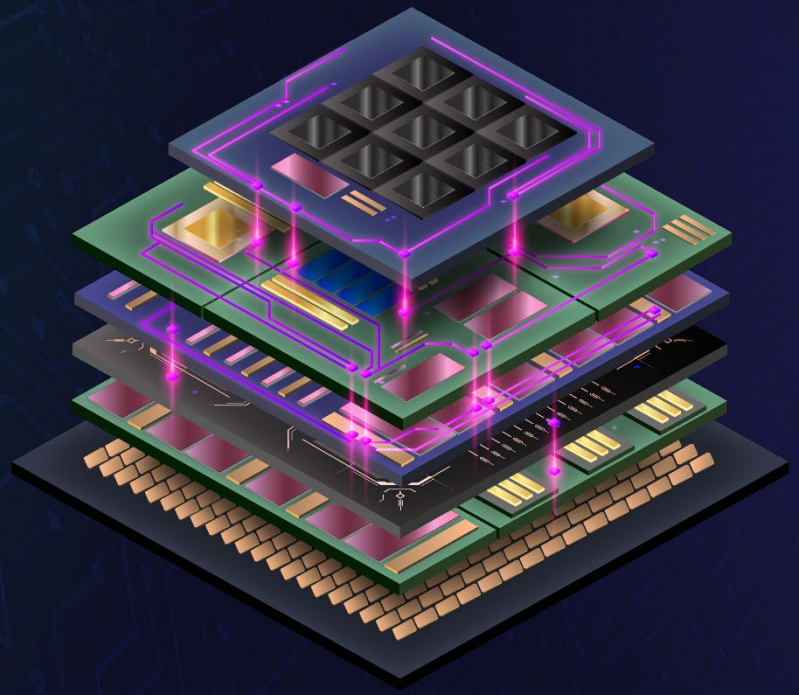
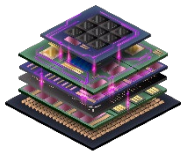
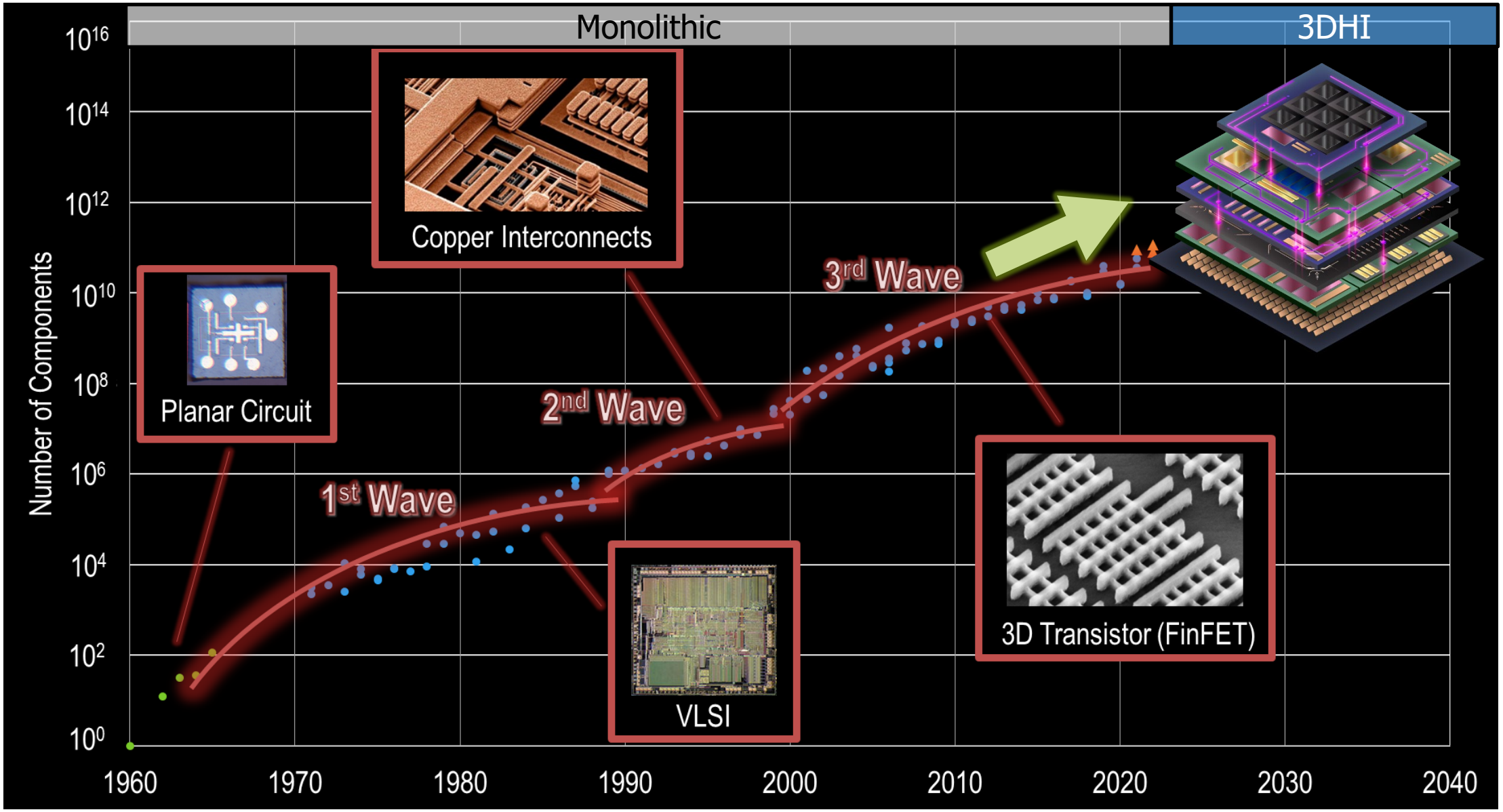
NGMM Program Update and Accomplishments

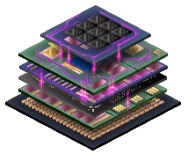
Michael Holmes
NGMM Managing Director, DARPA





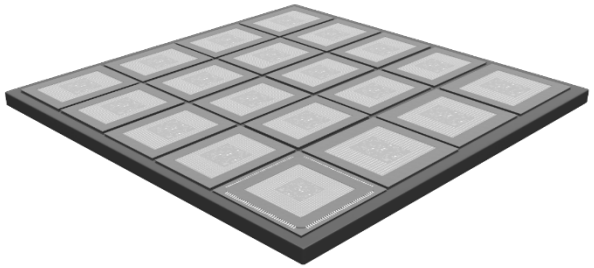
The Next Wave of Performance Enabled by **3D Heterogeneous Integration (3DHI)**

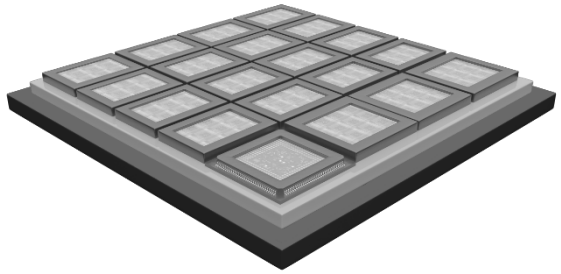


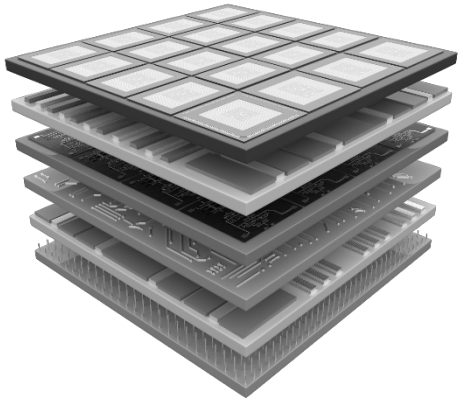


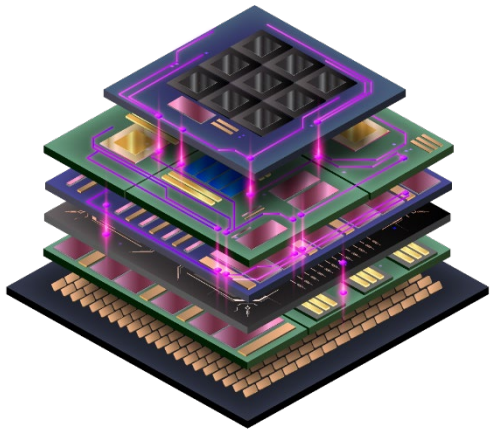
Levels of Integration – DARPA NGMM 3DHI

2D → 2.5D → 3D → 3DHI









DARPA NGMM

Silicon → Mixed Materials

Performance

1x → 3x → 30x → 100x

3DHI: Three-dimensional heterogeneous integration

NGMM: National Capability For 3DHI R&D and Manufacturing

Research

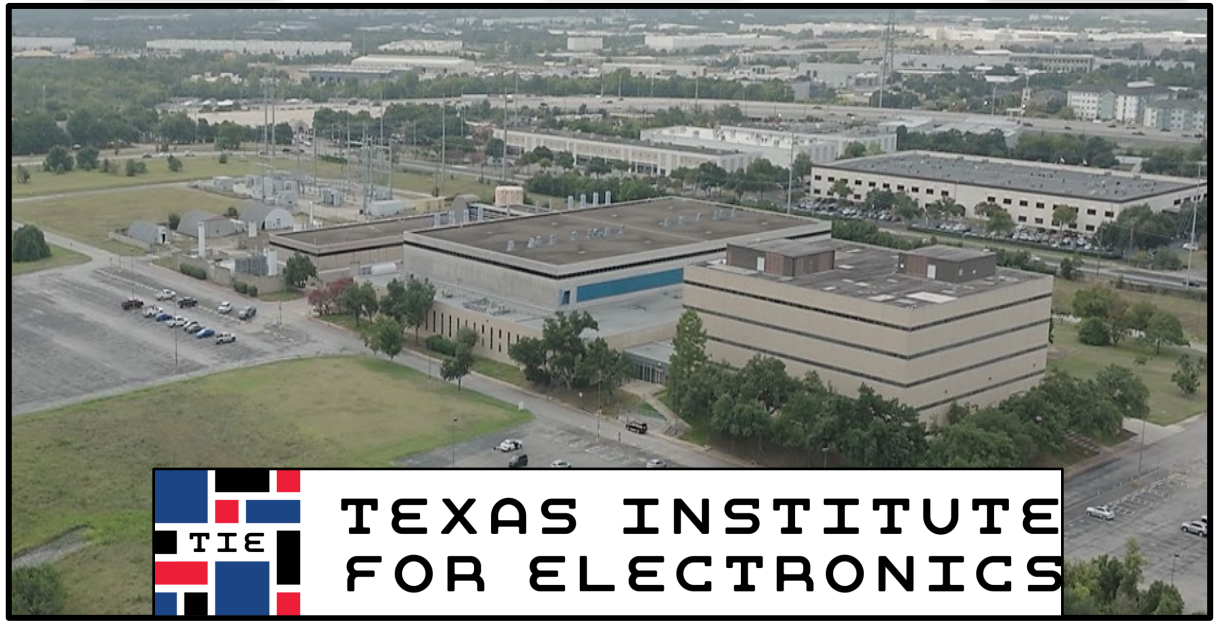
Prototyping

Manufacturing

Industry

Academia

Government



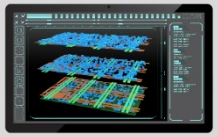
High Performance 3DHI Microsystems

Source: Adobe

Digital Twin

Standardized 3DHI Services

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

DARPA NGMM Innovation

Breadth of Periodic Table

Sub-Components Developed with Advanced Materials

Extensive Supply Chain

NGMM Innovation

Intimate Integration of Diverse Sub-Components

Electrical Performance

Mechanical Integrity

Thermal Stability

Reliable High Performance 3DHI Microsystems

Icon Source: FLATICON

NGMM 3DHI Exemplars


RTX


U.S. Air Force


U.S. Space Force

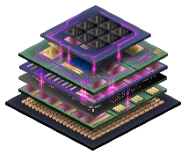

DARPA


U.S. Army

1. Phased Array	2. Focal Plane Array	3. Compact Power Converter
5G/6G Communications	Intelligence, Surveillance, Reconnaissance	Satellites/Spacecraft
Satellite Communications	Missile Warning and Tracking Missions	Air Vehicles
Software Defined Radio	Sensors for Advanced Infrared Search and Tracking Systems	Radiation Hardened Electronics
Weapons Detection	Environmental Monitoring	Electric Vehicles
Sensing in Degraded Visual Environments	Sensors for Autonomous Vehicles	Missile Seekers
High Bandwidth Communications	Sensors for Robotics	High Efficiency Computing Systems
Radar for Automotive, Air and Missile Defense, Ground Surveillance		On-Chip Power Conversion

Edge Compute

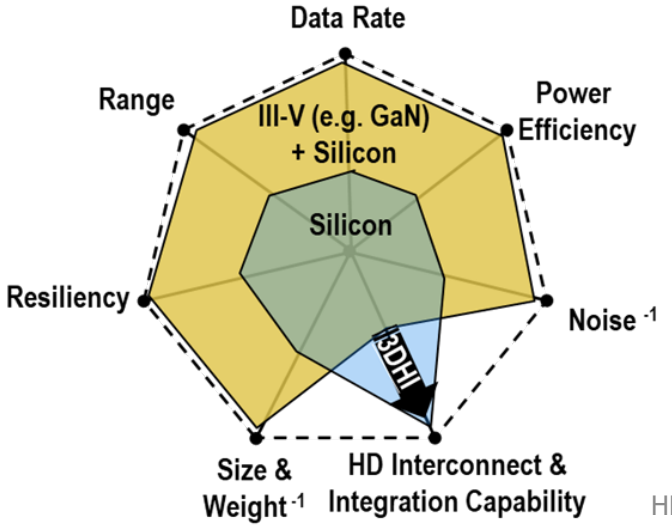
Exemplars Drive NGMM Technology Roadmap and Enable a Broad Range of DoW and Commercial Applications



Performance Impact of NGMM and Mixed Materials 3DHI

- **Next-Generation Microsystem Performance**

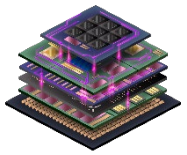
Application	Metric	Improvement
RF Phased Array	Radiated transmit power	**10×**
	Spectrum utilization	**100×**
	Communication range	**10×**
Focal Plane Array	Dynamic range	**100×**
Power Converter	Power density	**10×**



3DHI of III-V and silicon for RF phased array applications

- **Compact devices with over 10× reduction in volume**
- **Faster prototyping timelines**
  - Centralized manufacturing instead of multiple vendor hand-offs to complete processing
  - Common standards enabled by a production-ready 3DHI ADK

3DHI: Three-dimensional heterogeneous integration
ADK: Assembly design kit
HD: High density



TNC Baseline Process Capability Development Plan

PLANNED 3DHI LOW-VOLUME/HIGH-MIX FOUNDRY TECHNOLOGIES

1. Bonding

Die-To-Wafer	Die-To-Wafer & Wafer-to-Wafer
Thermocompression *Cu-Cu Cu-Sn*	**Hybrid** *Cu-Cu*

2. Through Substrate Via (TSV) and Advanced Substrates

Silicon	**Glass**
Compound Semiconductor	**Polymer**

Advanced Substrates

3. Routing and Reconstitution

Cu Routing Layers (200mm/300mm)
Cu Damascene, RDL/Bump

Sub-200mm Wafer Processing Enabled by Reconstitution

Mixed-Material Reconstitution

4. Thermal Solutions for Mixed-material 3DHI

Engineered Thermal Materials & Systems

Thermo-Mechanical Modeling & Reliability

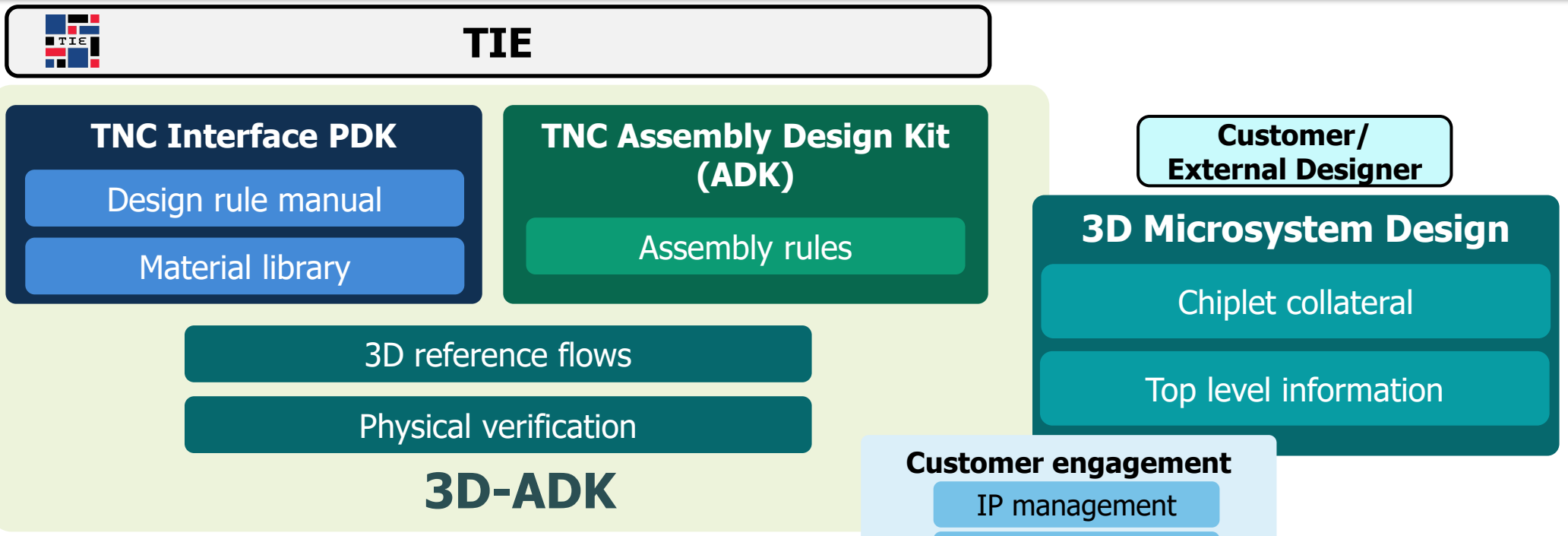
5. Failure Analysis, Characterization, Test & Reliability

6. EDA and 3D Assembly Development Kit (3D-ADK)

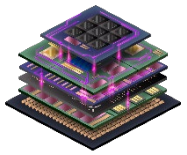
- **Domestic State-of-the-Art 3DHI Foundry**
  - Pure play 3DHI services
  - ITAR/EAR compliant operations
- **Mixed-Materials Heterogeneous Integration (3DHI) Capability Built on a Silicon Advanced Packaging Baseline**
  - Support for many wafer sizes and formats
  - All bonding completed at 200mm/300mm using reconstitution or related methods
  - Standardized planar interface with Cu Damascene processing to enable diverse materials integration
- **3D Assembly Design Kit and Support of EDA Vendors**
  - Reference flows for prototype development
  - Digital Twin representation to support modeling
- **Strategic Domestic Partnerships**

TNC EDA and 3D-ADK

Design Enablement with Commercial EDA Tools



- First version of 3D-ADK released in June 2025
- Enable 3D physical verification for March 2026 3D-ADK release
- Initial multi-physics simulation capability in 2026
- Partnering with government teams for review and verification



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

End Goal
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, Rapid Prototyping, and Manufacturing**
  - ✓**Foundry Services**
  - ✓**ITAR/EAR Compliant**
  - ✓**Self-Sustaining**
  - ✓**Cost Effective**

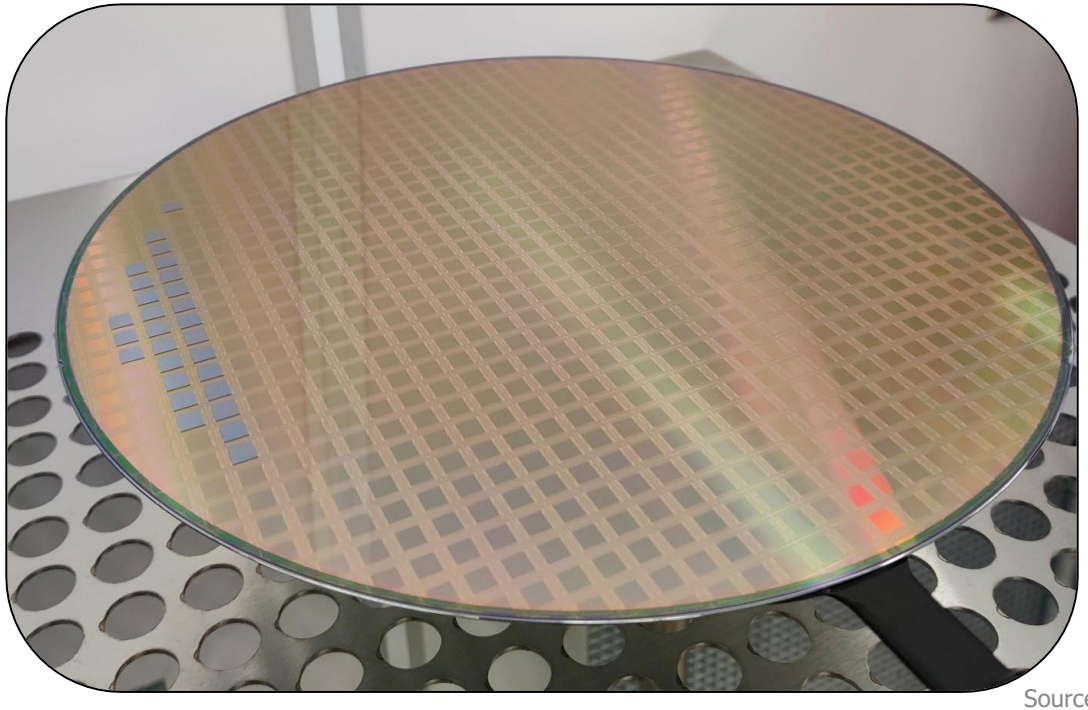
Phase 1: 30 months | **Phase 2: 30 months** | **3DHI Foundry Capability**

Today

July 2024 | **Oct 2025** | **Jan 2027** | **Feb 2027** | **May 2028** | **July 2029**

NGMM Year 1 Accomplishments

- **Successfully established D2W hybrid bonding process module (Si-Si)**
  - Obtained initial baseline yield
- **Completed key infrastructure construction at JJ Pickle research facility**
  - Development underway on hybrid bonding line
- **Commenced equipment installation at Montopolis manufacturing facility**
  - Critical tools in installation, staged for installation or ordered from vendors
- **Piloted a hands-on undergraduate semiconductor technical training bootcamp at Austin Community College**



Source: TIE

Wafer Backgrind

CMP

Optical Inspection

Cleanroom renovations and key equipment installation will be complete by January 2026