CALCE
CENTER FOR ADVANCED
LIFE CYCLE ENGINEERING

SMTA

AI Enhanced Physical Inspection for Counterfeit Microelectronics

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Genesis for Developing Secure Si-Interposers

PSM – Ushering PCB Security Through System-level MEMS Integration (N00014241205 6)

PM Meeting – 19th May 2025

UF | UNIVERSITY of FLORIDA

ASU

PSM Team

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Dr. Daniel Koller

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Shafkat Khan (Univ. of Florida ECE, Ph.D.)
Liam Hayes(Arizona State University ECE, Ph.D.)
Kyoungdu Kim(Arizona State University ECE, Ph.D.)
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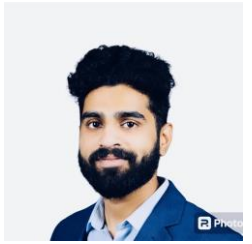
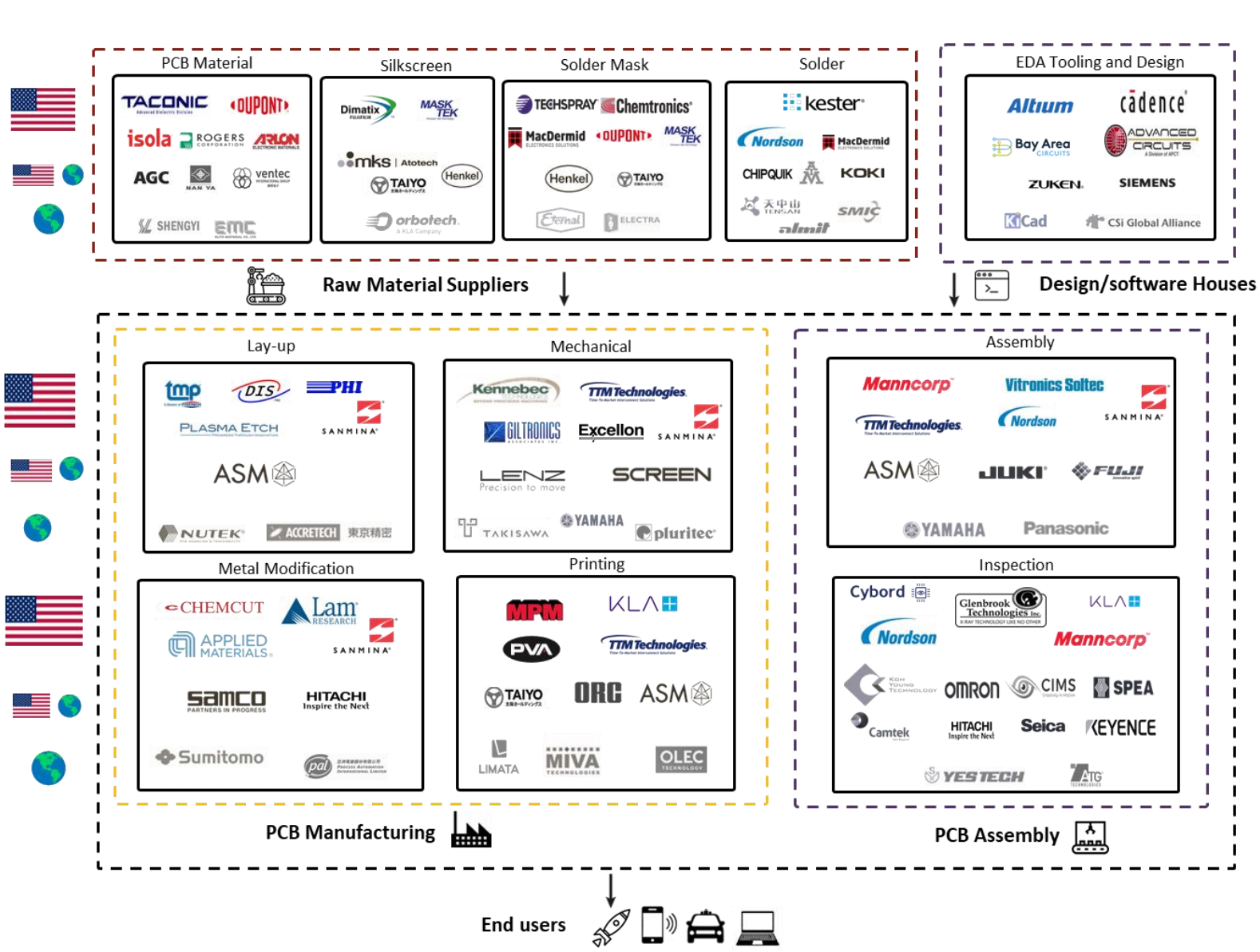
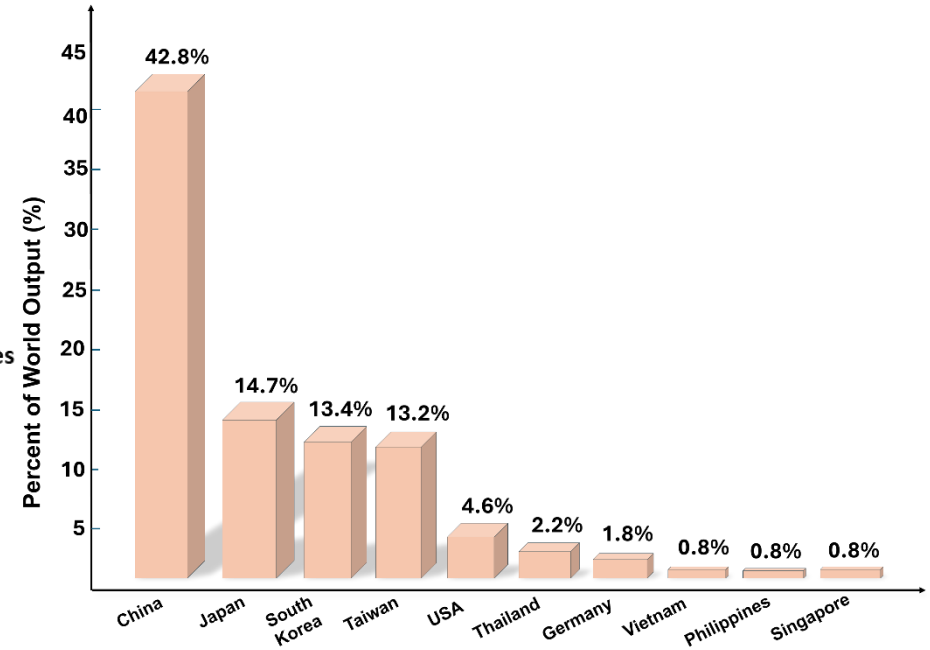



BACKGROUND

PCB Ecosystem and Market





- ✓ **Supply Chain**: Covers raw materials, PCB manufacturing, design, and assembly.
- ✓ **Key Players**: Includes DuPont, ASM, KLA, Nordson, etc.
- ✓ **Market Share**: Bar chart shows country wise production distribution.

Global Landscape

North America is in a Weak Position for AP/HI

Reference: Yole 2023

Scenarios – Real Time Attacks

Your Air Force

An F-16 pilot died when his ejection seat failed. Was it counterfeit?

By Rachel S. Cohen

Sep 13, 2022

David Schmitz, then a staff sergeant, poses in 2014 at at Joint Base Lewis-McChord, Wash. (Jacob Jimenez/Air Force)

Defense One

China's Copycat Jet Raises Questions About F-35

New technical specs about China's new J-31 fighter, a plane designed to rival the American-made F-35 Joint Strike Fighter, popped up on a Chinese blog last...

IEEE Spectrum

Invasion of the Hardware Snatchers: Cloned Electronics Pollute the Market

Fake hardware could open the door to malicious malware and critical failures.

Hackaday

IPhone 6S NVMe Chip Tapped Using A Flexible PCB

Psst! Hey kid! Want to reverse-engineer some iPhones? Well, did you know that modern iPhones use PCIe, and specifically, NVMe for their...

The Aviationist

Iran unveils reverse-engineered version of captured U.S. RQ-170 stealth drone

Iran unveiled an RQ-170 drone allegedly manufactured by reverse-engineering of US Sentinel drone captured in December 2011.

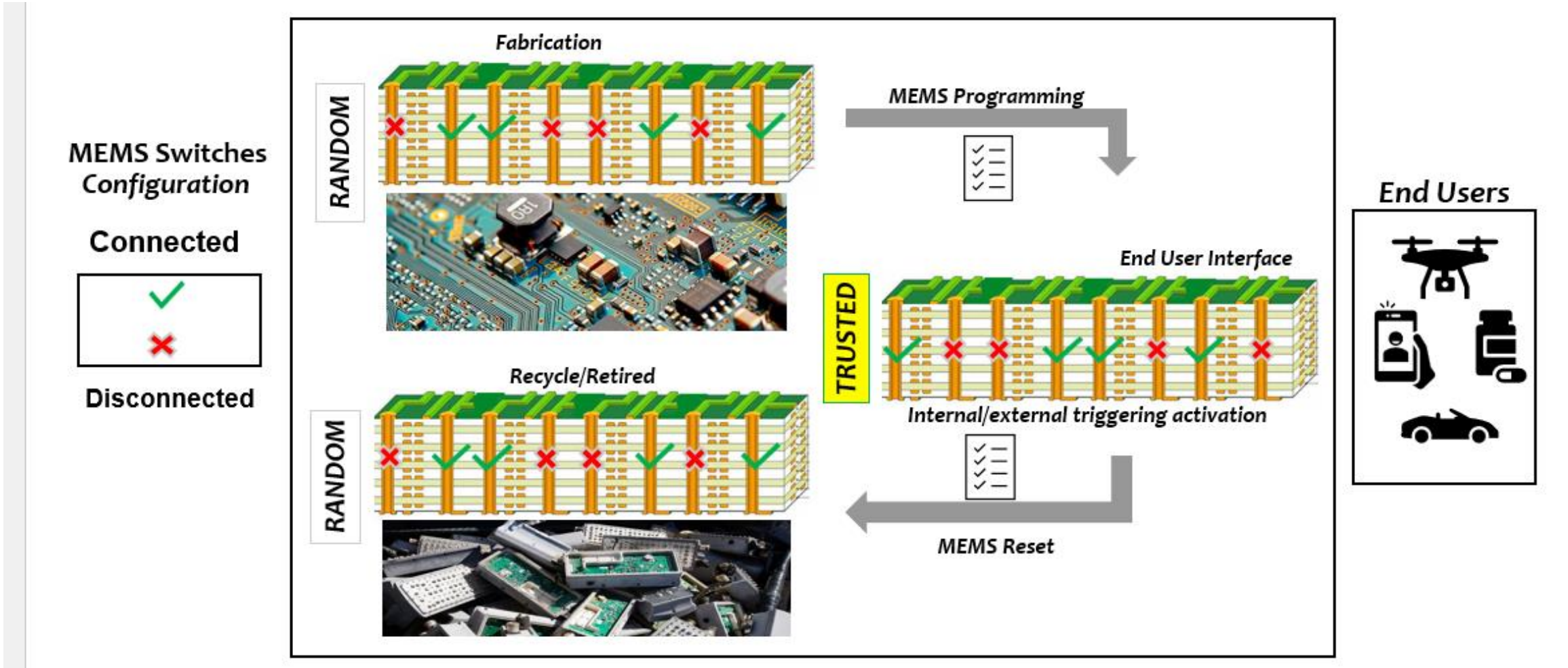
Hackaday

Reverse Engineering A PCB

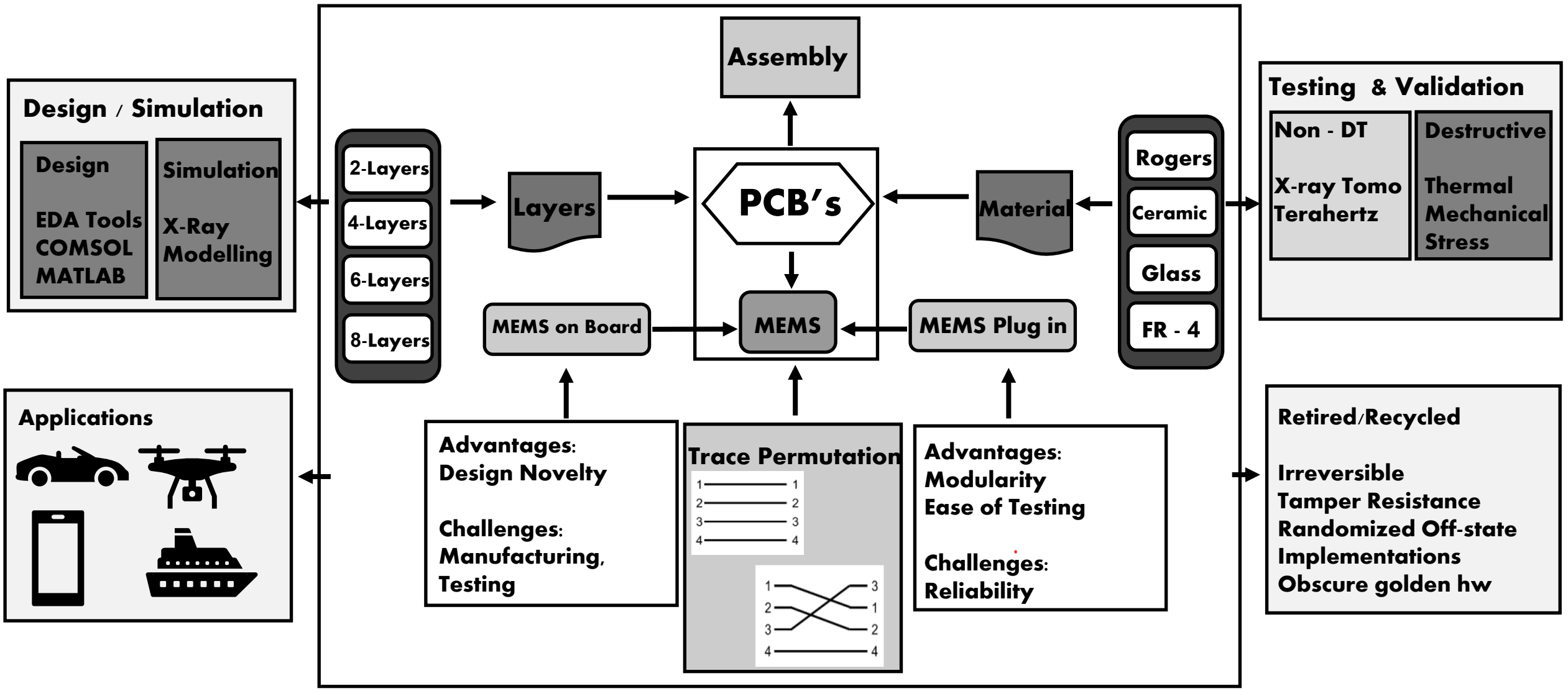
Occasionally when a device breaks, the defect is obvious. Whether it is a blown fuse or a defective capacitor, generally the easy to see...

RESEARCH APPROACH

PSM Strategy

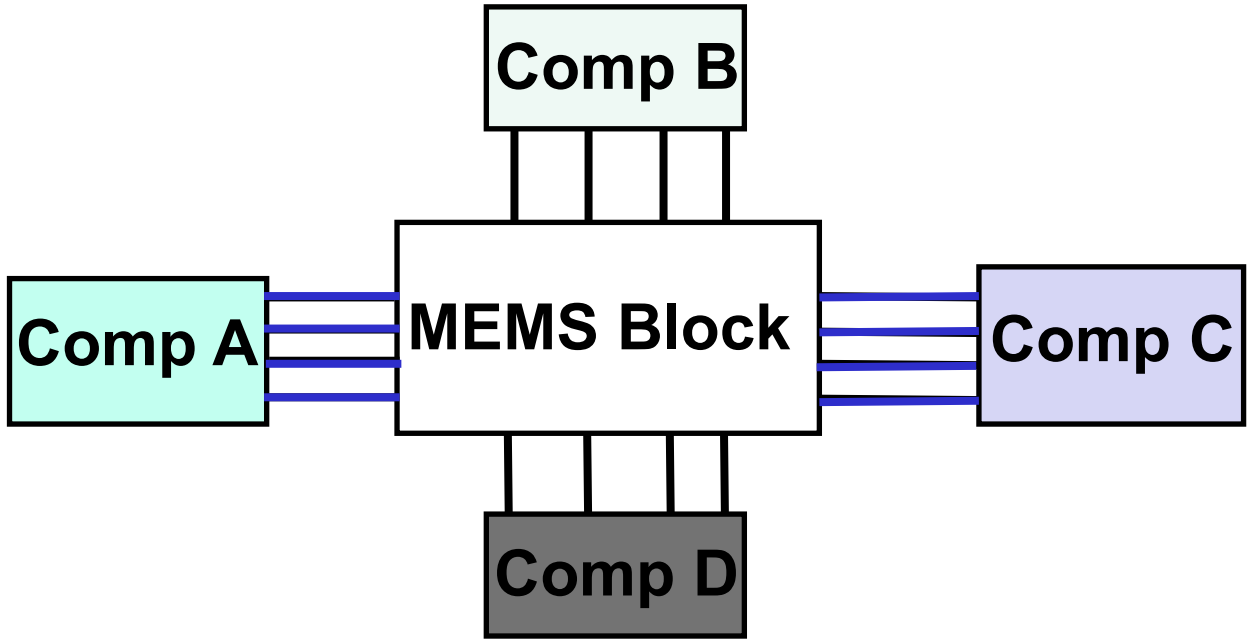


Solution Overview



Entropy Analysis – Case 1

Case 1: All 4 Traces Go to Only One Other Component at a Time



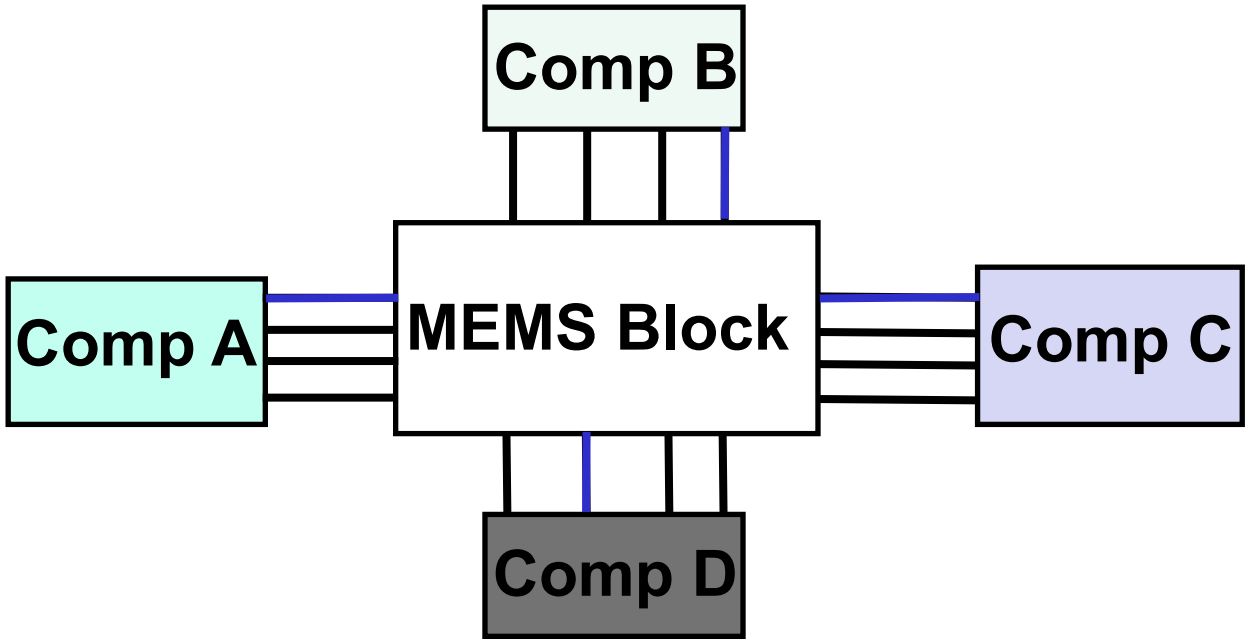
Case 1:

- Each component (e.g., Comp A) sends **all 4 traces** to just one of the remaining components (B, C, D).
- **3 destination choices** for each component.
- **4 traces** can be permuted in **4! = 24** ways.
- So, **total permutations per component** = 3 × 24 = **72**.

For each of the 4 components independently $72^4 = \boxed{26,873,856 \text{ total permutations}}$

Entropy Analysis – Case 2

Case 2: Traces Can Be Split Across Multiple Components



Case 2:

- Each of the 4 traces can be routed independently to any of the 3 other components.
- **Routing combinations per component** = $3^4 = 81$
- For each combination, **trace-to-pad permutations** ≈ 24 (assumes typical distribution like 2 to B, 1 to C, 1 to D).
- So, **total permutations per component** = 81 × 24 = **1,944**.

For each of the 4 components independently

$$1944^4 \approx \boxed{1.427 \times 10^{13} \text{ total permutations}}$$

Key Communication Unit

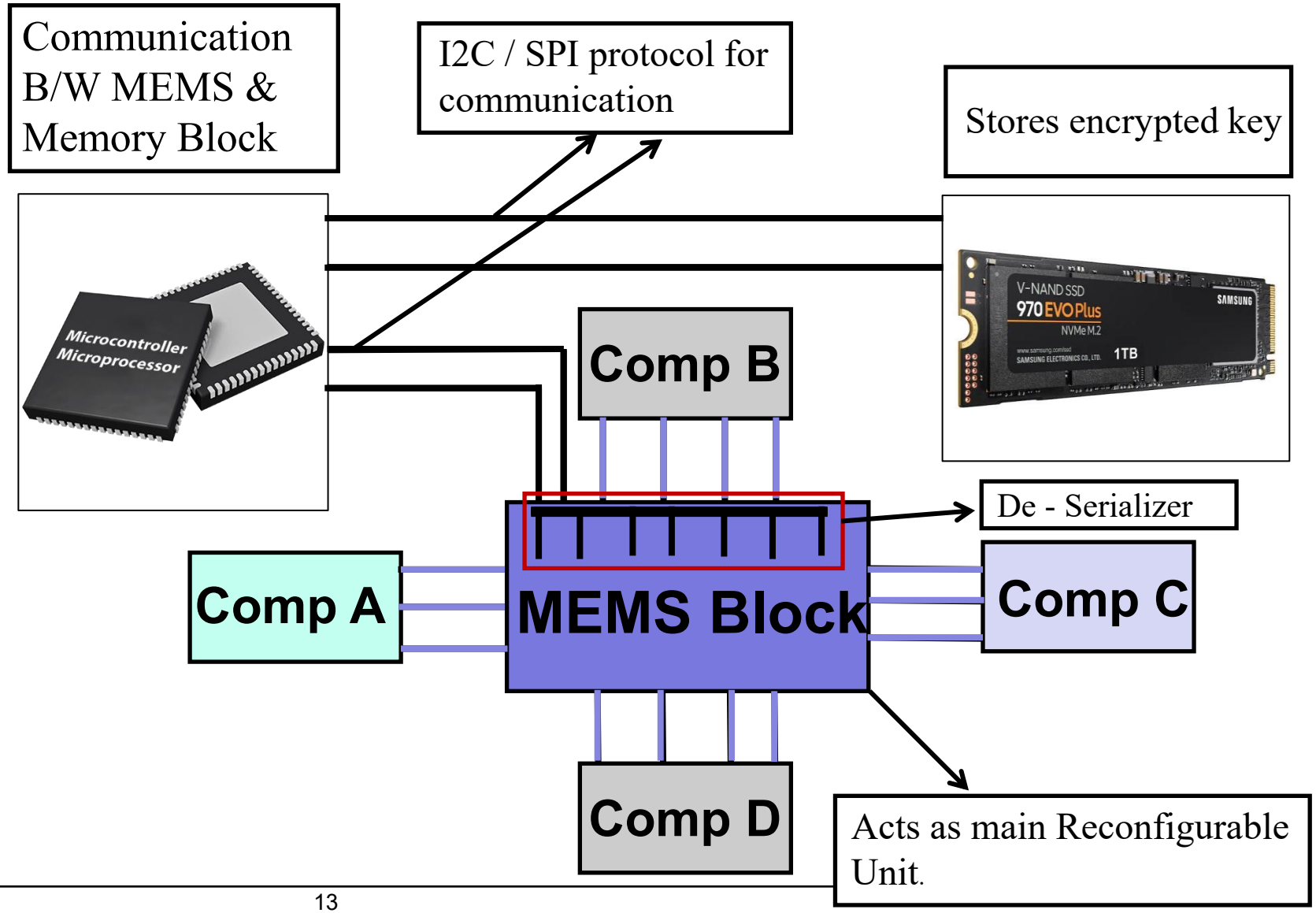
Step by Step Process

- **Power-Up**:
- Processor initializes and verifies the NVM integrity through digital certificate saved.

- **Key Retrieval**:
- The processor retrieves and decrypts the key securely.

- **Key Validation**:
- The MEMS block authenticates the key and configures accordingly.

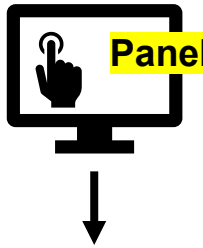
- **Configuration**:
- MEMS block establishes secure communication pathways between components.



MEMS-Enabled PCB Security (MEPS) – Workflow

Pre – Obfuscated Netlist → MEPS TOOL → Post – Obfuscated Netlist

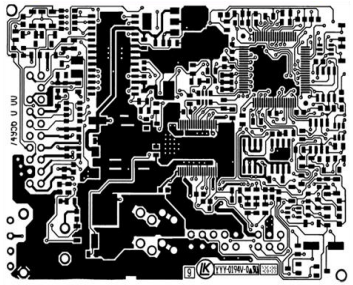
Constraints



User Inputs

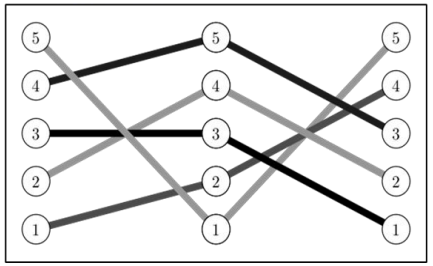
- Pre-Obfuscated Netlist
- Priority Components
- No of MEMS Plug In
- Size of MEMS Plug Ins

Parsed Netlist

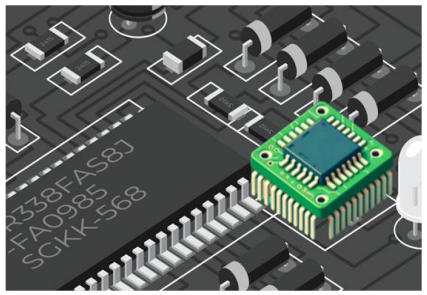


Identify Target Regions

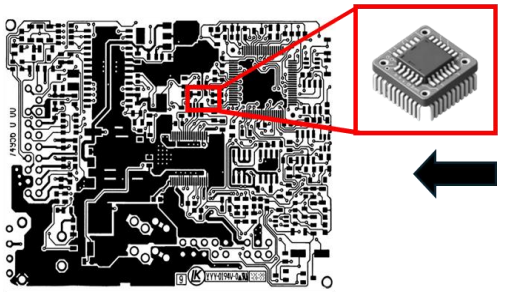
Assign Placement Scores



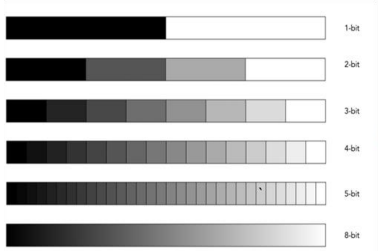
Finalize Placement



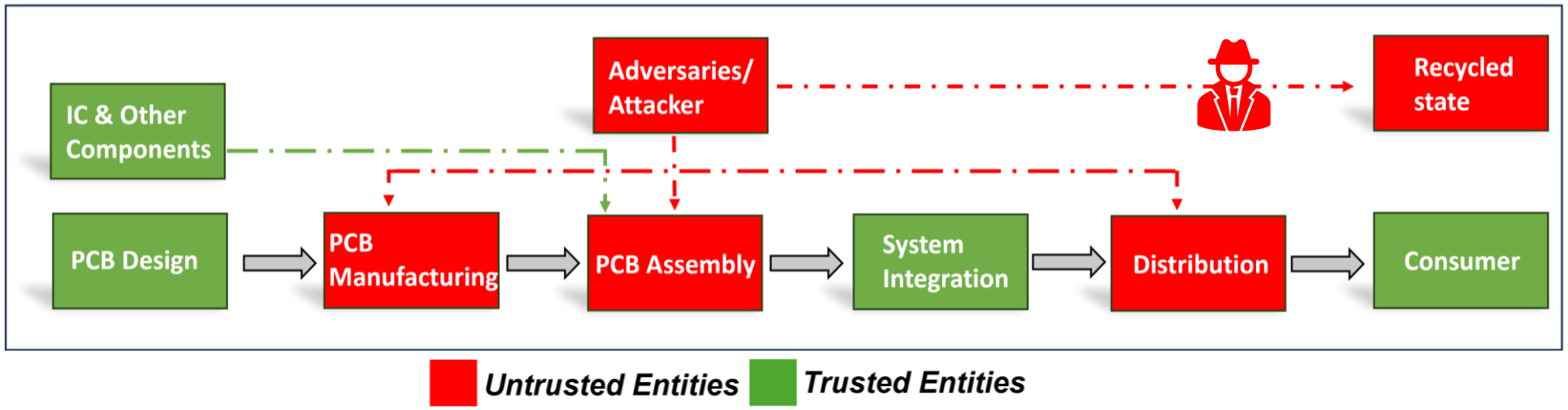
Modified Netlist



Configuration Bits

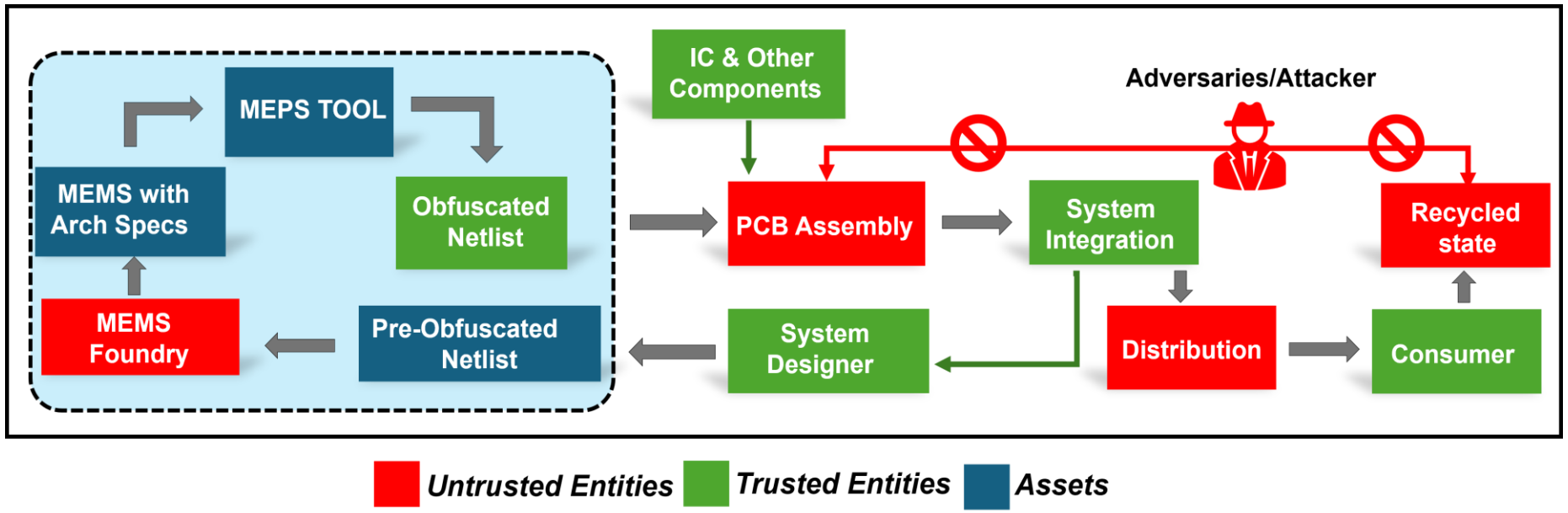


Supply Chain Before and After



Without MEPS

- Higher risk of tampering and counterfeiting.
- Predictable interconnects enable reverse engineering.
- Vulnerable end-of-life security.



With MEPS

- Unique MEMS arrays prevent replication.
- Reduced supply chain attack risks.
- Strong protection against reverse engineering.

MEMS Cantilever Beam Characteristics

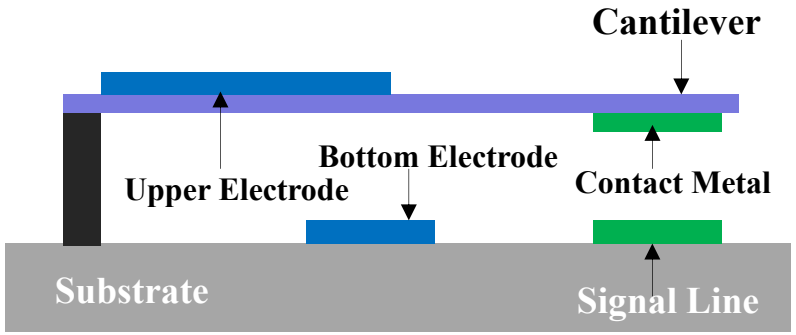


Table 1. Young's modulus and Poisson ratio for several materials

Material	Young's modulus (E) [GPa]	Poisson ratio (ν)
Polysilicon	141	0.27
Aluminum	70	0.33
Gold	79	0.44

for $L = 260$ μm, $w = 50$ μm, $h = 1$ μm and $d_o = 1$ μm

Beam Material	Density (kg/m³)	First natural frequency (kHz)
Polysilicon	2330	18.590
Aluminum	2700	258.03
Gold	19300	4.834

Component	Vibrational frequency
Submarine	10 – 200 Hz
Commercial aircraft	10 – 100 Hz
Military aircraft	10 – 2000 Hz
Medical devices (MRI)	20 – 100Hz

$$\frac{d^2y}{dx^2} = \frac{M}{EI}, \Rightarrow$$ Deflection of Cantilever beam

Higher deflection

Undesirable properties:

- Increased contact resistance
- Material fatigues
- Stiction
- Electrical failures

Natural frequency — **Higher the gap** — Operating environment frequency ⇒ Better performance

PSM proposed MEMS switch contains Aluminum, hence the optimal choice

Testing Methodologies

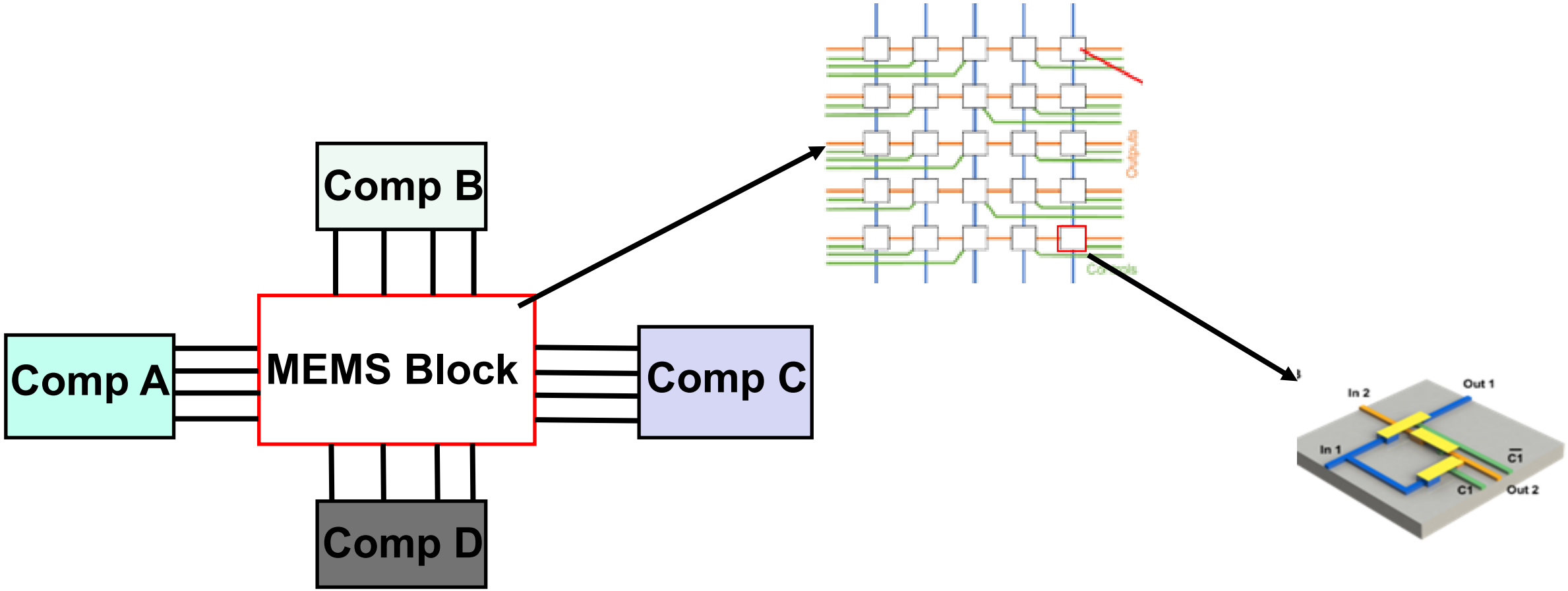
Tests	Details	Standards
Physical Inspection	Physical Inspection and Visual Check	ISO 9001:2015 – Quality management – Requirements. KGD
Electrical Characterization	Contact Resistance, Electrical Performance and Switching Performance Tests	MLF - PRF - 123 – Performance Specification Electronic Components, General Specification for, IEC 60512 – Connectors for Electronic Equipment Tests and Measurements, IEEE 1452 – Standard for a Smart Transducer Interface and Sensors and Actuators
Mechanical Characterization	Reliability and Durability Tests	IEC 60749 – Semiconductor Devices – Mechanical and Climatic Test Methods
	Temperature and Environmental Tests	MIL-STD-810 – Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
	Vibration and Shock Resistance	IEC 60068-2 – Environmental Testing – Part 2: Tests, Test B: Dry Heat

Additional Testing Plans

Tests	Standards
Hermeticity and Packaging Tests	ASTM E2512 – Standard Test Method for Determination of Noise Equivalent Power (NEP) and Noise Equivalent Concentration (NEC) of a Photoacoustic Spectrometer
Calibration and Standardization	ISO/IEC 17025 – General Requirements for the Competence of Testing and Calibration Laboratories
Failure Modes and Reliability Tests	JEDEC, JESD22 – Series of standards for testing semiconductors devices, including mechanical and Environmental tests.

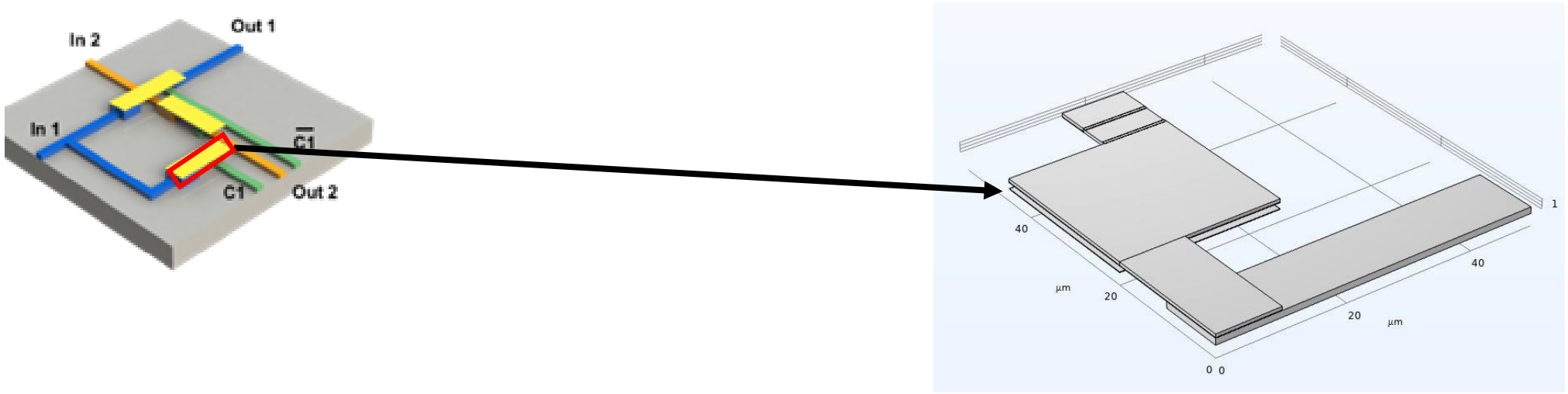
ASU Goals

- Design and Fabrication of MEMS block is critical to system level design
- Within each MEMS block, switching cells are present
- MEMS cantilever switches are the critical devices within each cell



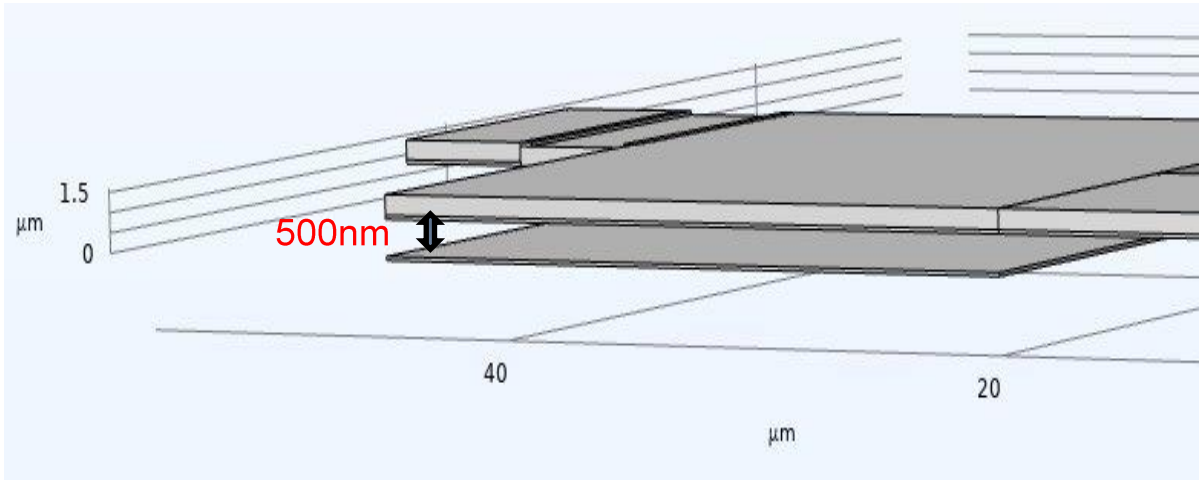
ASU Goals

- Initial design work – proof of concept for working switch structures
- Then, implementation into obfuscation cells and blocks may be initiated



Why MEMS?

- ❑No leakage current to detect at DC, difficult to detect at AC – Improves security by mitigating successful probing efforts
- ❑Sub-Micron Air Gap with high aspect ratio to cantilever height – makes optical and electron imaging difficult
- ❑Large dielectric features relative to metallic features – Further increases electron imaging difficulty
- ❑Commonly Fabricated – Much industry support from companies like HRL, ADI, TI...etc.



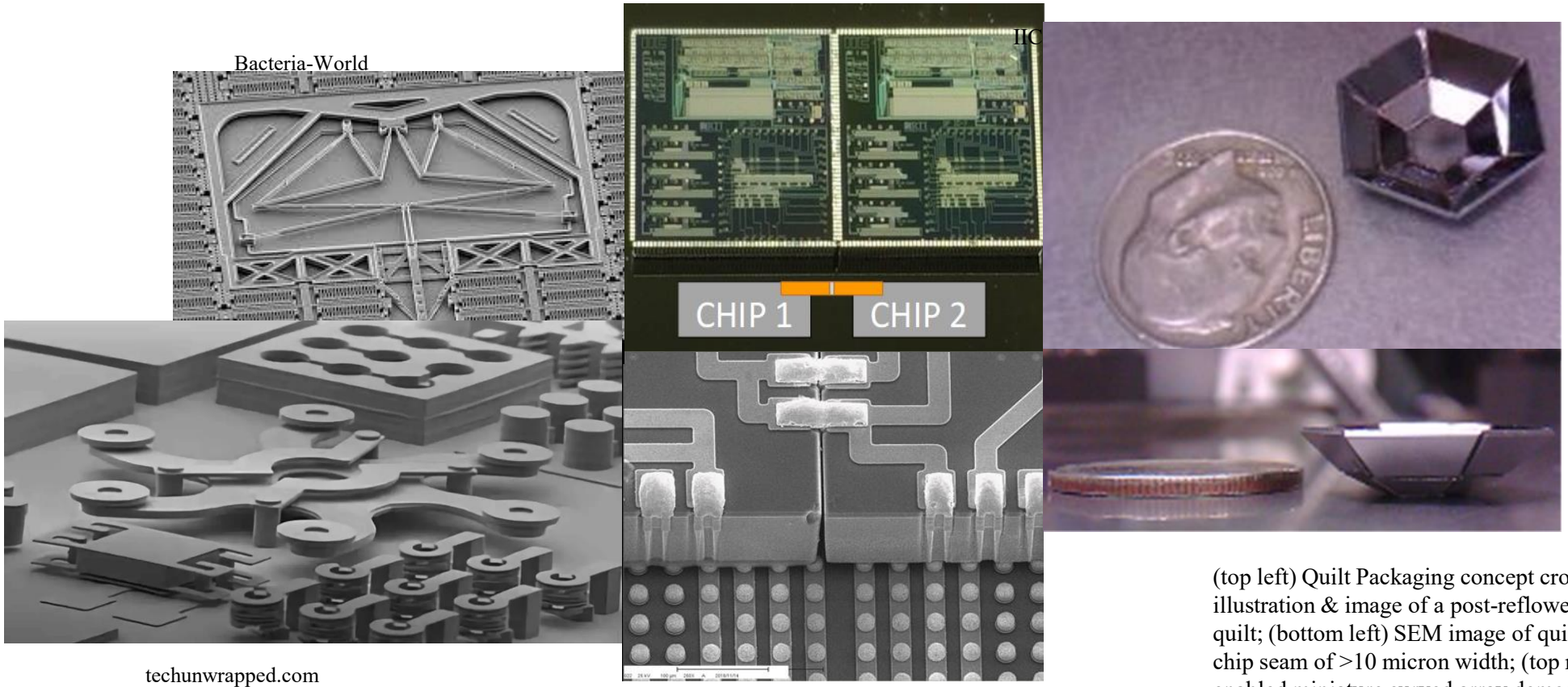
ANALOG DEVICES
HEAD OF WHAT'S POSSIBLE™

NHanced SEMICONDUCTORS

HRL LABORATORIES

NHanced Semi: Micro-Connections and 3D Structures

MEMS + Precision Electronics

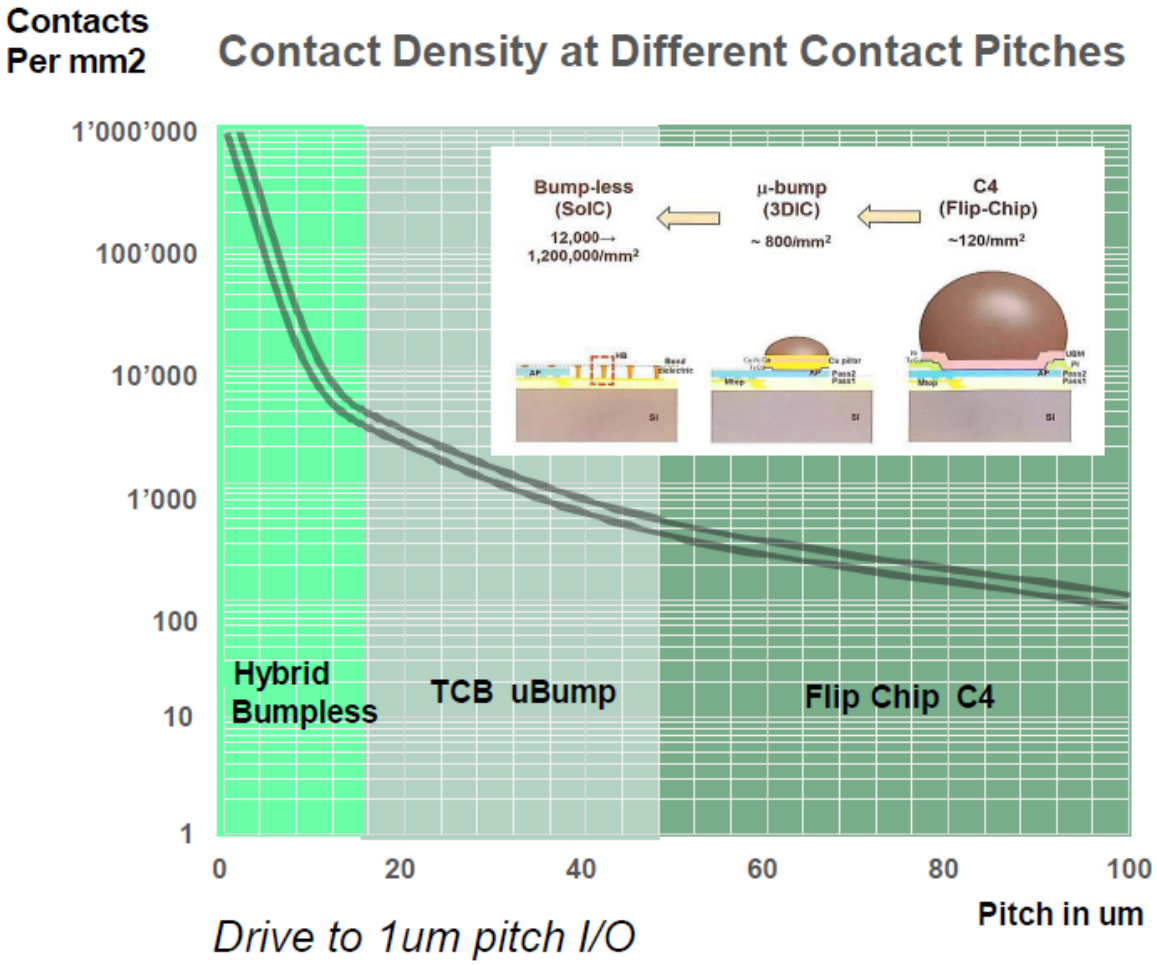


techunwrapped.com

(top left) Quilt Packaging concept cross-section illustration & image of a post-reflowed QP CMOS quilt; (bottom left) SEM image of quilted chip-to-chip seam of >10 micron width; (top right) QP-enabled miniature curved array demonstration article; (bottom right) profile view of QP-enabled miniature curved array.

NHanced SEMICONDUCTORS

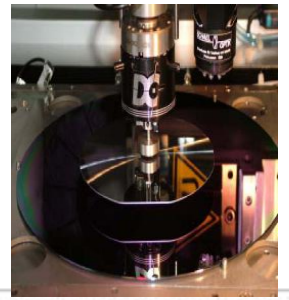
Hybrid Bonding Innovation

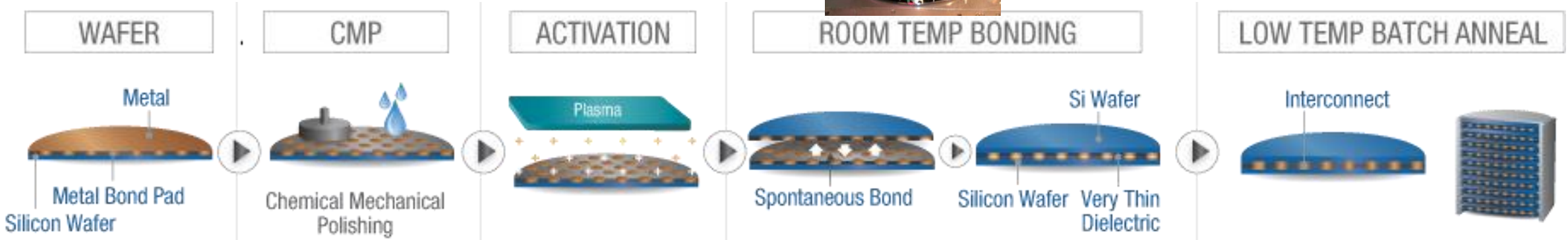


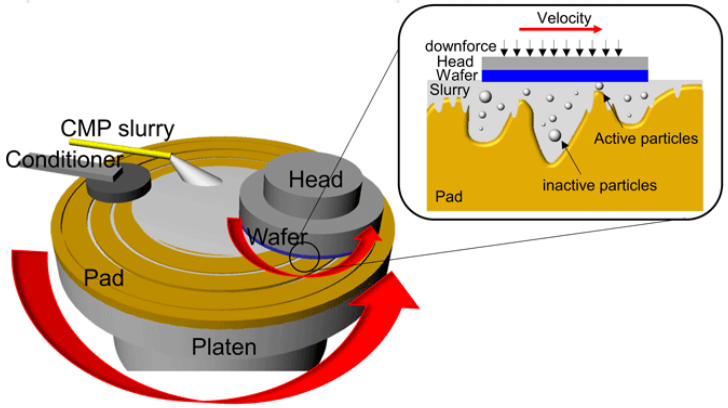
Tom Strothman, BESI

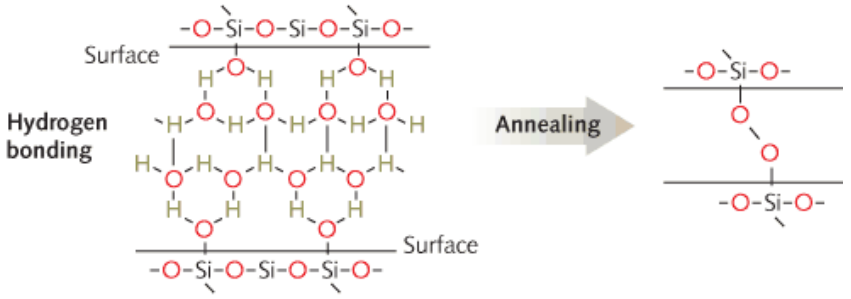
Intel

DBI®: Low Temperature Hybrid Bonding Process



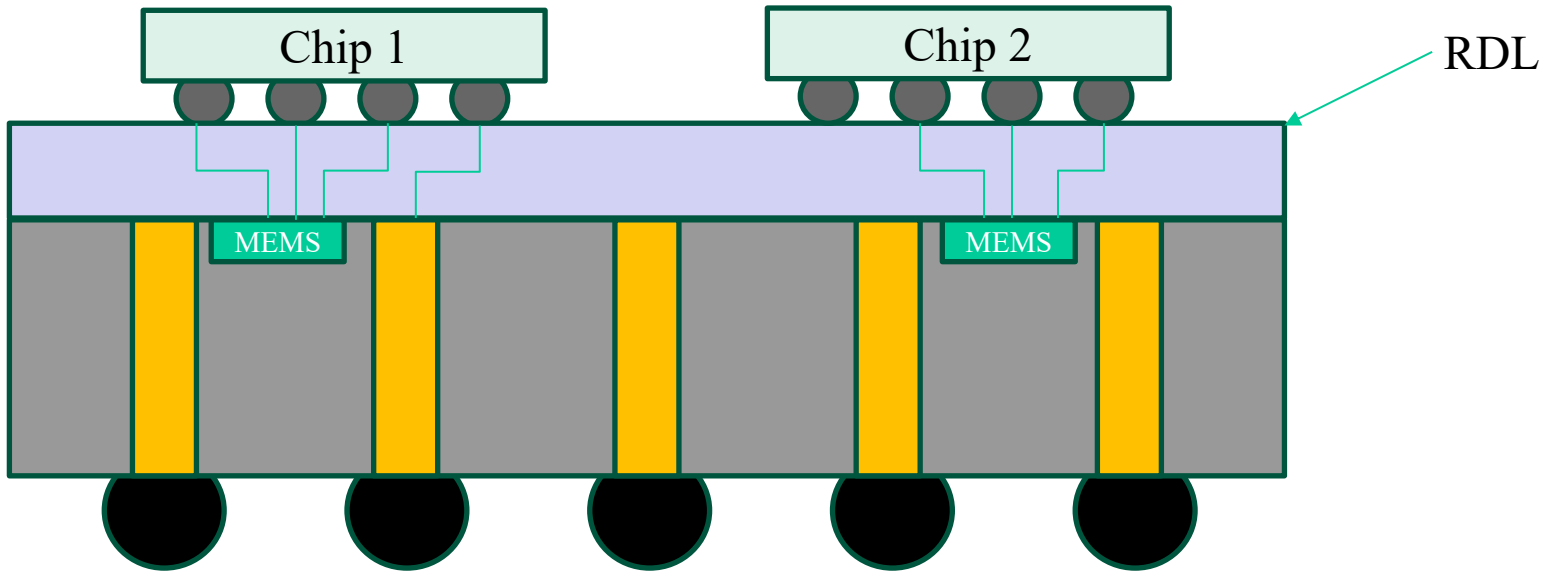




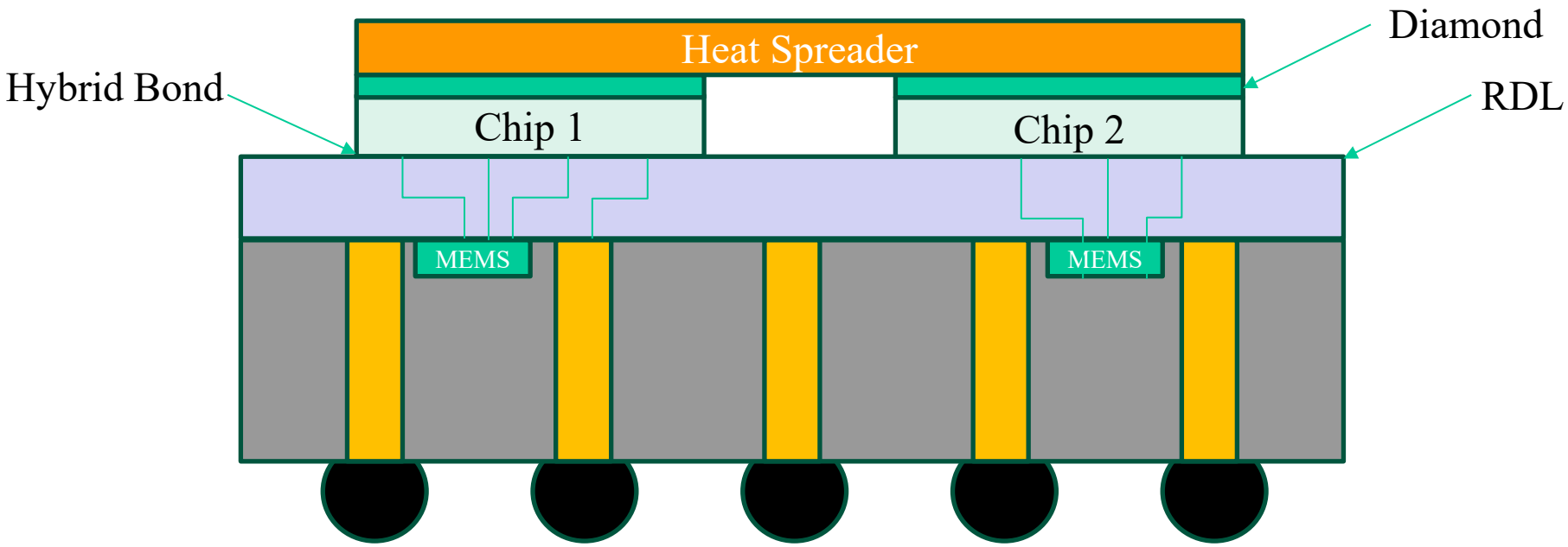


Jihoon Seo / Materials Research Society

Integrate a MEMS Device into a Si-Interposer



High Performance Package Using Si-Interposer



Testing Capabilities at SCAN Lab

Orion Nanofab
PHEMOS
Skyscan nanoCT
FERA3
LYRA3
Terahertz
Allied Sample Preparation
Optical Microscope
Acoustic

Virtual Walk: https://my.matterport.com/show/?m=YVWh646Zp5L
Lab Dataset: https://physicaldb.ece.ufl.edu/

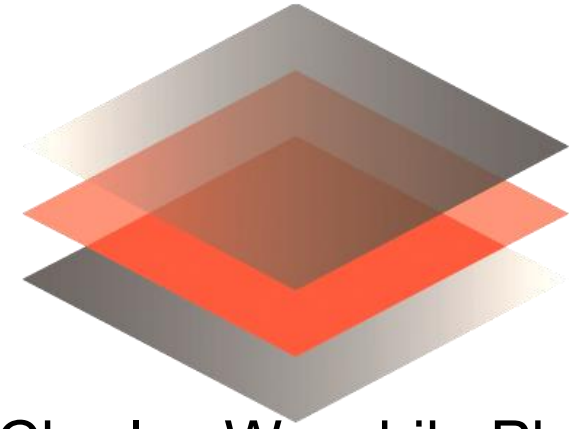
Summary

- A new focus on next generation of SECURED PACKAGES
  - Advanced Packaging
    - Unique MEMS arrays prevent replication.
    - Reduced supply chain attack risks.
    - Strong protection against reverse engineering.
  - Future is heterogenous integration using hybrid bonding
  - Interconnect focused – all BE0L additive processing
    - Better ROI
    - Lower development costs
    - Lower CAPEX
  - Leveraging existing foundries
    - Split Fab
  - More Than Moore Technologies
    - IP Centric
    - IP driven value – not cost of capital

Split Rock Lens – StackExchange

System Level Moore's Law

Thank You



Charles Woychik, Ph.D.
VP Business Development
NHanced Semiconductors, Inc.
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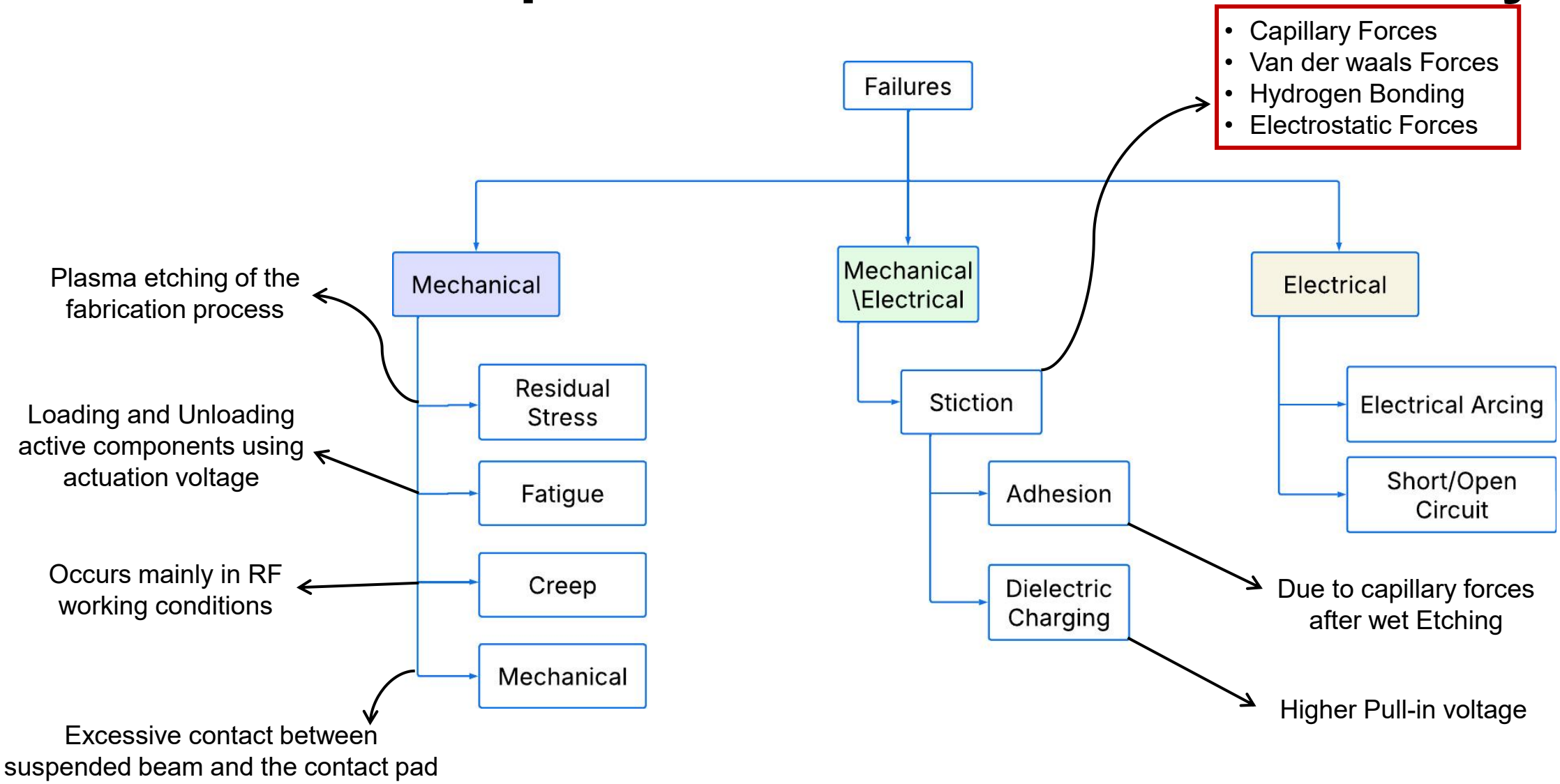
Backup

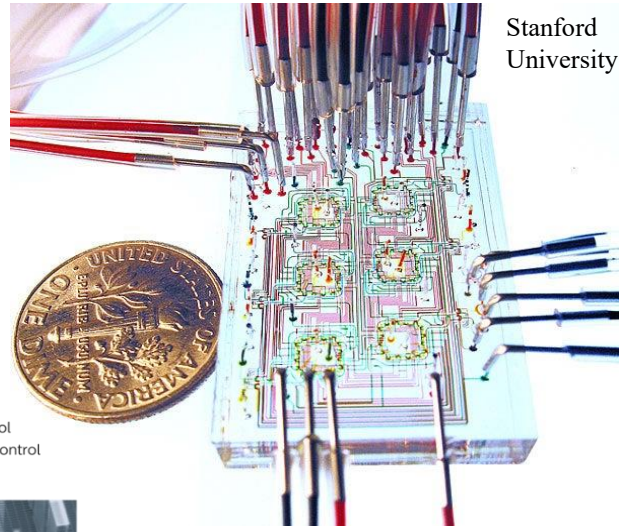
Failure Map of MEMS Switch for Reliability



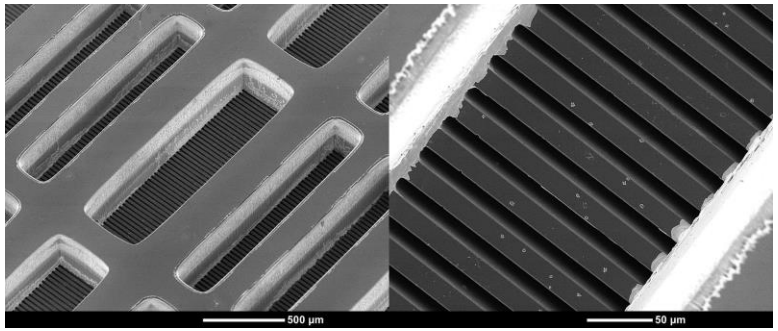
AP Services: Microfluidics and Cooling

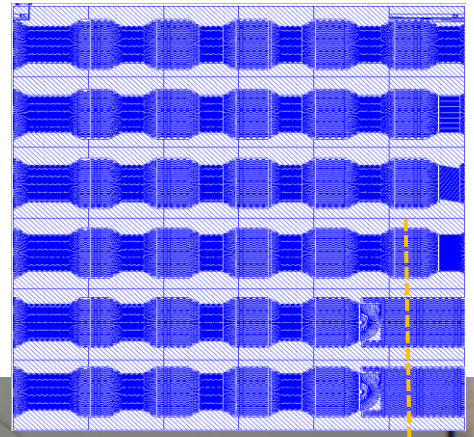
Chip Scale Cooling
For Ultra-Dense Electronics

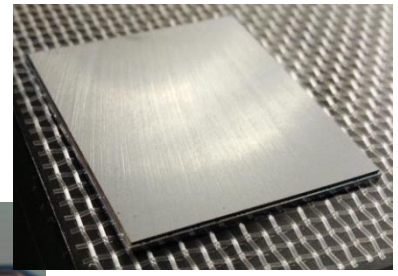
Biology + Electronics

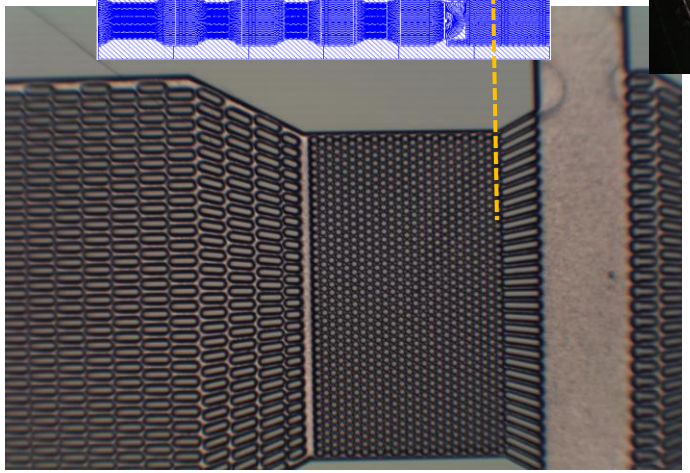


Purdue



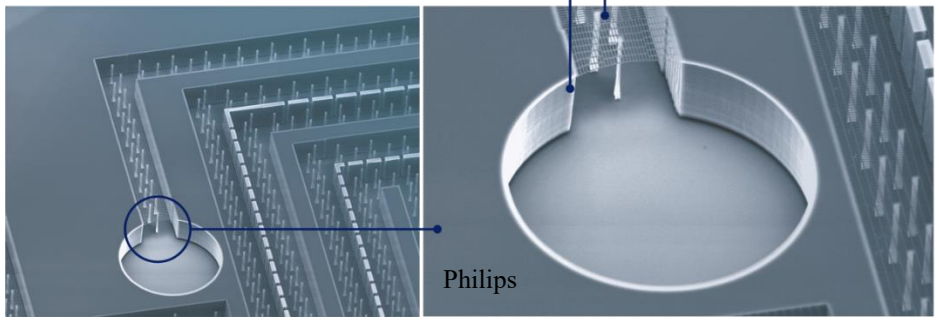






Our state-of-the-art tool set enables us to create microfluidic structures with accurate control:

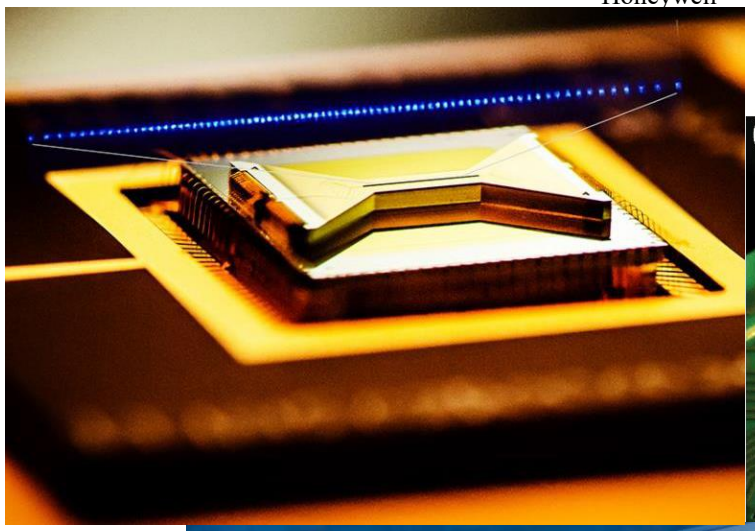
- <5 degree slope control
- Sub-µm feature size control
- µm range feature size



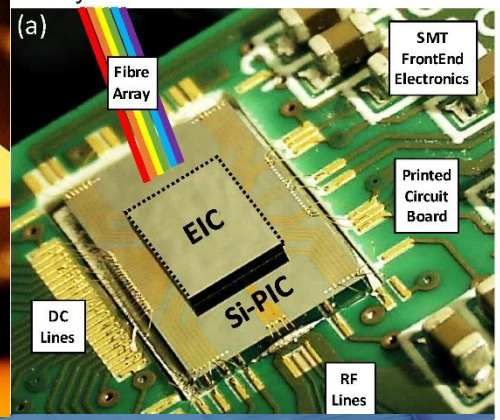
AP Market Drivers: Photonics & Quantum

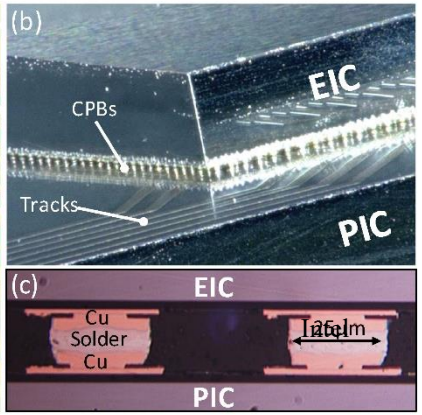
- I/O
  - Tb/s, <<100fJ/b
    - SiP 500ff I/O Load
    - 2.5D 25ff I/O Load
    - 3D 3ff I/O Load
- Processing
  - “Quantum Leaps”

Honeywell

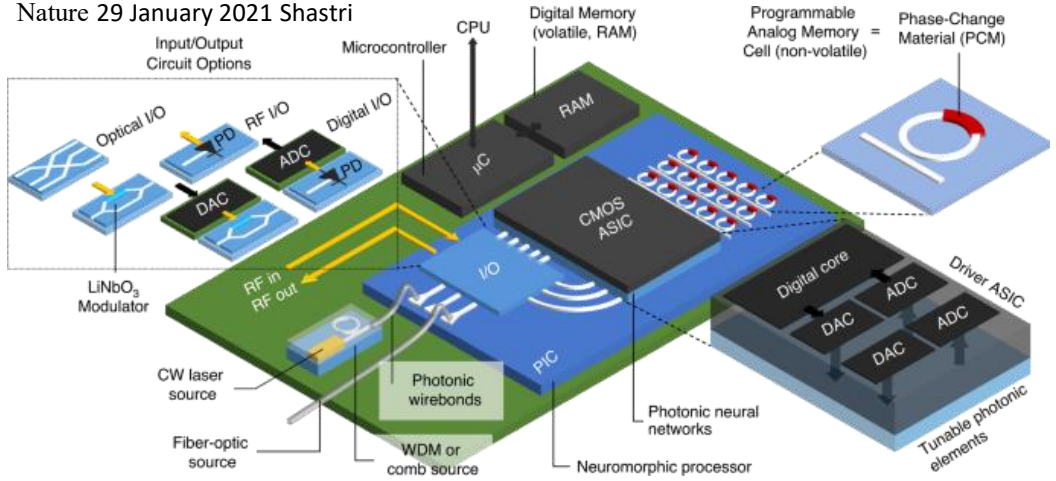


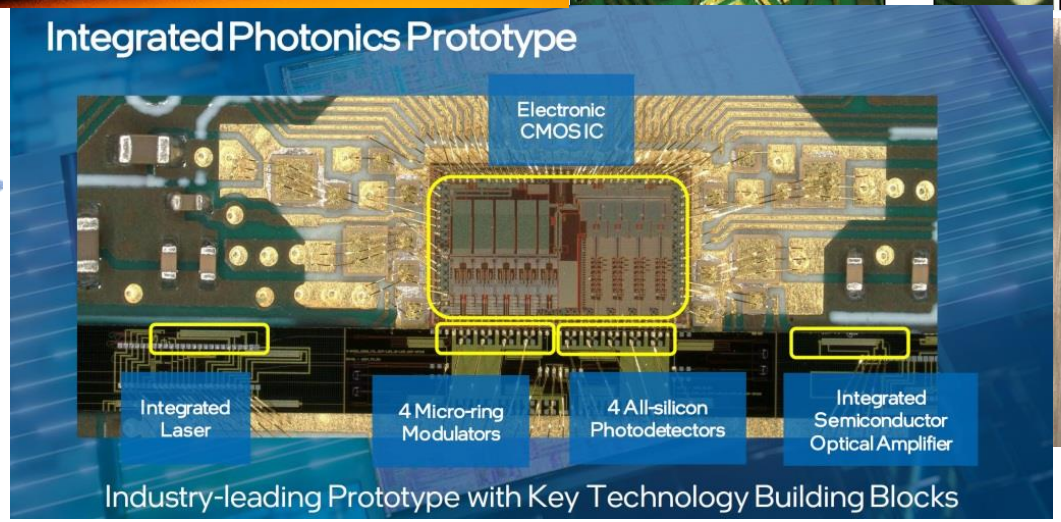
Tyndall National Institute Carroll et al

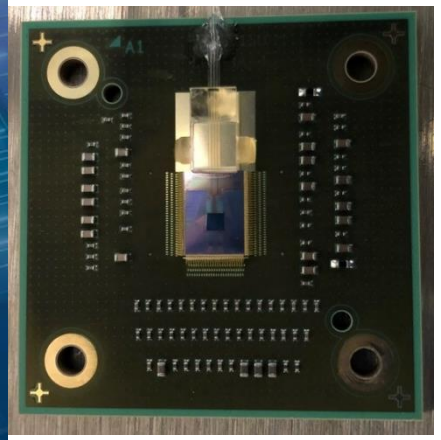




Nature 29 January 2021 Shastri



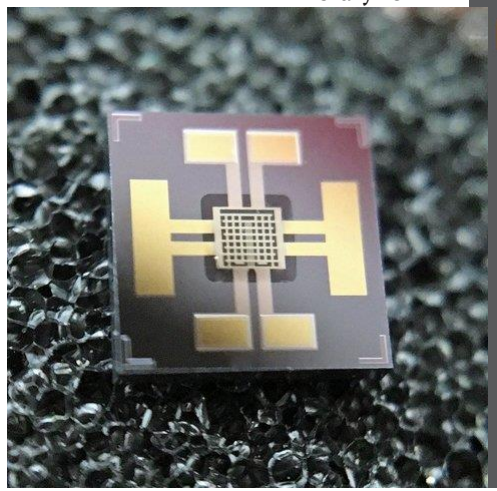


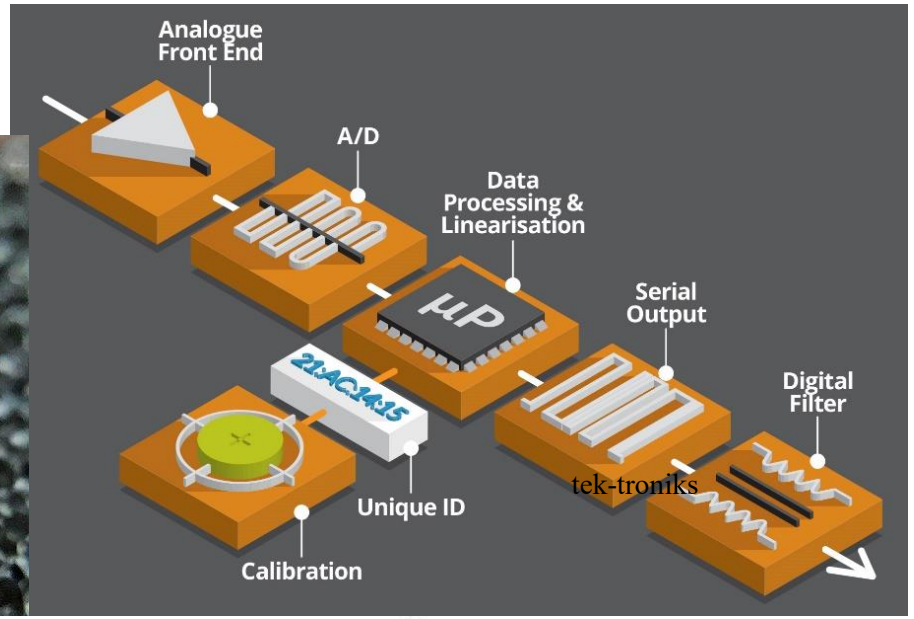


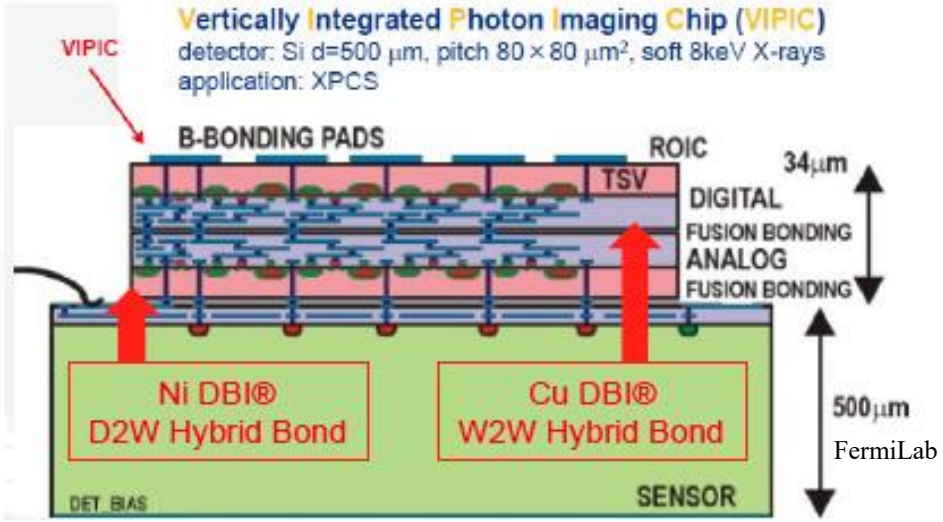
AP Market Drivers: Intelligent Sensors and Edge Compute

- Communication is limited
  - Data movement costs power
  - Data movement costs time
  - Data movement costs money
  - You can't aways "phone-home"

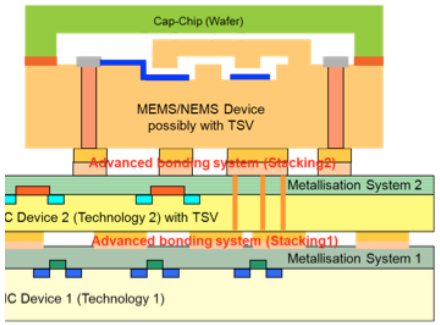
Micralyne







FermiLab



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