

# BRIDG Overview

Sep 20, 2018

109,000 sq ft facility  
26,500 sq ft, Class-100 CR  
9,400 sq ft, Class-10K CR  
10,000 sq ft, Lab Space  
“Trust-Enabled”, ITAR

**+Location Significance**

**+Purpose**

**+Abilities**

**+How to engage**



109,000 sq ft Facility  
26,500 sq ft Class 100 CR  
9,400 sq ft Class 10K CR  
10,000 sq ft Lab Space  
“Trust-Enabled”, US owned

**Nano-Electronics Fabrication Facility: Cleanrooms and Labs**  
**Located within a new 500-acre high-technology campus in Osceola County, FL**

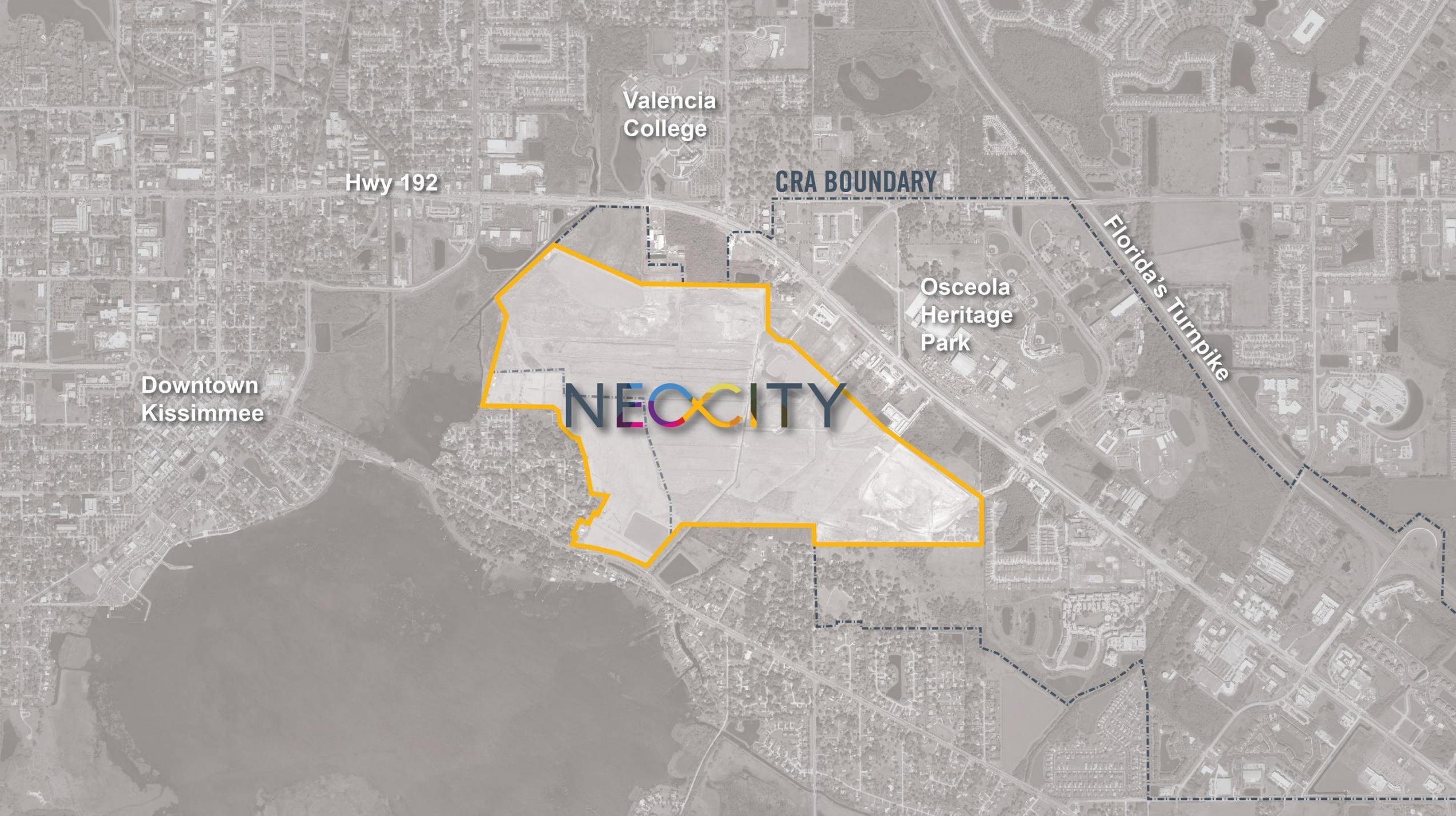
**+ 4 story, 100k ft<sup>2</sup> class A**

**+ BRIDG & IMEC; top-two floors**

**+ Possible co-location collaboration space within BRIDG or other floors depending on space requirements**

**+ Q2 2019 completion date**





Valencia College

Hwy 192

CRA BOUNDARY

Florida's Turnpike

Osceola Heritage Park

Downtown Kissimmee

NEOCITY

# NeoCity Vision



# NEOCITY



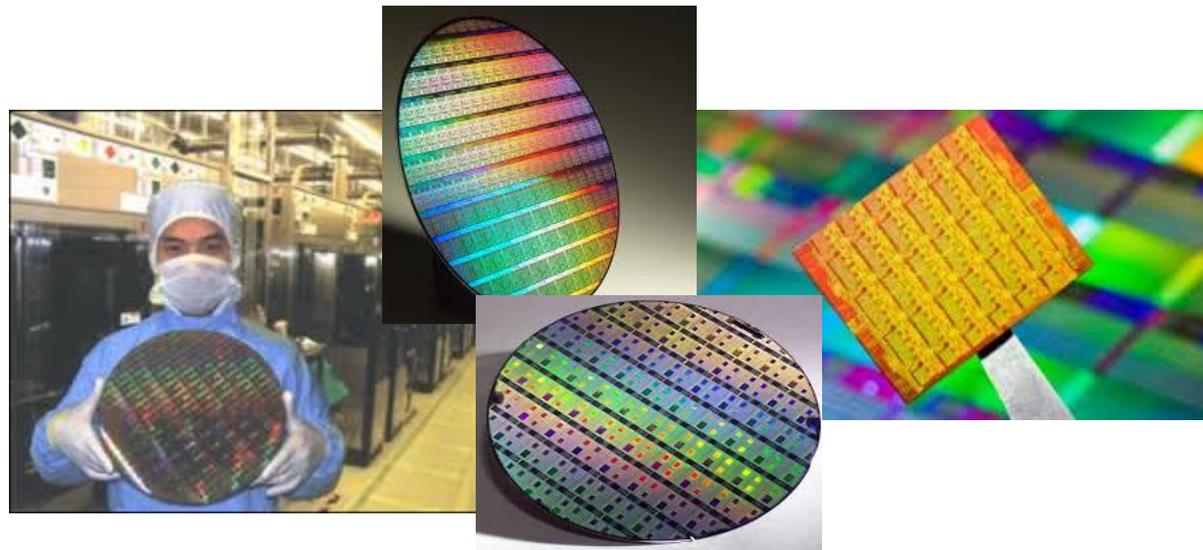
# Central Plaza



## + BRIDG is a service provider for

- Advancing the manufacturing readiness level (MRL) of technology
- Prototyping of semiconductor-based technologies using BRIDG IP
- Providing low volume production of semiconductor-based technologies

## + BRIDG does not compete with its customers... and thus is not a product / systems company



## Innovation Networks & Open Innovation Programs that Bring Industry, Universities and Governments Together

### Universities

- Conduit for research to enter the market
- Broader capabilities to enable funded research
- Partnered research capabilities



### Government

- Supports state and federal priorities
- Enable tech transfer from National research labs and agencies
- Vital role in national security



### Industry

- Emerging technologies
- Secure manufacturing
- New product evolution
- Low-volume production



### Suppliers

- Equipment
- Materials
- Software
- Industry R&D Labs & Programs



# BRIDG Facility



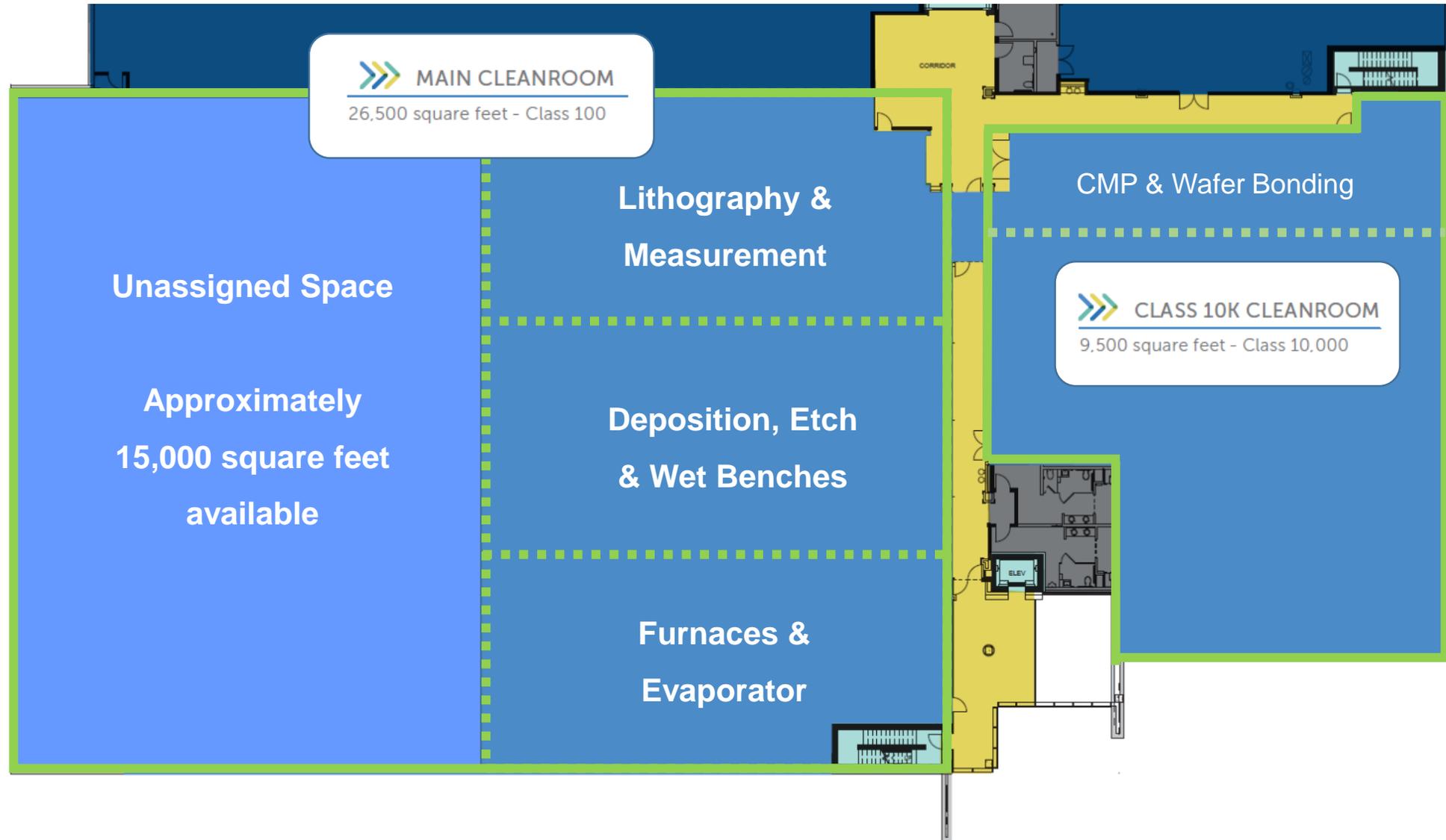
Main cleanroom operating at class 100,  
30K sqft



Cleanroom operating at class 10,000



26,469 SF sub fab



# Core Tool Installations Complete June 2018



## 200mm Tool Installation and Calibration

## + BRIDG is “Trust Ready”

- Heading towards DMEA Trusted Supplier Accreditation
- US employee workforce

## + DSS Facility Clearance at SECRET level

- **Received July 2018**
- Classified Document Safe

**SECRET**

## + ITAR Qualified

- Fab, Lab, Office and IT infrastructures

## + BRIDG has been sponsored by AT Program Office to become a cleared facility early 2018

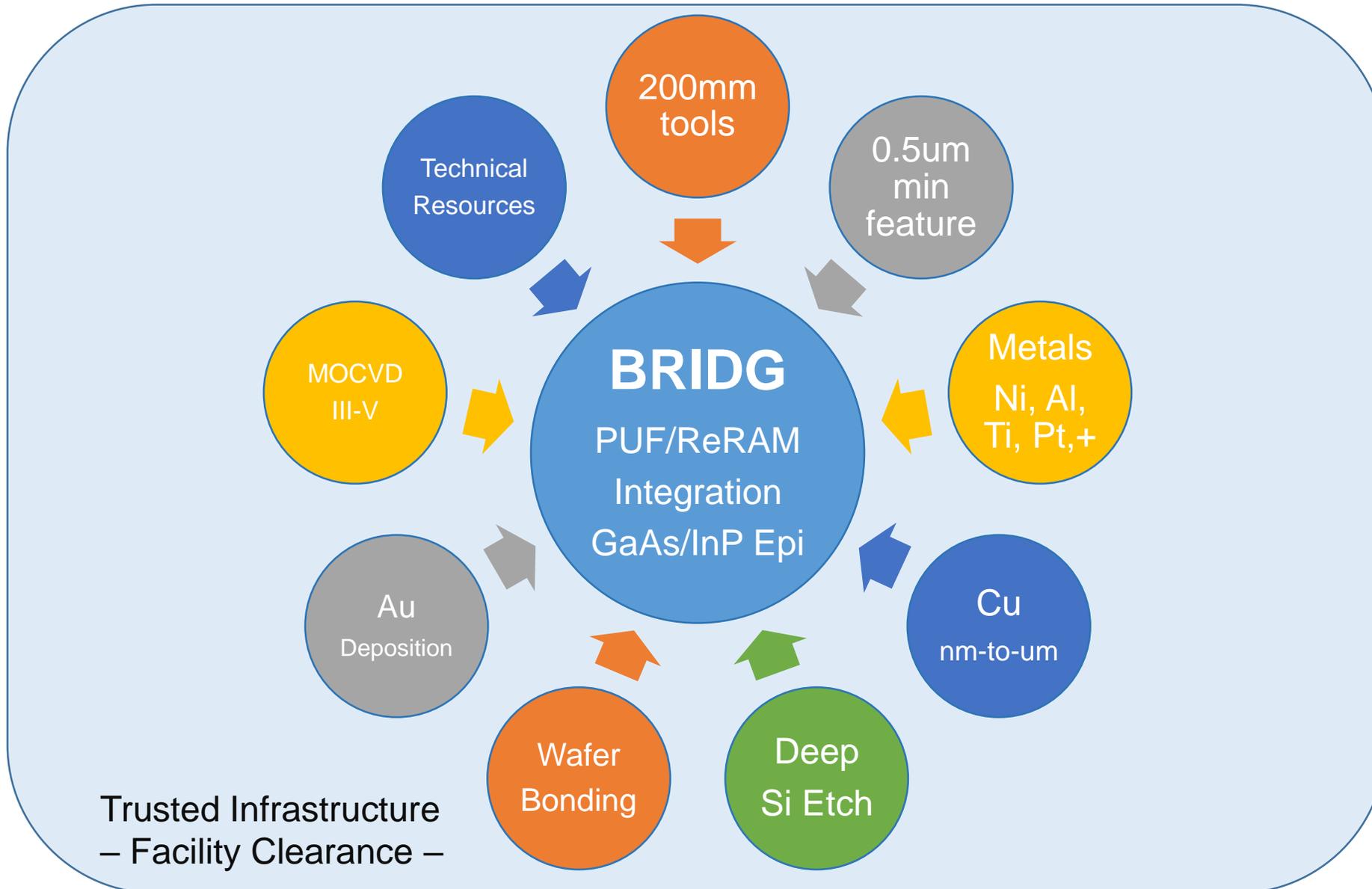


U.S. Department of Defense  
**DEFENSE SECURITY SERVICE**



**ITAR**  
Registered  
International Traffic  
in Arms Regulations





**FabTool Installations**

**PUF/ReRAM**  
*(Process Dev)*

PUF-based Post-Quantum Crypto Systems, HW Cybersecurity

ReRAM Memory

**System Integration**  
*(Process Dev)*

Imec collaboration opportunity

**Sensor/IOT Platform**  
*(Design & Develop)*

SWAP Enablement via System Integration w/ copper interconnect, 2.5D, 3D, Wafer & Die Bonding, Back End Of Line (BEOL) CMOS, System-in-Package (SIP)

Integrated wireless comms, security (networking & crypto), high perf uP w/ AI, mem, MEMS-IMU, and any other sensor

**Sensor R&D and Wafers**  
*(Process Dev)*

Imec collaboration opportunity

GaAs & InP epitaxial wafers for sensors, lasers, photoconductors, etc.

**MEMS**  
*(Technology Transfer)*

Motion Sensors, Virtual Reality Sensors, Augmented Reality Sensors, Acoustic & Pressure Sensors

**GaN Epi & Processing**  
*(Process Dev & Tech Transfer)*

GaN on Silicon Epi growth and device processing

RF and Power devices

**Silicon Photonics**  
*(Technology Transfer)*

Imec collaboration opportunity

Sensors, Imagers

**Legend**

- In Process
- Planned
- Consider
- Applications

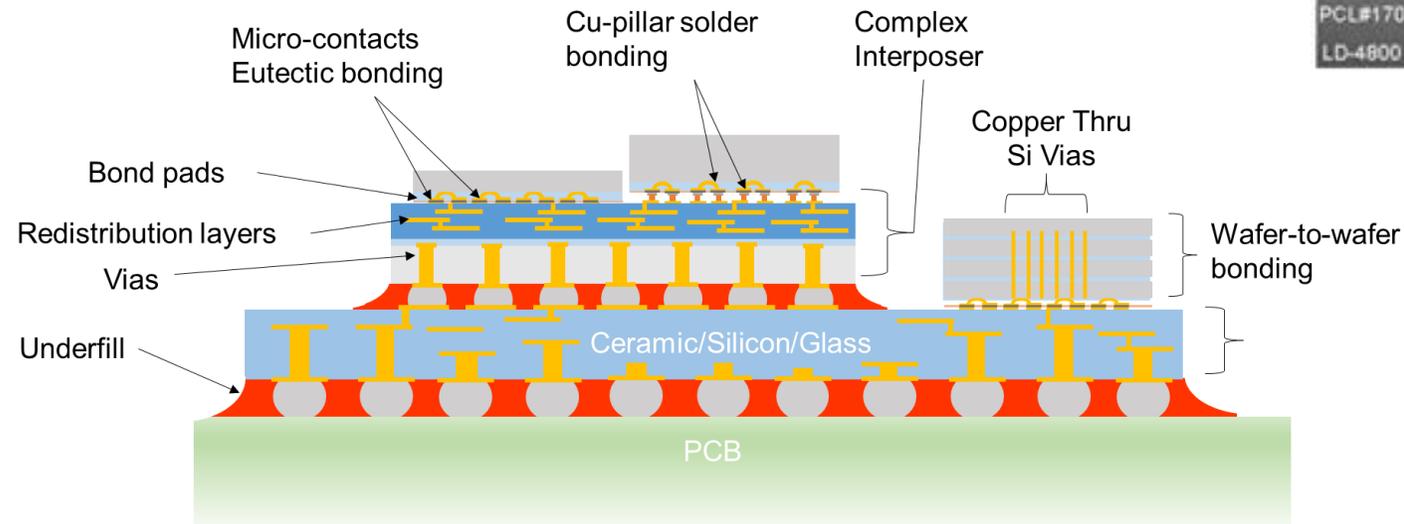
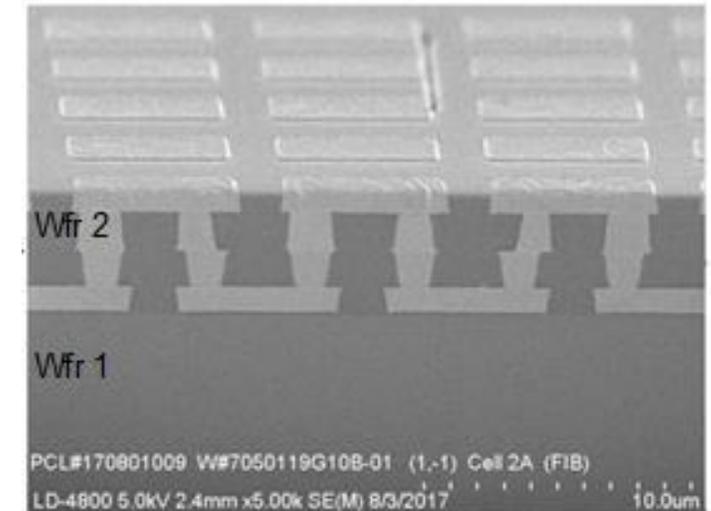


## + Development of advanced packaging and integration technologies to enhance

- Security– process split lots in non-secure foundries, assemble in a secure environment
- Expand system functionality – integrate multiple function die in a package
- Value – reduce size, weight and power
- Complex systems– heterogeneous integration, 2.5D, 3D

## + Initial processes

- Wafer-to-Wafer Bonding- oxide bonding, ultra-high density interconnect
- Wafer level fanout- thinned, creating an integration assurance platform



## + Resistive RAM (ReRAM) based Physically Unclonable Function (PUF)

- Newly discovered PUF capability leaves no trace or residue in hardware – extremely hard to discover

## + Applications: Secure the IOT, validate payment systems, ensure safe connectivity, smartcards, authenticate sensors, and protect sensitive military data and systems

## + Significance: provides a **root-of-trust for all layers of security** that is

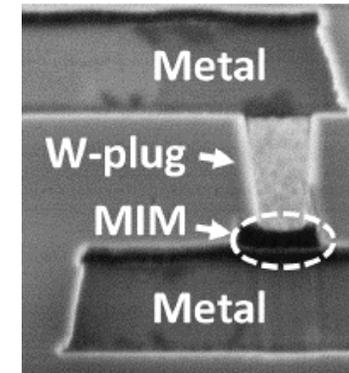
- Extremely **low power** (femto-Joules to read)
- Highly integrate-able into any computer system, ASIC, SoC and FPGA
- **Virtually impossible to hack**; non-detectable element
- Very high source of entropy with stability, reliability and performance
- Provides Anti-Tamper protection against cloning, counterfeiting, overbuilding, reverse engineering and data leakage
- Key storage, key management and crypto functionality
- Radiation hardened
- Requires specific methodology for using it



## + ***BUT... it still needs testing and qualification to gain market acceptance***

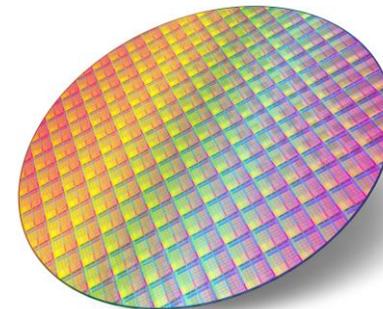
## + PUF / ReRAM

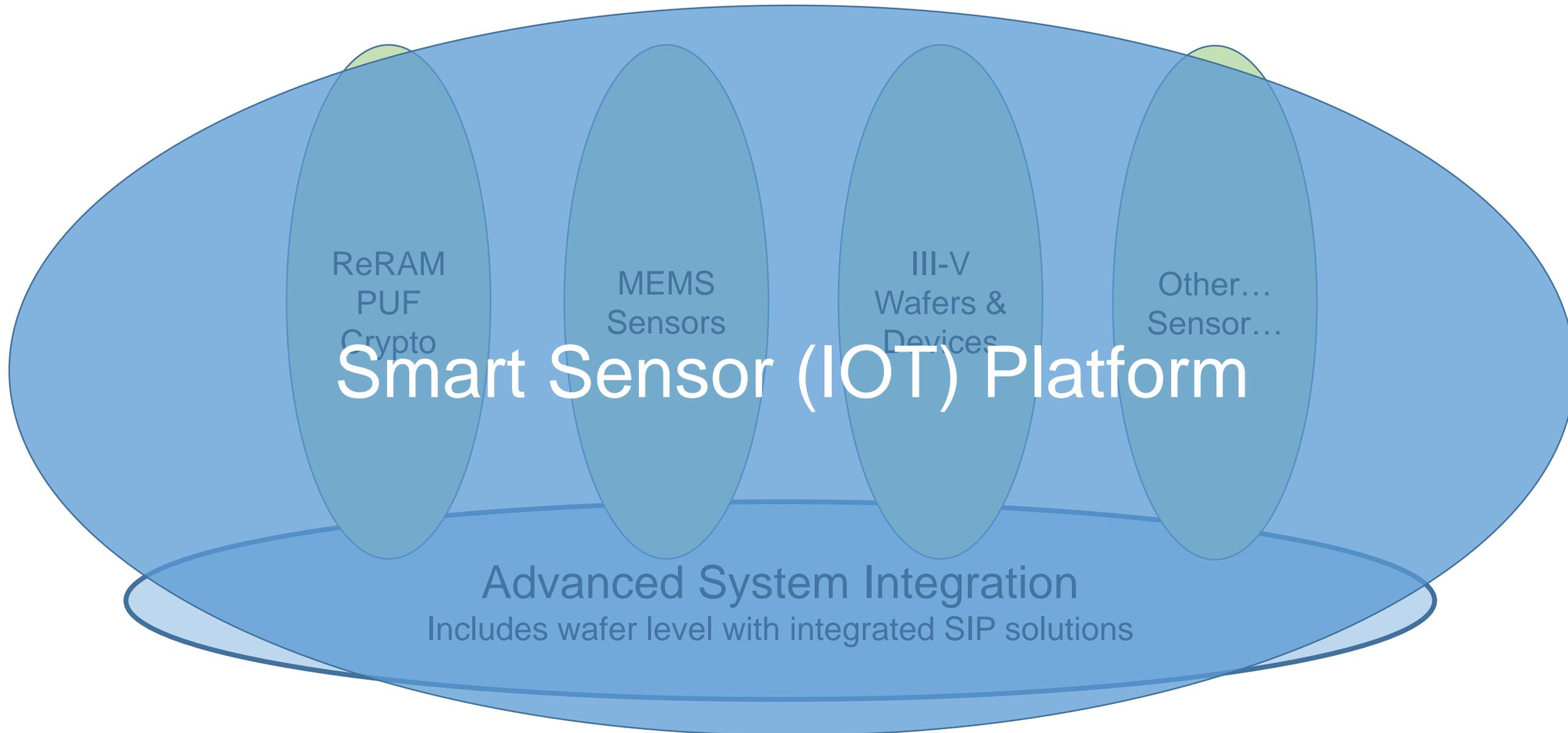
- Anti-Tamper, non-detectable information – Newly discovered PUF capability leaves no trace or residue in hardware – extremely hard to discover
- Significance -enables a cryptography solution that is
  - > Extremely **low power** (femto-Joules to read)
  - > Highly integrate-able into any computer system
  - > **Virtually impossible to hack**
  - > Radiation hardened



## + III-V Epi Wafer Growth (non-GaN)

- Establishing III-V MOCVD reactor for unique wafer/device growth
- Small batch for cost effective epi-design evaluations
- InP, GaAs, others





## IMEC R&D PLATFORMS

### APPLICATION DOMAINS

SMART HEALTH



SMART MOBILITY



SMART CITIES



SMART INDUSTRIES

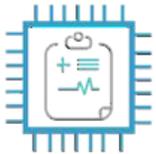


SMART ENERGY

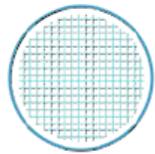


### SEMICONDUCTOR & SYSTEM TECHNOLOGIES

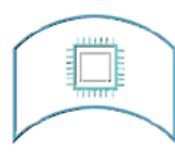
CORE CMOS



SENSOR TECHNOLOGY



FLEXIBLE TECHNOLOGY



PATTERNING TECHNOLOGY    LOGIC TECHNOLOGY    MEMORY TECHNOLOGY    INTERCONNECT TECHNOLOGY    3D INTEGRATION OPTICAL I/O

### DIGITAL TECHNOLOGY PLATFORMS

NETWORKING



DIGITAL PRIVACY & SECURITY



SOFTWARE & DATA MANAGEMENT SK



IMEC STATE-OF-THE-ART PHOTONICS FABRICATION FACILITIES

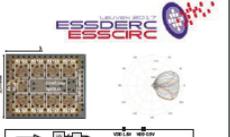


60 GHz phased-array transceiver in 28nm CMOS



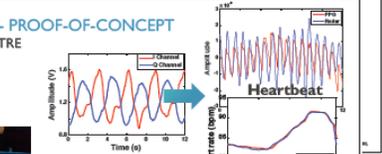
FRONT-END MODULE – GENERATION 5 FOR 60GHZ 5G COMMUNICATION

- Solution for highly integrated 60GHz phased-array radio transceivers including
  - PA's, LNA's, RF phase shifters, RFVGA's and combiners/splitters
  - 8 antenna paths, 5deg phase resolution



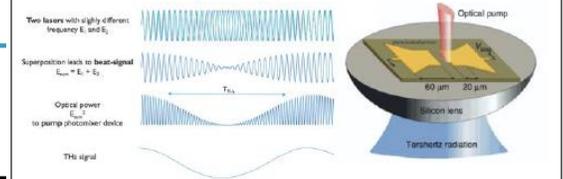
LOW-GHZ RF SENSING - PROOF-OF-CONCEPT PROTOTYPES AT HOLST CENTRE

- Low-GHz radar prototypes
  - 2.4GHz / 5GHz Doppler
  - 7GHz FMCW



PLENOPTIC HYPERSPECTRAL COHERENT THz IMAGER

THz SOURCE BY PHOTOMIXING



## Lithography

- Stepper –Nikon i-Line i12
- Coater / Developer – TEL ACT8

## Deposition

- CVD HDP – AMAT Centura
- CVD – AMAT Centura (W)
- CVD – Novellus C2 Sequel (SiN, SiO2)
- PVD – AMAT Endura (Cu, TaN, Al, TiN, RPC)
- Evaporator – Temescal UEFC-4900 (Au, Pt, Ti, Al, Ni, etc.)
- Furnaces – Tel Alpha 8s (Oxide, Nitride, Poly, Diffusion)

## Anneal

- Furnaces – Tel Alpha 8s Anneal
- RTA – SSI Solaris

## Etch

- AMAT CENTURA (Metal Etch)
- AMAT CENTURA (Oxide Etch)
- AMAT CENTURA (Poly Etch)
- Deep Silicon Etch – SPTS Rapier
- Asher – Trion Apollo III

## Plating and Wet Processes

- Batch Solvent Tool – Bold Technologies
- SEMSYSCO Triton (Electroplating, Liftoff, Solvent Strip and Acid Clean)
- Wafer Scrubber – OnTrak DSS2
- Wet Bench – JST (Acid, Base)
- Wet Bench – Bold (Solvent)

## CMP

- CMP – AMAT Mirra Trak (Cu)
- CMP – AMAT Mirra Trak (Oxide/W)

## Implant

- Ion Implant – Varian E500 (Medium Current)

## Wafer Bonding / Die Bonding

- Bond Aligner / Mask Aligner – SUSS MABA8
- Bond Alignment Metrology – SUSS DSM8/200 Gen2
- Bonder, Permanent – SUSS XB8
- Print Transfer – Xceleprint

## Material Preparation

- Laser Scribe – Lumonics GSI
- Box Washer – Flouroware HTC-810

## Metrology / Inspection

- CD SEM – SEM5 Hitachi 9200
- XRD, XRR, XRT – Panalytical X'PERT3MRD
- Defect Inspection – KLA 2139 - Bright Field
- Ellipsometer, Stress Measure – KLA F5x
- Goniometer – Rame-Hart
- Defect Measure – KLA Candela CS920
- Profiler – KLA P-170
- Digital Microscope - Keyence
- Overlay – Inspectrology
- 4-Point Probe – CDE

## Epi Growth

- III/V MOCVD – Veeco D180

## BRIDG is also a resource for microelectronics STEM workforce development:

Industry-driven workforce development program

Workforce Development Advisory Board

Ongoing engagement with defense companies, industry associations, universities to identify needs; periodic surveys

Convey information to pertinent academic institutions, and professional and industry associations

Develop and execute new coursework and programming for:

Undergraduate and graduate (course work, research projects, internships, training workshops, webinars)

Community college manufacturing training centers, leveraging NSF-funded Nanotechnology Applications and Career Knowledge (NACK) and Florida Advanced Technological Education (FLATE)

Small and medium-sized enterprises

Industry associations/professional societies

Internships for undergraduate and graduate students

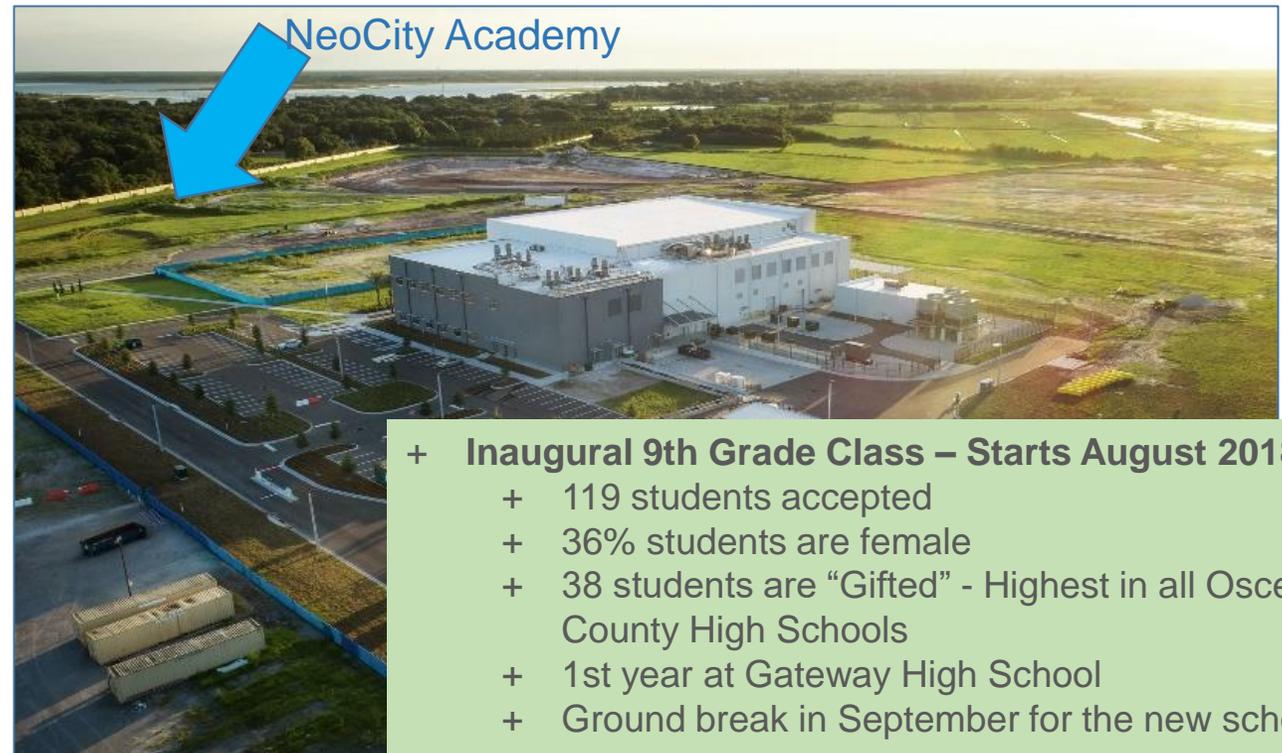
Foster university-industry personnel exchanges

**NeoCity Academy:** Osceola School District to construct demonstration magnet high school onsite. Land provided by county through unique cross-collaboration partnership.

BRIDG worked with County and SEMI to obtain certification as the **sole provider of SEMI curriculum**

+ Cultivate 10 year pipeline of next generation high tech workforce

+ <http://neoc.osceolaschools.net/>

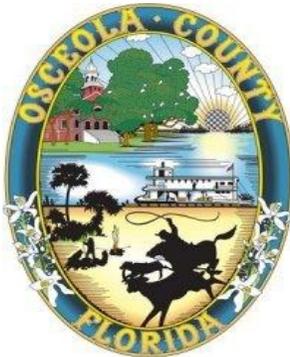


- + **Inaugural 9th Grade Class – Starts August 2018**
  - + 119 students accepted
  - + 36% students are female
  - + 38 students are “Gifted” - Highest in all Osceola County High Schools
  - + 1st year at Gateway High School
  - + Ground break in September for the new school

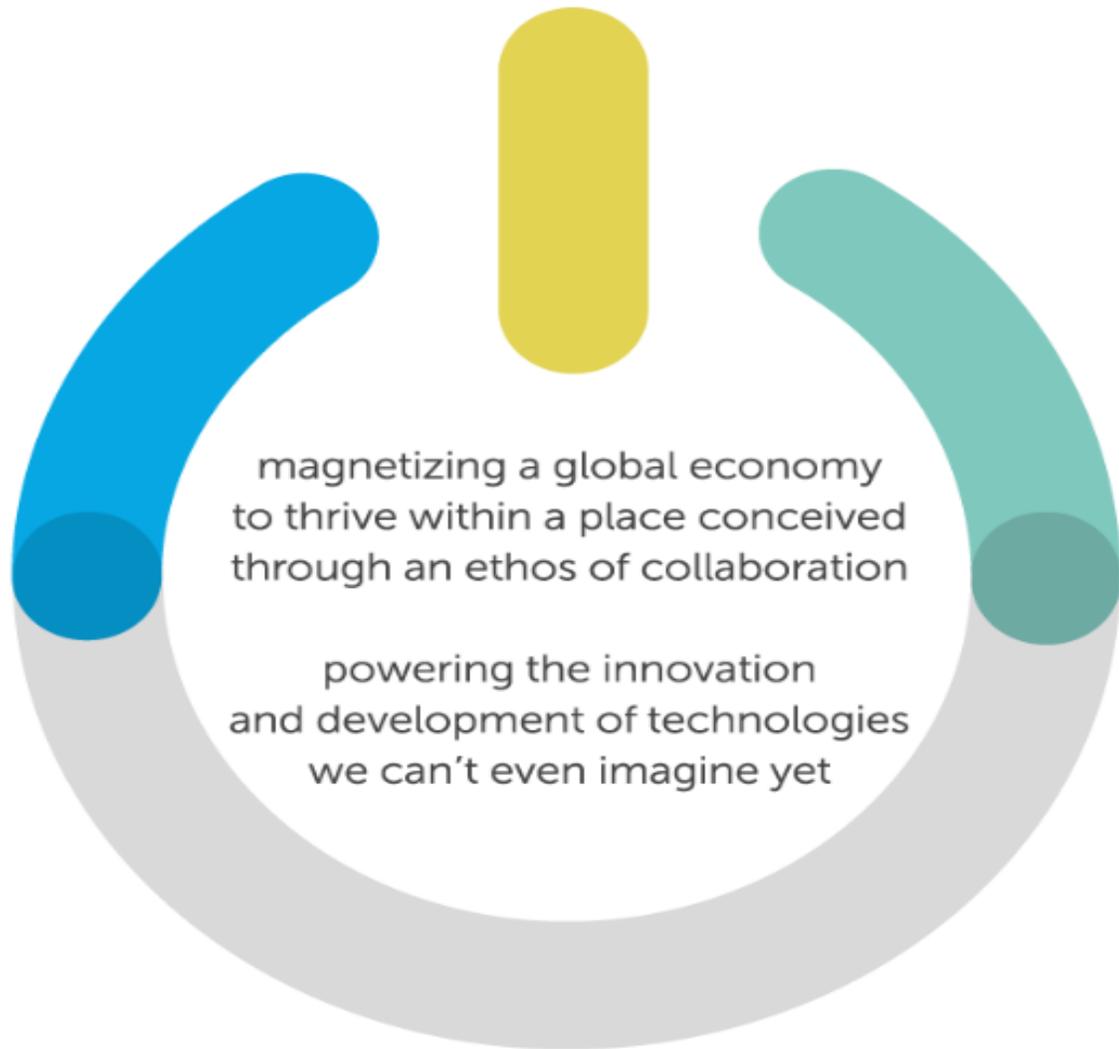
# Momentum!!



UNIVERSITY OF  
CENTRAL FLORIDA



# Join Us



Join us in the next evolution of  
innovation!

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[GoBRIDG.com](http://GoBRIDG.com)

+ There currently is no US-based “Open Access” GaN capability

- Captive fabs only
- Major open access supplier is IQE in the UK

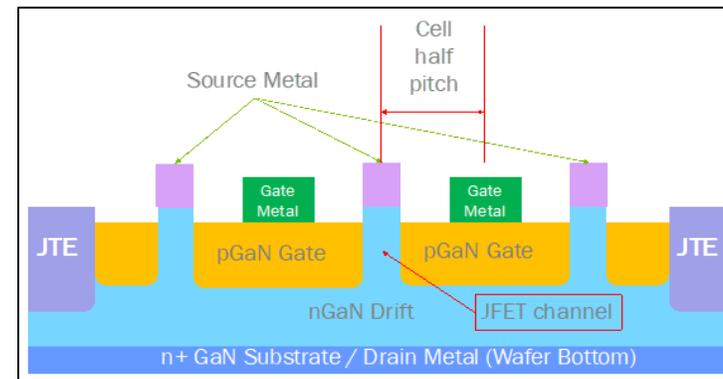
+ BRIDG could be the Open Access GaN fab in the US

- GaN MOCVD epitaxial growth on 50mm to 200mm wafer
- Multiple substrates can be supported: SiC, Si, GaN, QST, other...
- Wafer processing for device design can also be supported
- Low Volume Production capable

+ MOCVD tool acquisition needed

Goals could include:

- Improvement of p-GaN layer quality.
- Address Al<sub>x</sub>Ga<sub>1-x</sub>N/GaN interface issues and reduce leakage current.
- Microstructural Analysis of the device structures by TEM/HR-XRD to enable performance improvement.
- Overall improvement of performance and reliability.
- Plan to off-set substrate expenses.
- Lift-off process of GaN substrate re-use.



p-GaN is an important component in FinFET Structure for RF devices

From NEXGEN Power Systems

**Ecosystem Development which expands upon the Public-Private Partnership Model to provide tools, services, and capabilities that make a public-private partnership, like BRIDG, successful and sustainable**

- Industry & institute partnerships provide exposure, marketing, and demand-driven programs
- Depth of technology expertise and processing capabilities ensure maximum technology impact

## **1. Industry Process and Product Development Partners**

- Manufacturing Institutes, SUNY Polytech, imec
- National Labs – Argonne, Sandia

## **2. Supplier Presence**

- Multiple Process & Analytical Equipment Suppliers, Materials Companies
  - > TEL: Leading equipment suppliers (demo facility, advanced processes & tools, joint development programs,...)
  - > SPTS (process and tool development), SUSS (demo facility)

## **3. BRIDG and NeoCity**

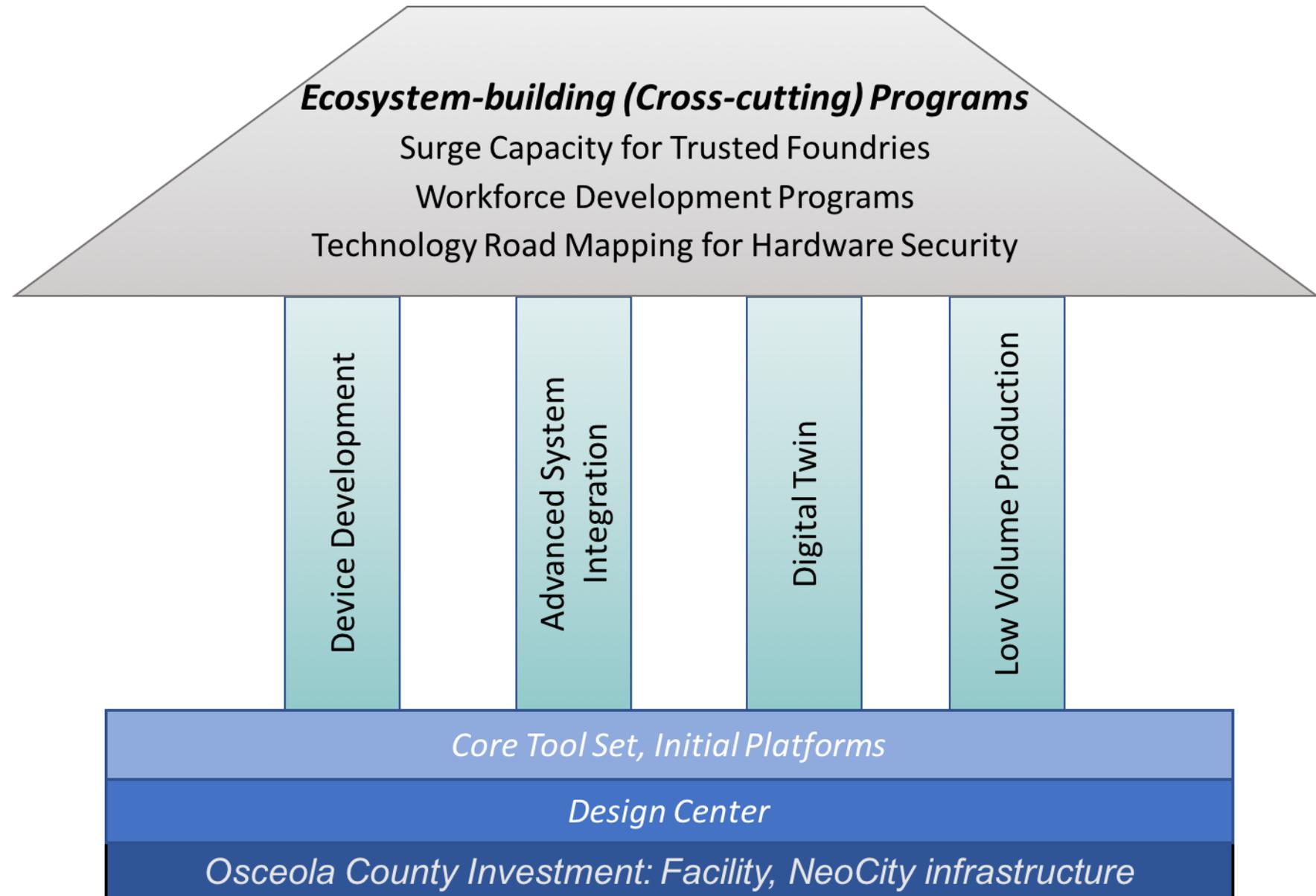
- Smart Communities, Agriculture, and Food Production Technologies and Organizations
  - > **Smart Ag. Program:** US Ag. Committee, FL Dept. of Ag., UCF, UF, IA, CA, TX, NY
  - > **Smart Kitchen / Food Production:** Darden Corp., Rosen College & UCF, imec, BP, Tupperware
  - > **Brainport:** Opportunities to be a base for EU Industries and International Start-ups

## BRIDG is...

- + A vital node in U.S. microelectronics ecosystem
- + U.S.-based, U.S.-owned *not at risk of being acquired*
- + Trust ready
- + One-way conduit for best of Europe technologies

## BRIDG can...

- + Help DoD meet its microelectronics challenges with turnkey capabilities
- + Provide priority access for DoD customers
- + Conduct manufacturing engineering education programs with high schools, community colleges, universities and companies



## + III-V Epitaxial Wafer Growth

- Establishing III-V MOCVD reactor for unique device growth
- Small batch for cost effective epi-design evaluations

## + Offer un-processed epi wafers

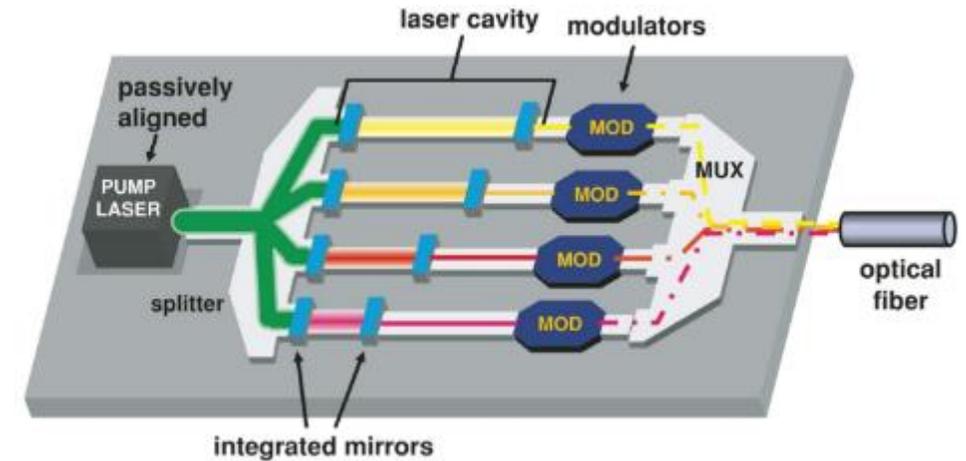
- Laser & small companies
- Little capacity in the open market– IQE, HQ'ed in Ireland
- Quick turn small lot market
- Short lead
- Small lots

## + Silicon Photonics, under consideration

- Evaluating mil-aerospace market applications
- MOU to license imec's Si-Photonics Process

## + Business Assessment starting now

- Complete by end of 2018



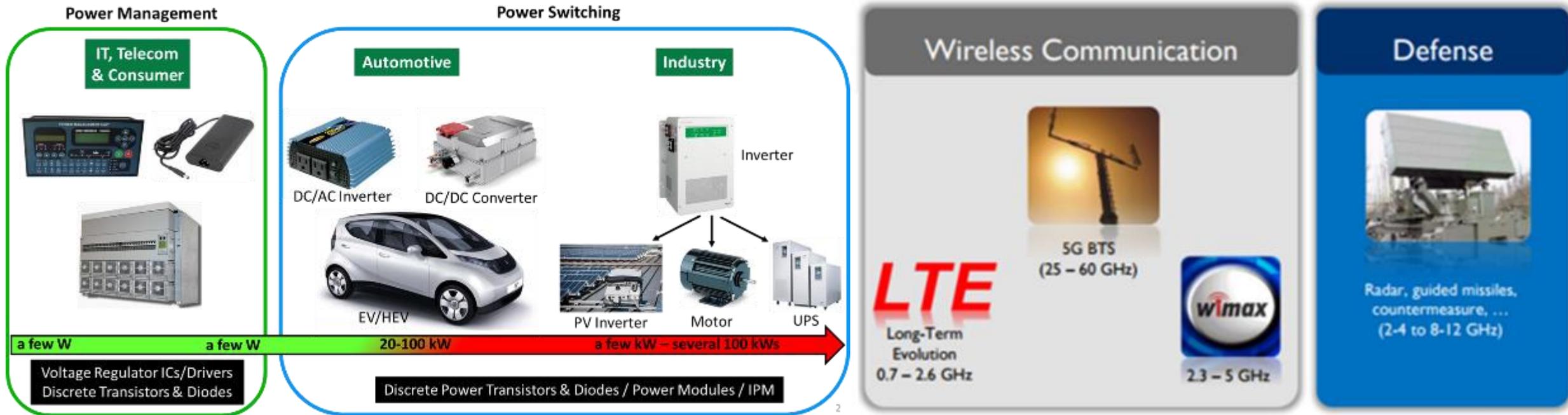
## + Vertically integrated GaN Facility for the fabrication of packaged GaN RF/Power Devices

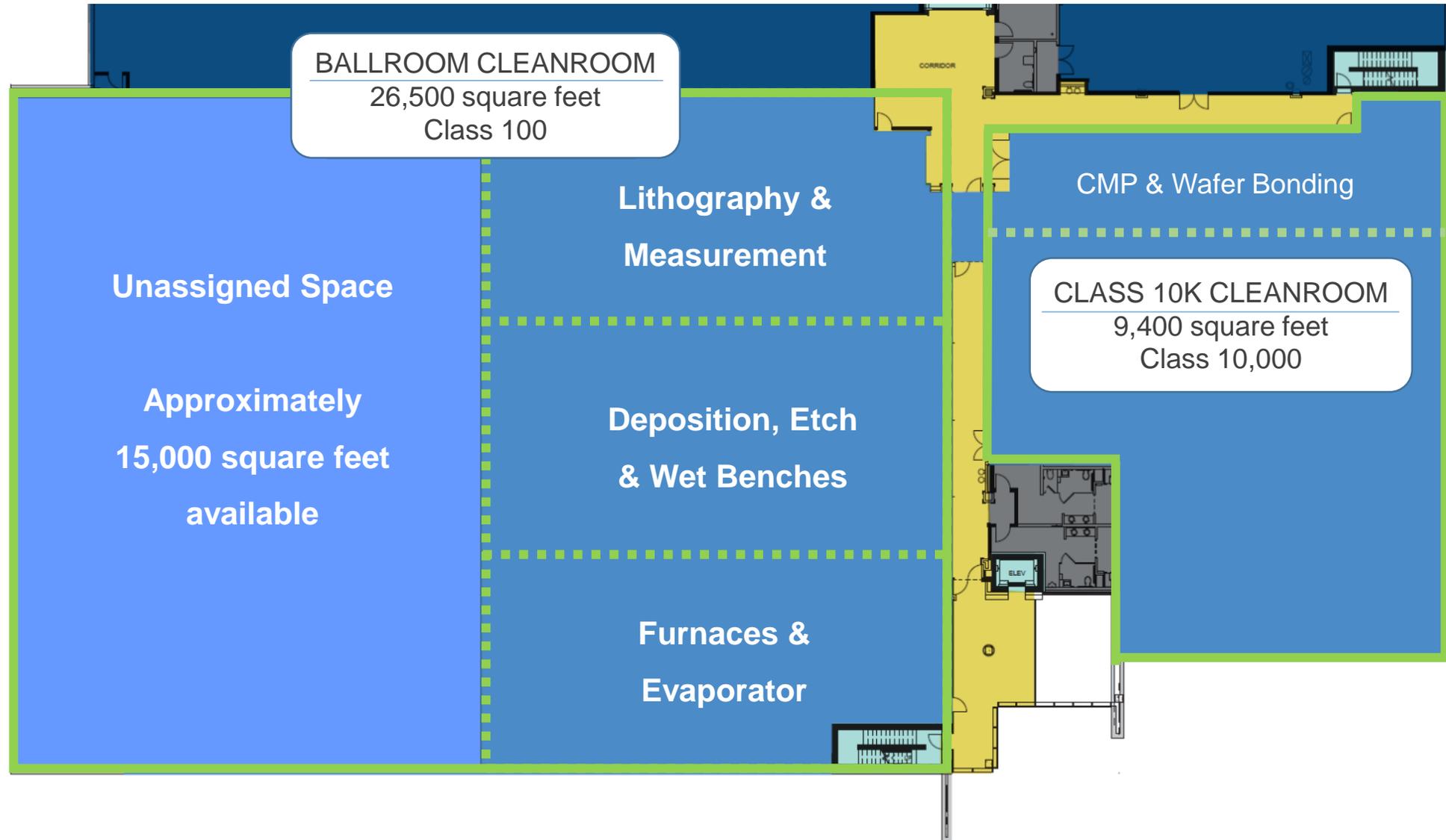
- State of the art MOCVD facility for the growth of high low defect density GaN Structures – Capable of supplying templates up to 8”
- Advanced Materials Characterization Facilities for Structural and Morphological Analysis
- Device Fabrication Facility... Can do both Epitaxial GaN growth and device processing in-house
- Packaging Capability

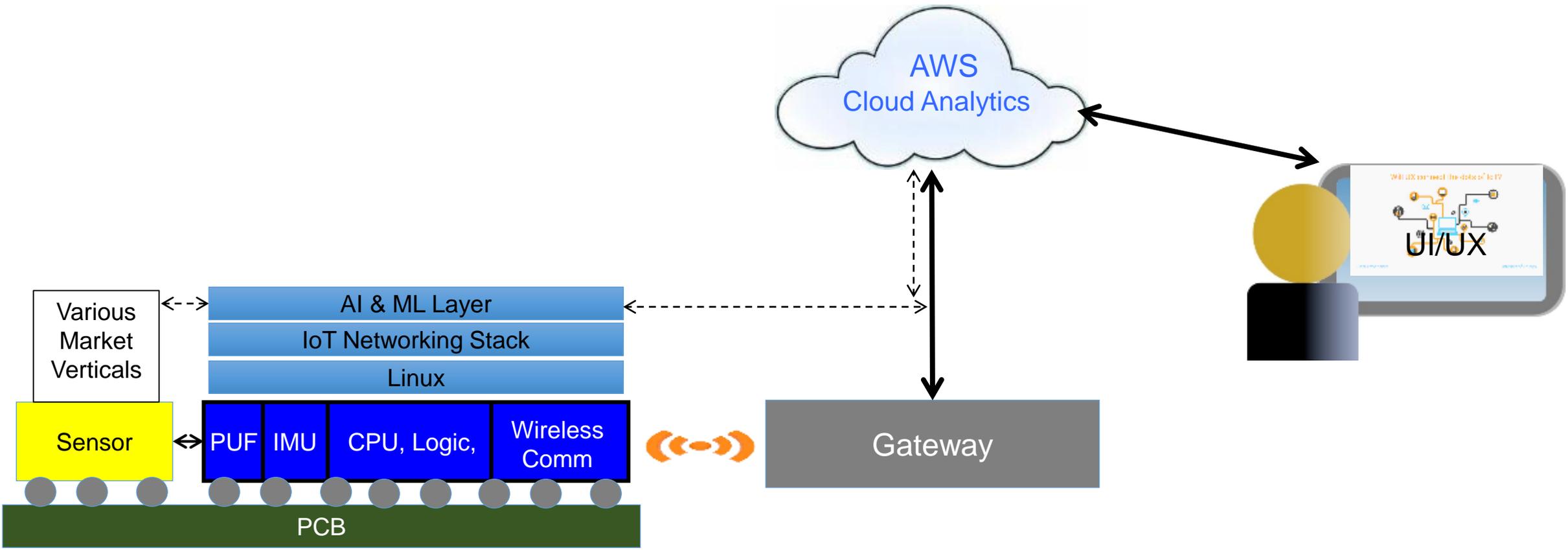
## + Major improvement of 200 mm GaN/Si Material Quality by the improvement of Buffer Structures and Doping Methodologies

- Improvement of device performance (Reliability improvement, Breakdown Voltage, low leakage current)
- Cost reduction through Yield Improvement and Performance Uniformity
- Device Fabrication Process Automation
- Advanced Packaging and Size Reduction
- 1200 V Power and RF prototype Devices by 2020-21
- Low cost 1200V Power and RF Devices with reliability >10000 hours by 2021-22

## Develop 8" GaN templates on Si and Engineered Substrates for the realization of high performance Power and RF Devices







Uniquely Identifiable IoT Sensor Module  
Total Size ~ 70x70mm, SiP 50 x 50mm

The AI & Machine Learning layer on the IoT modules allows the sensors to mine intelligent data. For the cloud to analytics to analyze

## **BRIDG can help DoD meet these challenges:**

**+ Not-for-profit public private partnership → priority access for DoD**

**+ Platform for:**

- Low volume production of customized microelectronics for DoD applications
- Leading edge microelectronic device development, prototyping, pilot production, LRIP
- Moving DoD-funded microelectronics development through MRL 4-8
- Providing prototyping, demonstration, validation and manufacturing capabilities

**+ U.S.-based; U.S.-owned**

**+ No risk of company or foreign acquisition**

**+ “Trust Ready”**

- ITAR compliant; Controlled access to production areas
- SECRET level facility clearance

**+ Proximity to major U.S. defense contractors and commercial industry**

**+ Critical Support for DoD Manufacturing and USA Innovation Institutes**

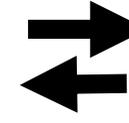
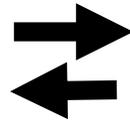
**+ One-way conduit for European fab technologies**

**+ Partnerships with universities/non-profits & innovative high school for STEM workforce development**

## University/Lab Research



## Volume Manufacturing



### BRIDG INFRASTRUCTURE:

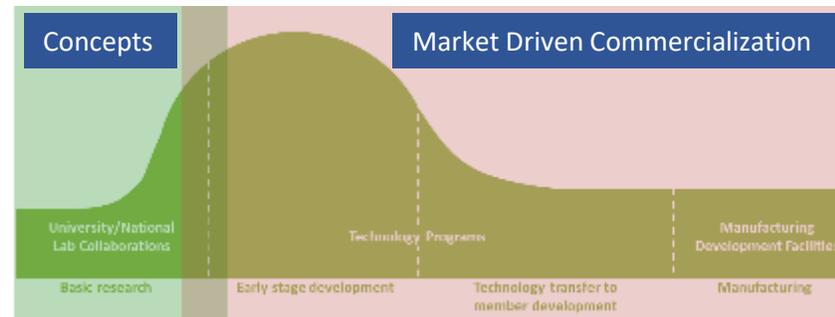
- + Accelerate high potential technologies into next generation products & systems
- + BRIDG and partners develop and provide commercialization infrastructure
- + Capability for proof of concept, custom development, pilot production
- + IP Protection, Funding Coordination
- + Small Business Enablement

### CONCEPT:

- + Creative ideas
- + Centers of Excellence
- + Novel techniques & innovative technologies
- + Fundamental research
- + Market Intelligence

### COMMERCIALIZATION:

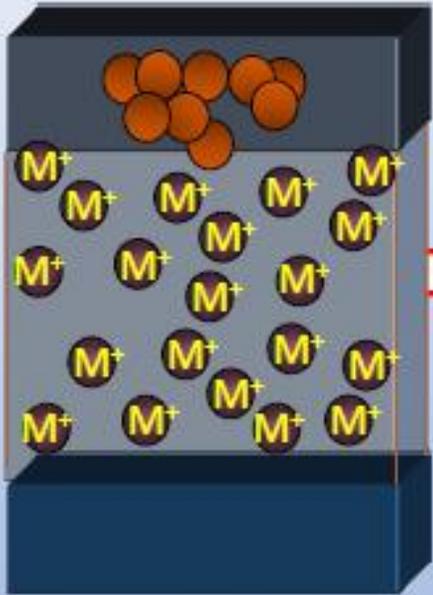
- + Advanced Imagers, Sensors and Photonics
- + Heterogeneous System Integration
- + Advanced Materials for RF, Power and Sensing Applications
- + Emerging technologies, including ReRAM and direct patterning
- + Hardware based cybersecurity



# Basic mode for ReRAM: Programming

**20 MΩ**

*Active Electrode*



*Inert electrode*

**FORMING**

**5 KΩ**



**0=LRS**

Strong filament

**Reversible**

**20 KΩ**



**1=HRS**

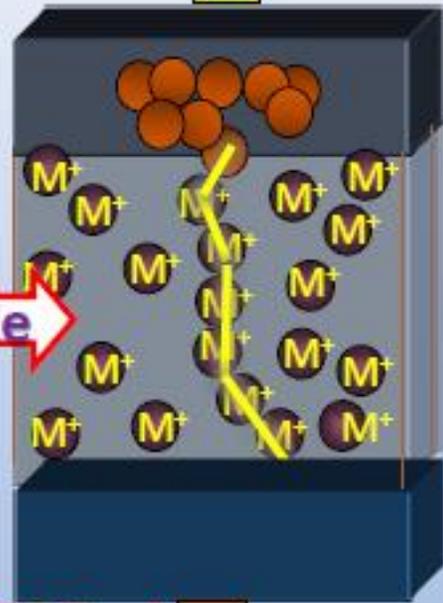
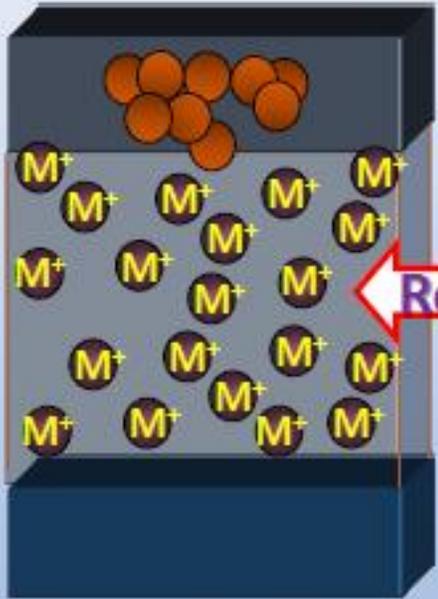
Open filament

# Low power PUF CRP generation

**20 MΩ**

**3 MΩ**

*Active Electrode*



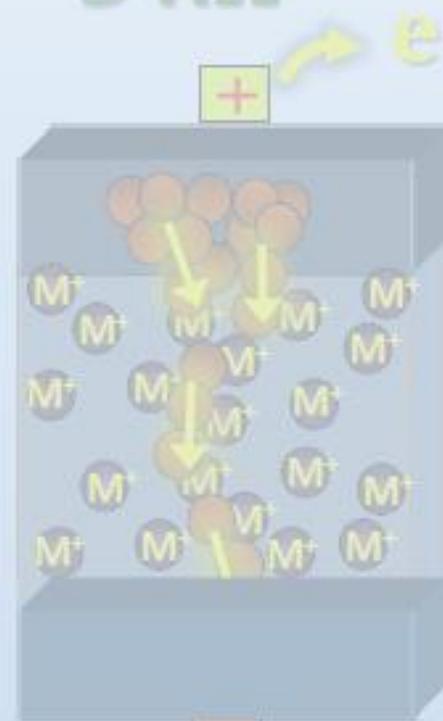
*Inert electrode*

**100 nA**  
**1 μs**

Low power PUF:  
Temporary filament

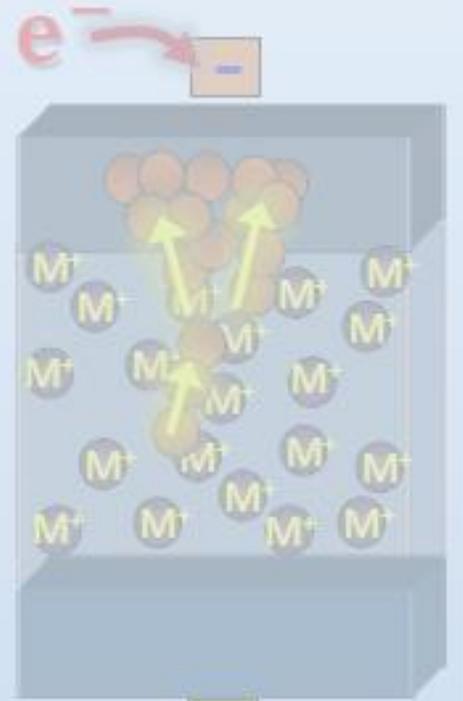
**5 KΩ**

**20 KΩ**



**LRS**

Strong filament



**HRS**

Open filament

PUF Type		Power	Time	Energy	Implementation details
Arbiter		$50\mu W$	$5ns$	$0.24 pJ$	450 gates
Ring Oscillator		$0.4\mu W$	$2.5\mu s$	$1 pJ$	19 stage Oscillator, 32nm CMOS
Ring Oscillator		$150\mu W$	$1.60\mu s$	$250 pJ$	41 stage Ring Oscillator
Delay Line		$17\mu W$	$4ns$	$70 fJ$	
SRAM		$17mW$	$35ns$	$600 pJ$	250nm CMOS – 64Kb RAM
SRAM		$1 \mu W$	$1 \mu s$	$1pJ$	10T - 90nm CMOS – 32Kb RAM
Latch		$200\mu W$	$600ps$	$120 fJ$	DSTC latch (10 transistors)
FF		$200\mu W$	$200ps$	$40 fJ$	Sdff flip flop (23 transistors)
HfOx	Vset	$80\mu W$	$25\mu s$	$2nJ$	10 cycles: $10\mu A - 0.8V$
ReRAM	RCP	$1nW$	$10ns - 100\mu s$	$0.01-100 fJ$	1 cycle: $10nA - 100mV$

- + **AFRL excited about potential of this new PUF capability**
  - Dr. Bertrand Cambou (inventor at NAU) fully engaged
- + **Currently 16 months of research completed**
- + **Approved for new 3-4 year program to dig deep and answer all the open questions**
- + **AFRL BAA for FY19**
  - \$1.8M/yr for 3 years, \$950K in year 4, starting FY19
  - DARPA providing some of above funding
  - Expecting Lockheed Martin and Northrop Grumman to bid
  - BRIDG shown as wafer/chip supplier in AFRL slides
- + **Provides the data needed for this ReRAM/PUF technology to gain wide acceptance**
  - Includes the application IP (how to read the PUF, bin the R info, and use for crypto, RNG, etc.)

- Wafer Probe and Test
- SEM with FIB
- Reliability ovens
- AFM
- RTA
- Wafer bonder <75nm accuracy
- Backgrinder
- Edge Grinder
- Si CMP
- High Accuracy Die Bonder
- Fine Line Lithography – 193nm / e-beam
- Atomic Layer Deposition (ALD) Tool for metals
- <200mm coat/develop
- InP ICP etch tool
- Dicing saw & mounting
- SAM
- Materials Coater
- Hall Measurement Tool
- Rapid Thermal Annealing (RTA) – Automated
- Tape and Frame
- Temporary Bonder
- Molecular Beam Epitaxy (MBE)
- Transmission Electron Microscope (TEM)
- Vector Network Analyzer
- Wafer Grinder

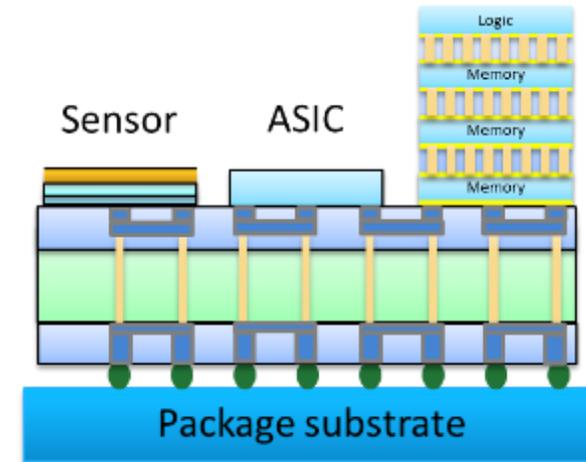
To Enable Further  
Advances in...

- Hardware based cybersecurity
- Heterogeneous System Integration
- Advances in SWaP, system miniaturization
- Emerging technologies, including ReRAM and direct patterning
- Advanced Materials for RF, Power and Sensing Applications
- Advanced Imagers, Sensors and Photonics

## Provide solutions for size, weight and power reduction which address challenges faced by conventional scaling

### Improved performance

- Heterogeneous Integration (Si, III/V, Photonics)
- Ultra-High Density (Wide I/O -  $10^6$ )
- Power Consumption and System Response Time
- Robust Operating Temperature Range (77K to 673K)



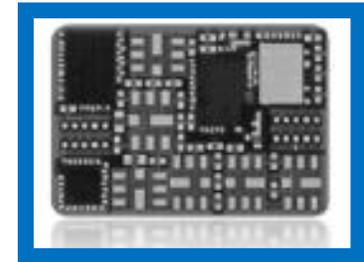
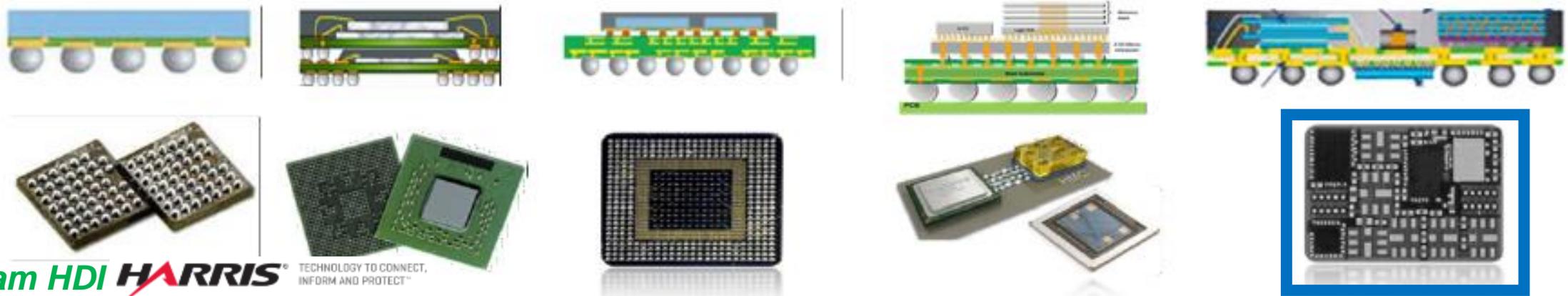
### Improved Form Factor

Transform traditional sensing techniques allowing continuous monitoring and the ability to monitor more...

**Enabling System Miniaturization**



WLCSP      Flip Chip      Fan-Out      2.5D & 3DIC      System in Package



*Program SIP*

*Program HDI* **HARRIS**® TECHNOLOGY TO CONNECT, INFORM AND PROTECT™

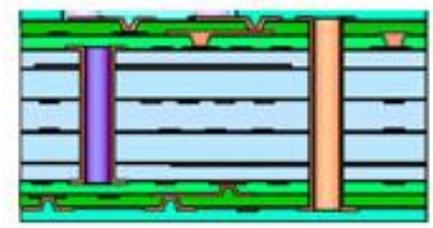
Wafer Bonding

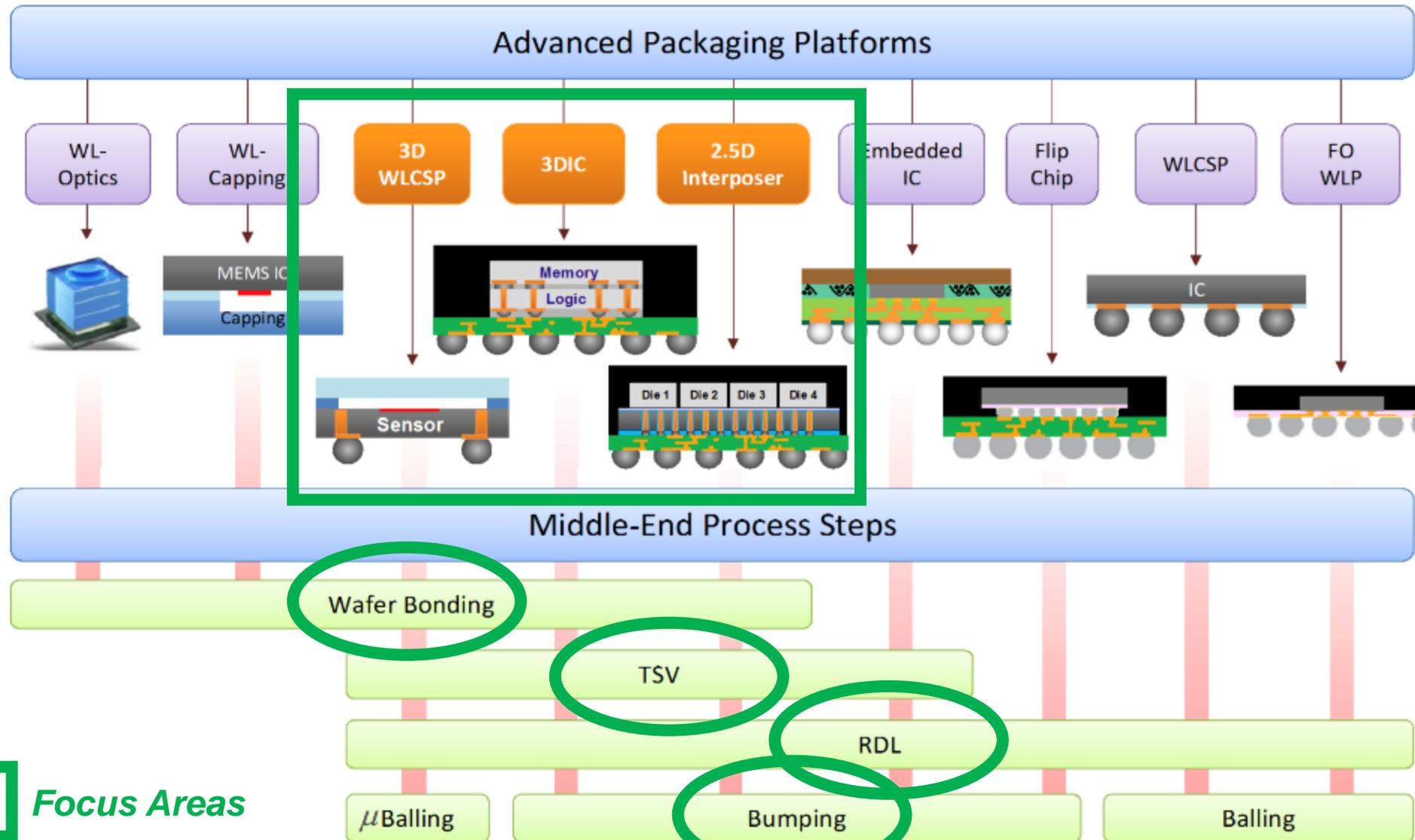
**Wafer - level**

Bumping	Cu Pillar	Through Silicon Via	RDL
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**Substrate - level**

THP, Via fill, RDL





Value Creation

