3DHI for Aerospace and Defense Applications: State-of-the-Art Edge Computing and High-Bandwidth Communications

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Timothy Lee, a Boeing Technical Fellow based in Southern CA, leads the development of disruptive microelectronics technologies for advanced communications networks and sensor systems for airborne and space applications. His current research interests include silicon Application Specific Integrated Circuits (ASICs) and gallium nitride Monolithic Microwave Integrated Circuits (MMICs), and 3DIC technologies for vertical integration of digital Si chiplets and analog/RF devices. He led the development of hardware for satellite communications and has built phased-array antenna electronics for commercial and US government customers. Lee hold SMEE and SBEE degrees from MIT and a Master's degree on System Engineering from USC. He is an active volunteer in the IEEE. He is a past member of the IEEE Board of Directors (2021-2022) and past President of the IEEE Microwave Theory and Technology Society (MTT-S). He leads several Technical Working Groups in the IEEE Heterogenous Integration Roadmap (HIR) and in the IEEE Future Networks Technical Community.

BR&T Capabilities Intro | Innovation Landscape @ Boeing

Boeing Commercial Airplanes (BCA)

Product Development

Boeing Research & Technology (BR&T)

Aurora Flight Sciences · wisk · Disruptive Computing & Networks

SKYGRID (A Boeing, SparkCognition Company.) · BOEING ANALYTX

IT&DA · BOEING AVIONX · HRL LABORATORIES · ae HORIZONX

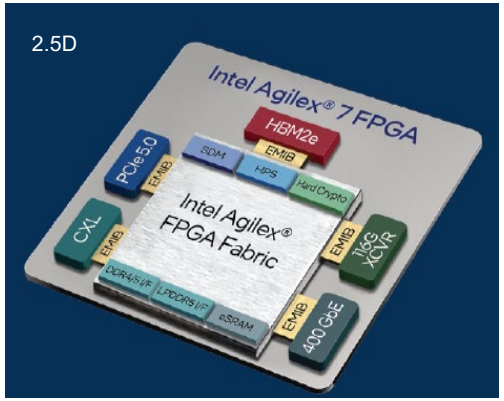
Boeing Global Services (BGS)

Boeing Defense, Space & Security (BDS)

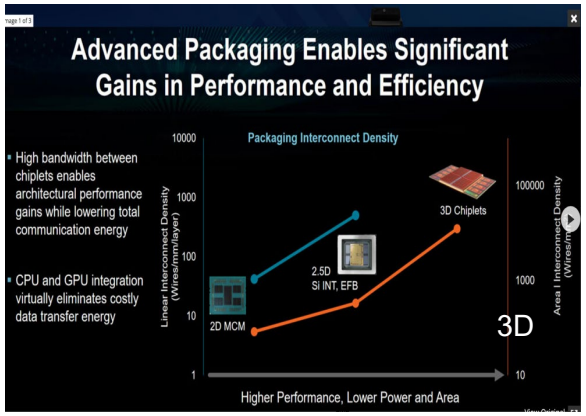
Phantom Works

BR&T is the centralized R&D organization within Boeing, supporting BDS, BCA & BGS

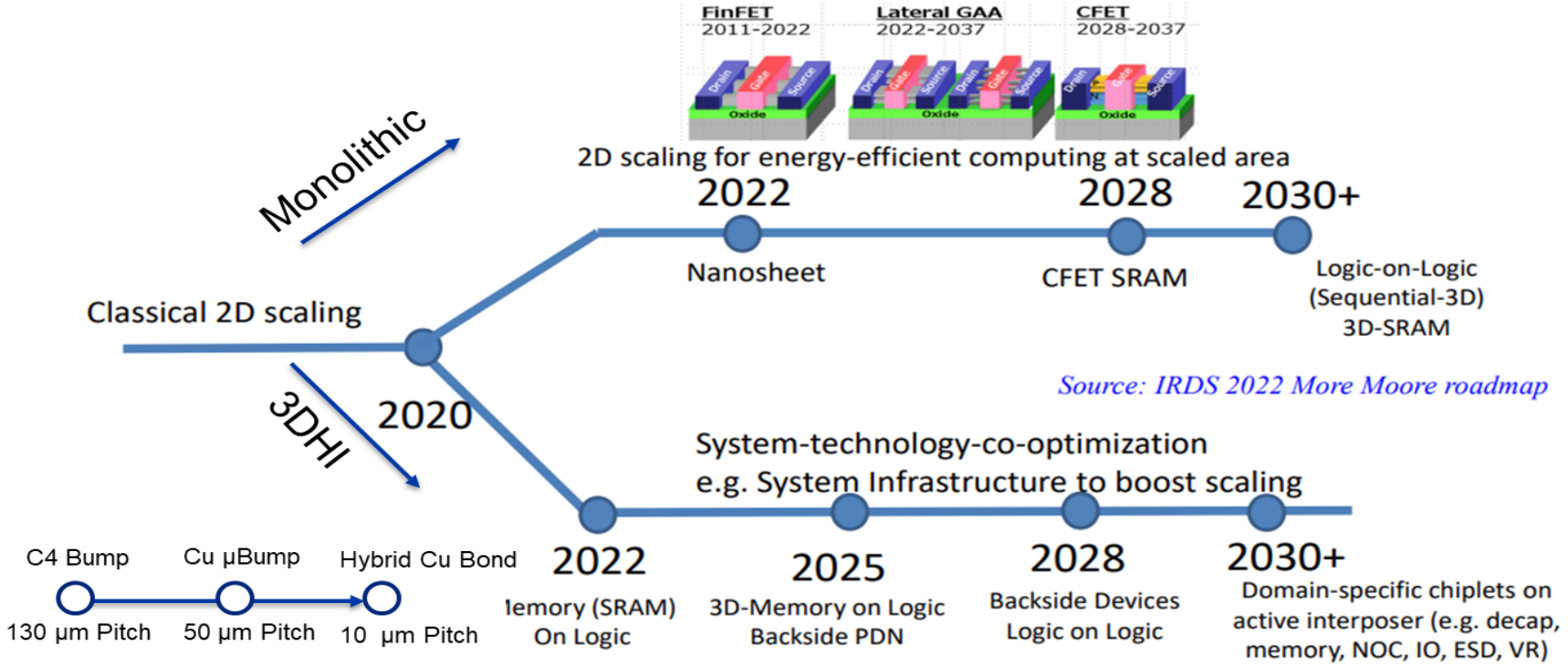
3DHI – Disruptive Technology for Next-Generation Microelectronics



Source: Intel Agilex 7 with HBM2e



Source: AMD, ISSCC 2023



NoC: Network on Chip
VR: Voltage Regulator
ESD: Electrostatic Discharge

- 3DHI (2.5D & 3D) complements Monolithic Scaling
- 3DHI integrates different materials (Si, III-V, photonics, MEMs, etc.)
- Enables 10X to 1000X improvements in SWaP for AI/ML enabled architectures

Benefits apply to both commercial and aerospace applications

BLUF – Aerospace / Defense wants to have same 3DHI technology access as the big commercial companies!

Benefits apply to Commercial and DoD Systems

- Lower latency, lower power and high bandwidth interconnects
- Ability to mix and match chiplets at various technology nodes
- 10X - 50X reduction in data movement energy costs
- IP re-use of proven silicon
- Tight integration between logic and memory
- Higher die yields due to smaller chip(let) size

Support Dual-Use Applications

- HPC
- Autonomy Enabling AI/ML Hardware
- Energy Efficient Computing
- High bandwidth communications (5G/6G)
- Secure Edge Computing

DoD / Aerospace Unique Requirements

- **Operate in Harsh Environments**
- **Mission Critical**
- **Human Safety**
- **Integration of III-V, Si and Photonics**

Challenges for Defense Applications

- **Extreme Environments**
- **Cost of Technology Access**
- **Domestic Trusted Supply Chain**
- **Low volumes & High Product Mix**
- **Long lifecycles & Parts Obsolesces**
- **Proprietary Interfaces**

3DHI will enable more capable systems for aerospace & defense missions

Aerospace Use Case: Making Autonomous Flight a Reality

- Mission: Passenger Air Taxi
- Power: All Electric
- Configuration Lift + Cruise
- Range: 90 miles / 144 km
- Seats: 4 + luggage

Wisk Gen 6

https://wisk.aero/autonomy/

- Mission: unmanned refueling & ISR
- Power: Rolls-Royce turbofan engine
- Configuration Lift + Cruise
- Range: 580 miles / 930 km
- Carry 16,000 lb (7,250 kg) of fuel

MQ-25

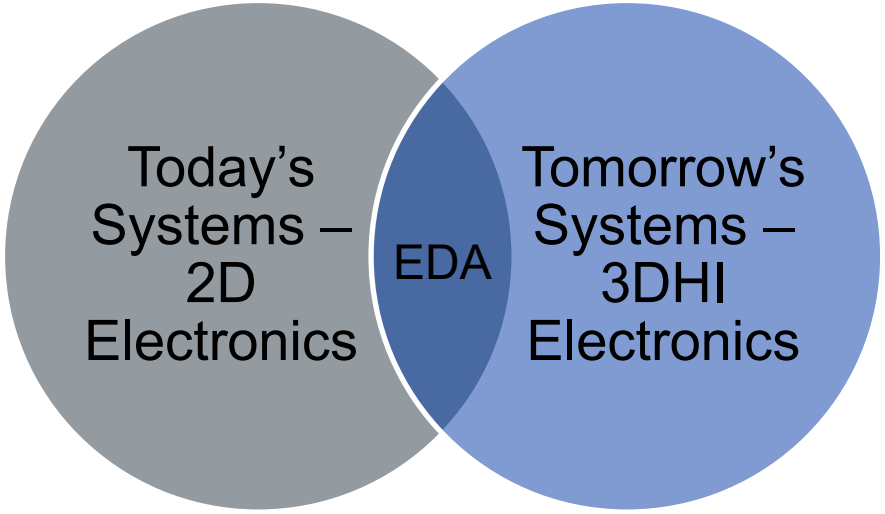
https://www.boeing.com/defense/mq25/

Advanced semiconductors + 3DHI will pave the way for affordable and reliable navigation, C2 and operational capabilities to advanced ubiquitous autonomous flights for commercial and DOD platforms

https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2160662/mq-25a-stingray/

EDA Challenges to Adoption of 3DHI Adoption – Systems Approach Needed

- Seamless integration into Model-Based System Engineering frameworks
- Multi-scale: Systems, IC and Packaging that exceeds six orders of magnitude (nm to m)
- Multi-Physics: multiple coupled electrical, thermal, and mechanical effects / analyses
- Multi-EDA: Support of best available tools and standardized databases
- Multi-PDKs: Seamless support of IC and interposer PDKs and packaging ADKs
- Multi-IP: Integration of custom IP + 3rd Party IP
- Hardware and software verification
- Multi-Team: Requirements through implementation and deployment cross many internal teams and external partners

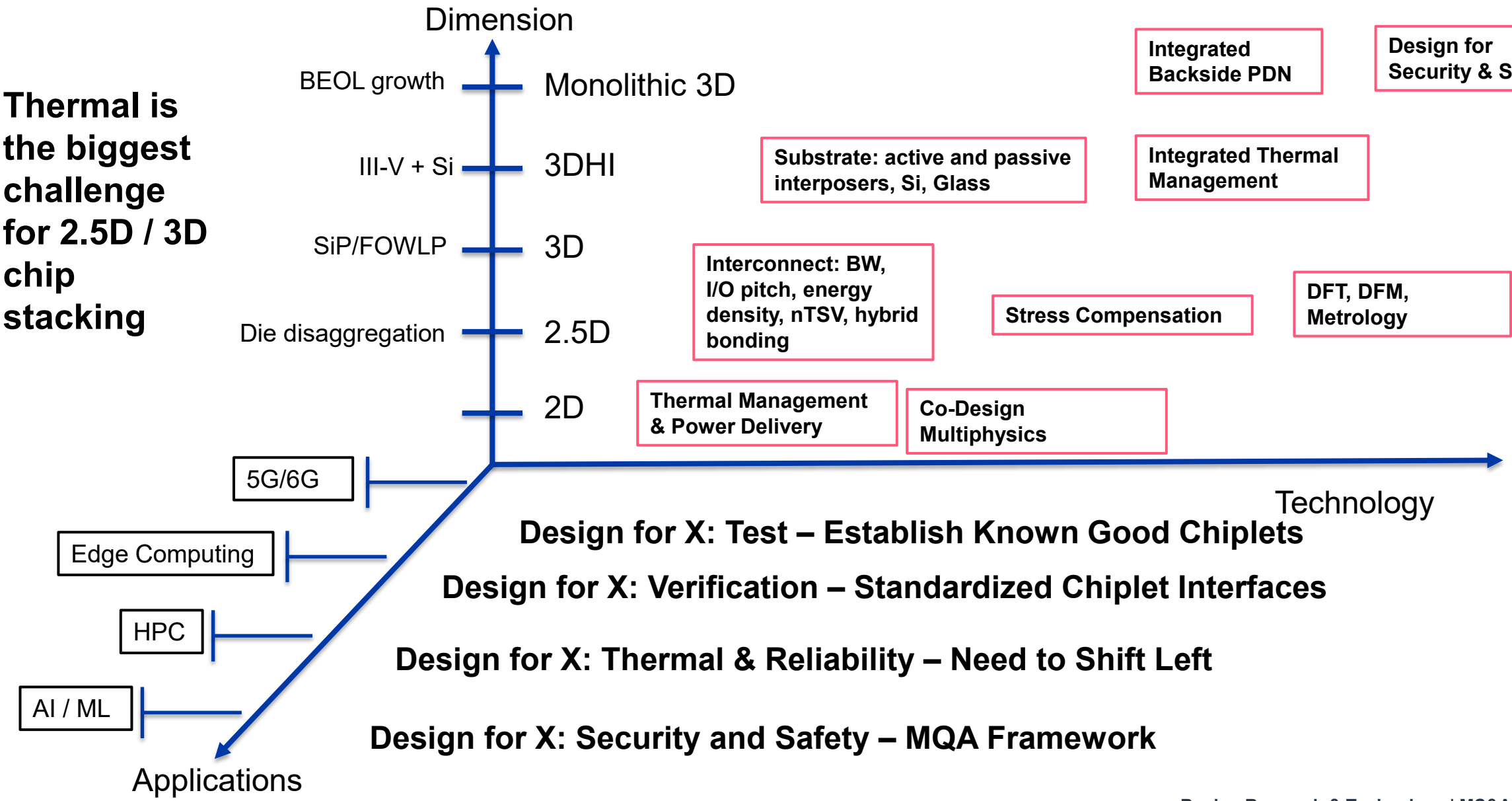


- **The use of 3DHI EDAs already underway under NGMM**
- **Design for Extreme Environments**
- **Multi-PDKs and ADKs**
- **Standardized Interfaces**

Predictive 3D-aware EDA Tools will enable optimal designs with lower resources and costs

Challenges for 3DHI EDA Ecosystem – Design for X

Thermal is the biggest challenge for 2.5D / 3D chip stacking



Integrated Backside PDN

Design for Security & Safety

Substrate: active and passive interposers, Si, Glass

Integrated Thermal Management

Interconnect: BW, I/O pitch, energy density, nTSV, hybrid bonding

Stress Compensation

DFT, DFM, Metrology

Thermal Management & Power Delivery

Co-Design Multiphysics

Design for X: Test – Establish Known Good Chiplets

Design for X: Verification – Standardized Chiplet Interfaces

Design for X: Thermal & Reliability – Need to Shift Left

Design for X: Security and Safety – MQA Framework

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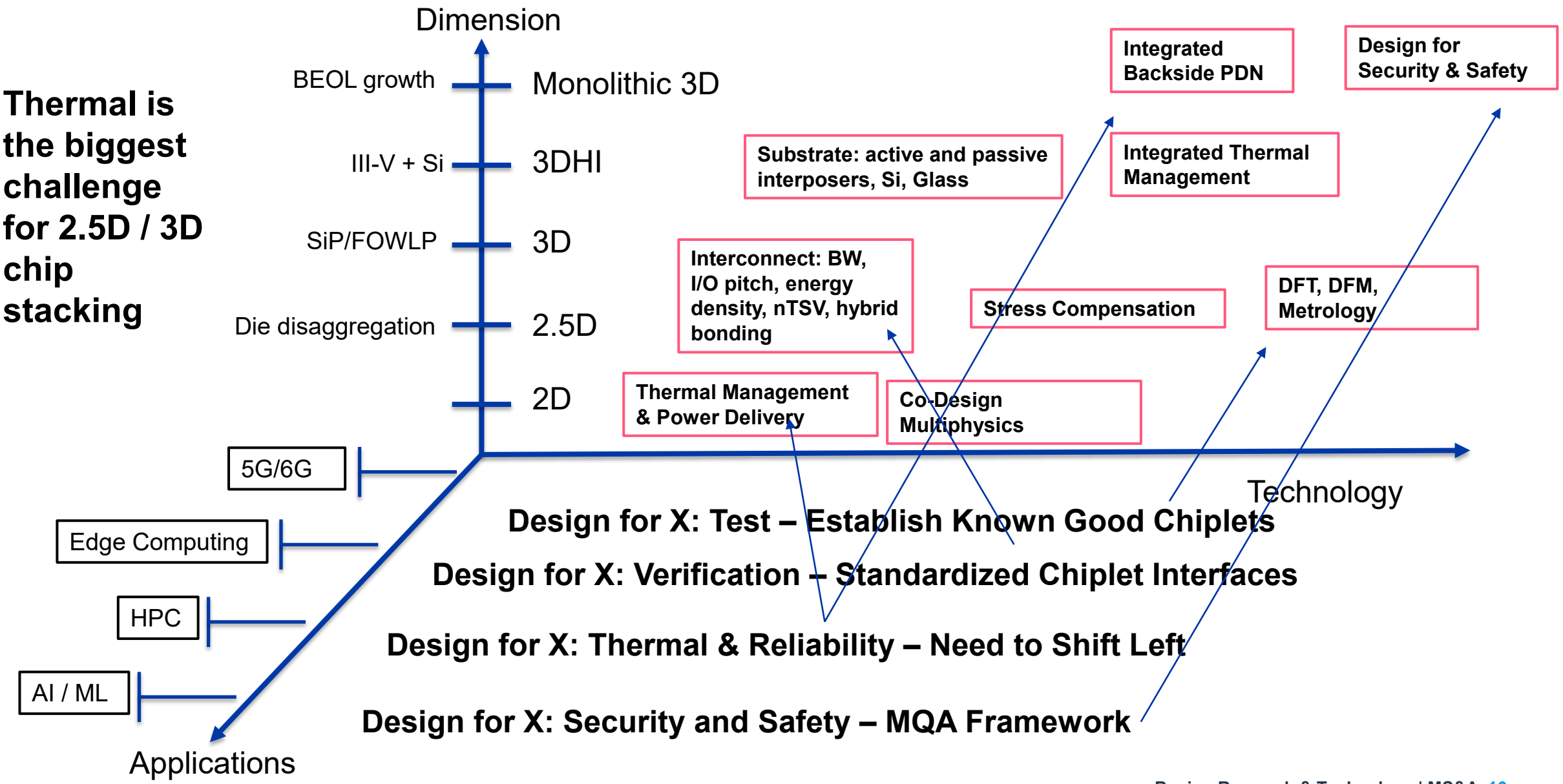
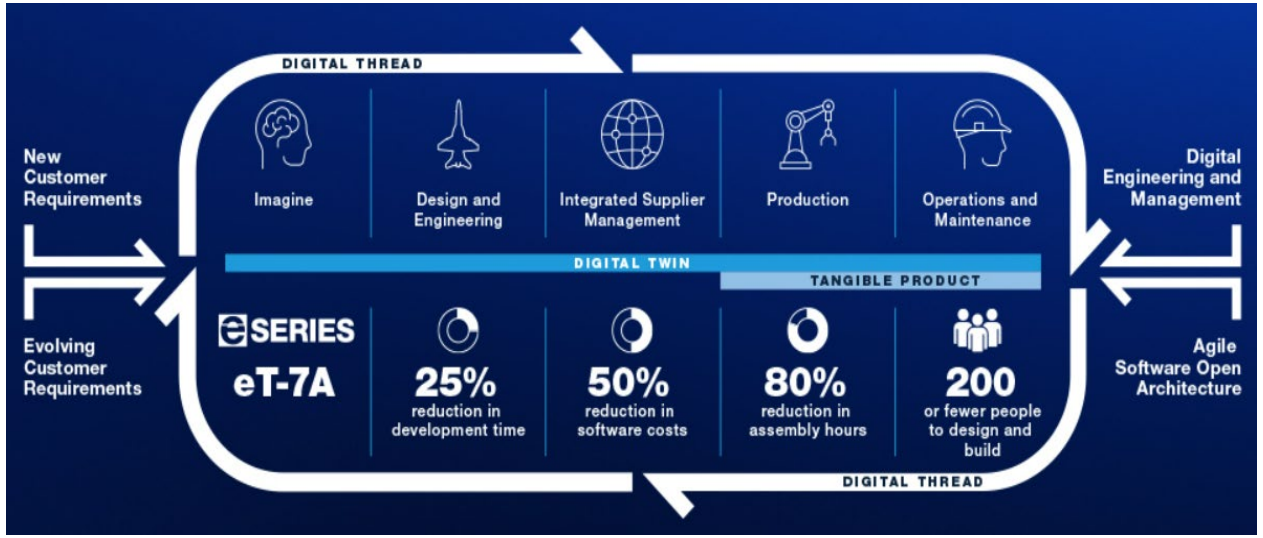


Revolutionary Advancements for Future High-Performance Mission Systems will be enabled by 3DHI Technologies

3DHI EDA Tools must be extended to support Digital Twins Simulation and Verification from Systems to Chips Level



- **Enable New Applications for the Warfighter**
  - AI/ML – integration of logic and memory
  - High bandwidth communications – integration of RF/Analog to Logic
  - ISR data processing – integration of optical/IR/RF detectors / transceivers
- **Challenges**
  - Integration of III-V and silicon-based electronics and photonics to achieve much higher bandwidths at low pJ/bit
  - Digital Twins and Physical Design now extends across 6 order of magnitude of dimensions
    - Platform Requirements
    - Mission Electronics / payloads / architectures
    - Sub-System design & optimization
  - EDA for co-design of 3DIC, substrate, package, and board for electrical, thermal, reliability, power

New Paradigm:

- **The Package is the System: Closing the gap between the virtual world and the real world to improve safety, quality, productivity, cost, resiliency and customer satisfaction**
- **Multi-physics-based EDA tools are needed to increase fidelity of simulation and to reduce risk**

https://www.boeing.com/defense/jadc2/digital-acceleration/index.page

Thank you!