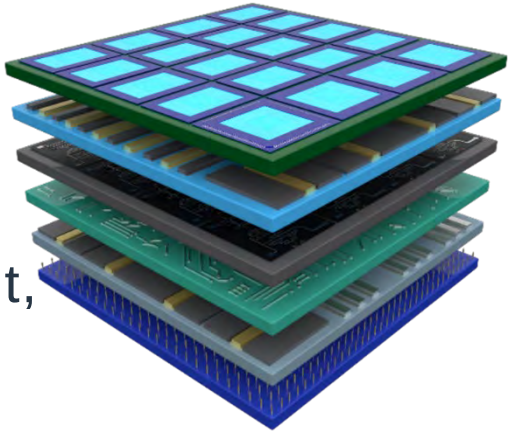
NGMM Design Challenges will bolster the TIE NGMM leadership position in 3DHI for multi-materials

Want to Learn More About NGMM?

- **Join us at the inaugural NGMM Summit:** October 27-28, 2025, Austin, TX

- Connect with stakeholders across government, industry, and academia on shaping the future of U.S. microelectronics 3DHI manufacturing. Highlights include:

  - **Inside NGMM**: Early customer/partner engagement, program timeline, and ways to get involved in 3DHI R&D and prototyping
  - **Technology roadmap:** Overview of 3DHI process technology roadmap and design/development infrastructure
  - **Progress in action:** Hear the latest on facility, infrastructure, equipment, and key milestones in process development



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