International Consortium for Advanced Manufacturing Research

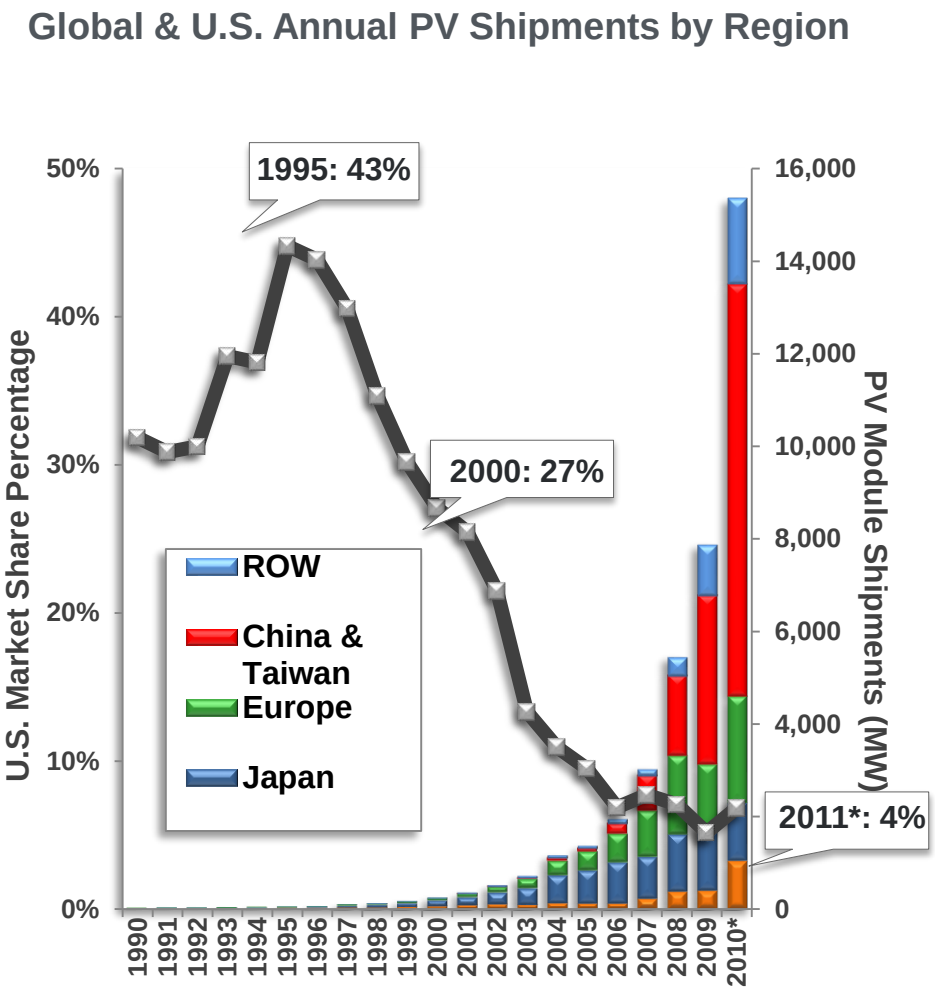
(ICAMR)

International Technology Consortium

Public-Private Partnership Consortium Strength and Success Factors

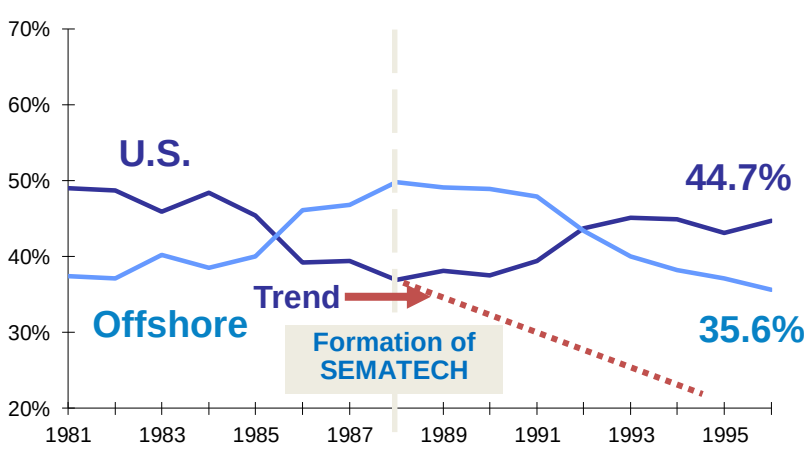
- A clear industry-led model and mission
- Optimized to drive industry alignment in critical focus areas
- Complex technical program management with measurable success criteria
- Leveraging of government and industry funds
- Commercialization of industry and research community innovations
- Focused on development and improvement of complete value chain
- Member engagement:
  - Member company assignees for tech transfer
  - Member advisors at all levels (strategic, technical, operational)
- Improved manufacturing productivity keeps industry advancing
  - New products / markets, improved competitiveness and productivity
- Agility to adapt to changing needs
- Highly effective leverage ➔ High ROI

U.S. Manufacturing Market Share



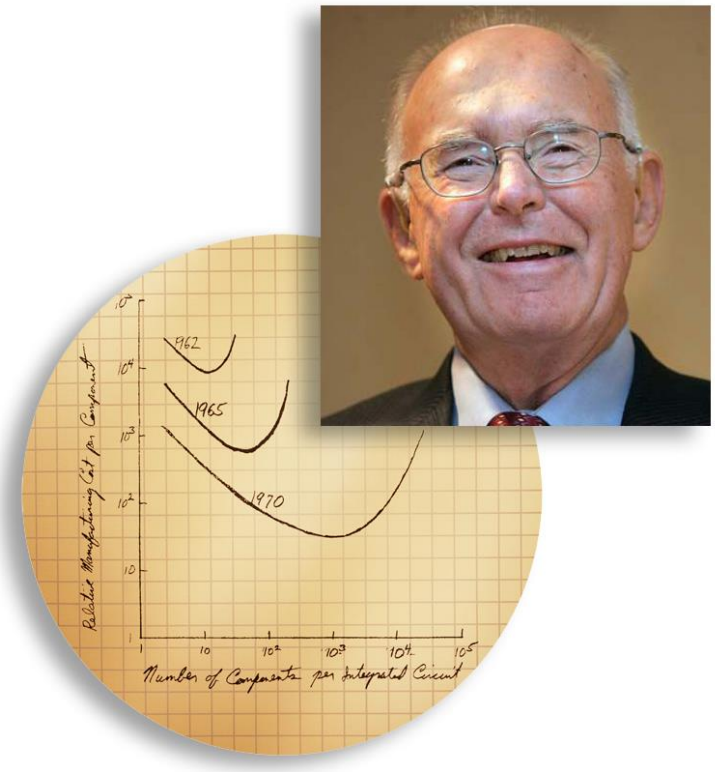
"The most significant finding of the Task Force is that U.S. ***technology leadership*** in semiconductor manufacturing is rapidly eroding and that this has serious implications for the nation's economy and immediate and predictable consequences for the Defense Department."

*- Defense Science Board Task Force on "Semiconductor Dependency - **February 1987***

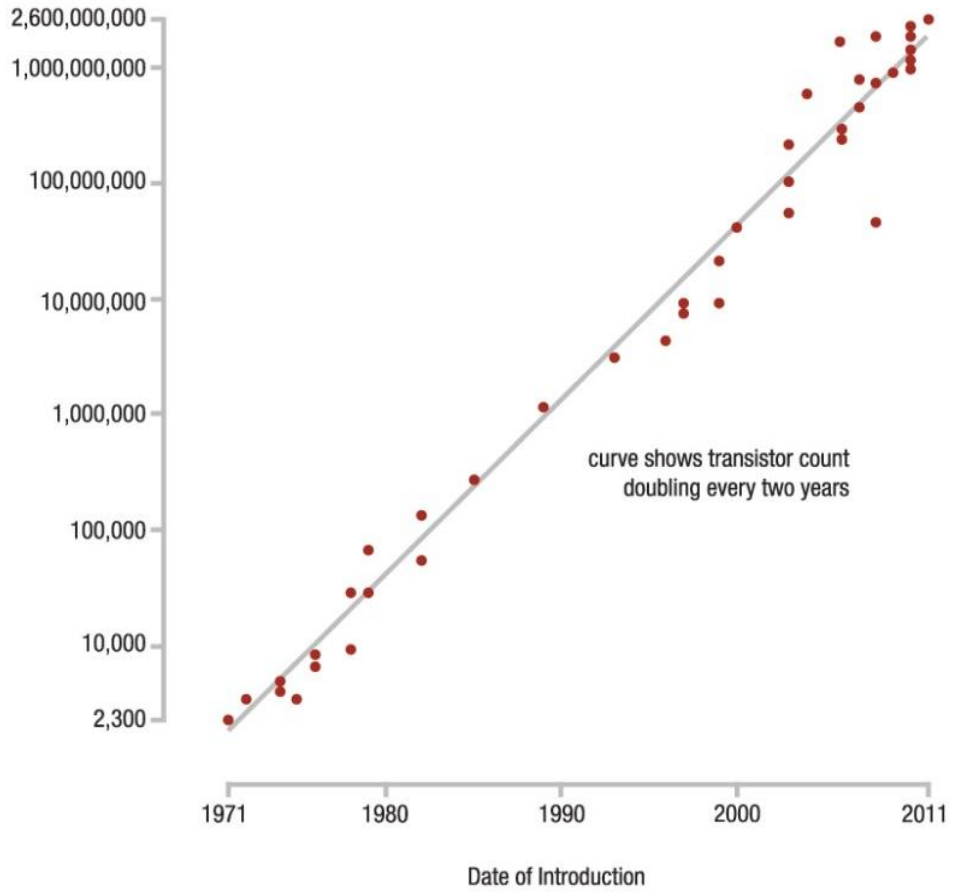


Source: VLSI Research Inc.

Moore's Law
Driving both Performance and Cost



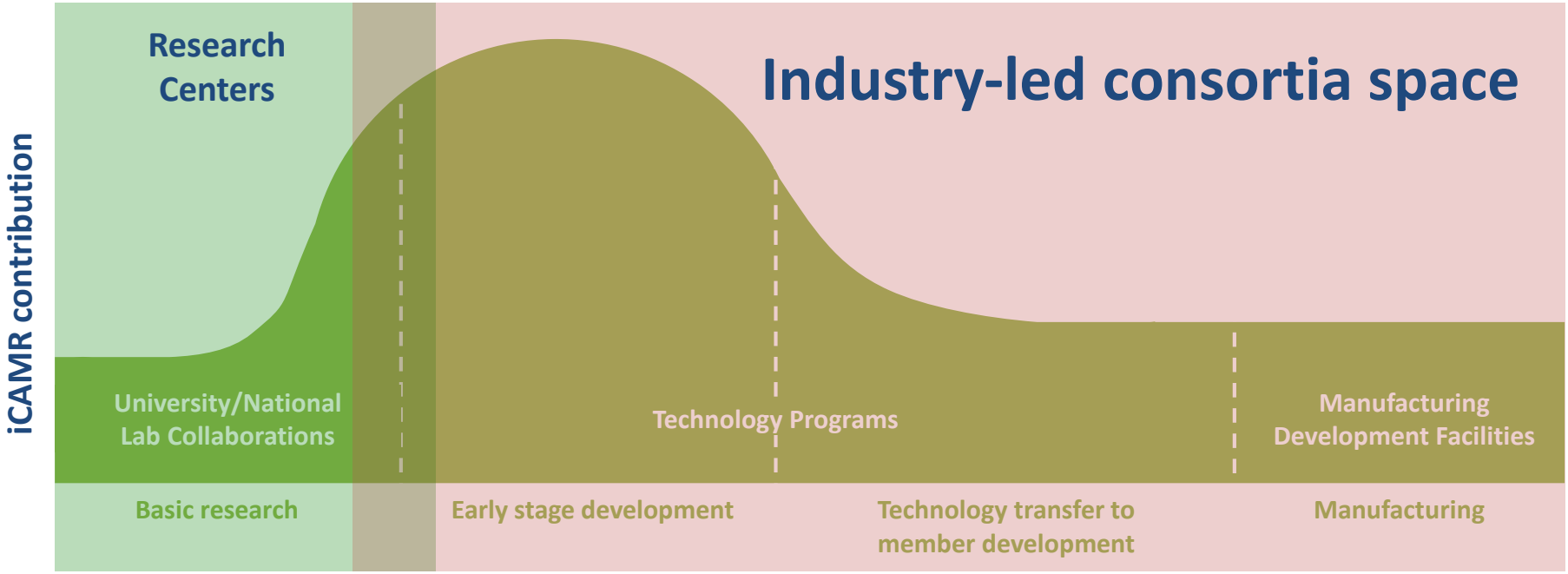
Microprocessor Transistor Counts 1971-2011 & Moore's Law



Comericalization “Valley of Death”

Bridging research, development, and manufacturing

- An industry-led, membership driven consortium
- Driving technical development and consensus for the industry
- Pulling research into the industry mainstream
- Leading major programs to address critical industry manufacturing challenges
- Focus on manufacturability – process development / supply chain / prototyping



Emerging Technologies - Challenges and Solutions

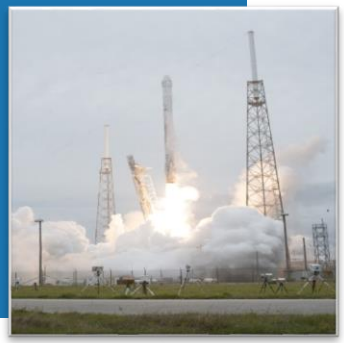
The challenge	Collaborative solutions
• Industry alignment	• Create industry roadmap and standards
• Significant process, manufacturing, and technical design challenges	• Collaborative R&D, access to equipment and facilities to speed process and product development
• Lack of industry collaboration, direction, and alignment around needs/challenges	• Utilize & expand consortium model across entire value chain, develop a robust supplier industry around common needs
• Access to leading-edge capabilities	• Build / provide access to advanced manufacturing development facilities & labs
• Testing and reliability	• Establish critical test, reliability, and analytical capabilities
• Manufacturing cost	• Improve manufacturing methods to enhance productivity and reduce costs
• System integration, technology commercialization, & workforce development	• Launch specialized programs and infrastructure to support industry needs and growth
• Emerging technologies manufacturing scale-up challenges – small and large businesses	• Leverage industry-government-university capabilities and resources through the consortium to provide manufacturing scale solutions

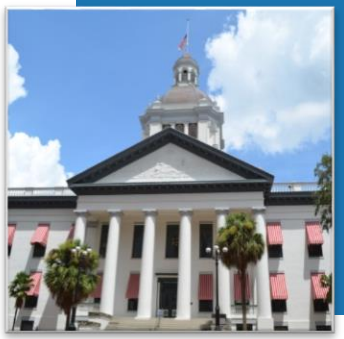
New Era of International Industry Program Collaboration

Launch innovation networks: bringing industry, universities and governments together

Industry

- Emerging Technologies
- Manufacturing
- Commercialization



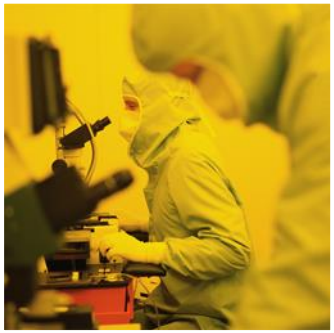


Government

- International
- State of Florida
- National research labs and agencies
- Attract joint funds

Universities

- Universities in U.S., Europe, and Asia
- Funded research
- New ideas and approaches
- Partnered research capabilities



Suppliers

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

iCAMR

Consortium Proposal and Mission Summary

- **Consortium Goals**
  - ***Establish international consortium focused on the >$500B advanced sensors and devices industries***
  - Create and fund a world-class facility for advanced R&D, commercialization & manufacturing (Florida)
  - Form a trusted, participant-friendly business and operational relationship
  - Drive integration of advanced processes and materials on Si into next-gen devices & packaging
  - Serve as a manufacturing development platform to attract / grow new technologies & products
  - Establish base for future centers – Manufacturing Competitiveness, Adv. Energy, Emerging Tech Commercialization
- **Solution Requirements for Emerging Technology Manufacturing Gaps**
  - ***Emerging industries require access to affordable advanced devices and materials integration platform***
  - "Smart Planet" future sensors and advanced devices are required to have higher performance, lower power, resistance to harsh environments → at low cost (in everything – cars to biomedical products)
- **Differentiator**
  - ***International advanced materials and device manufacturing development center focused on:***
    - Integration of semiconductor based processes, equipment, materials & circuits into future products
      - Smart sensors and photonics devices, etc.
- **Mission**
  - ***Partners' one-stop for development and integration of advanced devices and materials***
    - Processes, tools, prototyping, EDA, and providing access to materials (like GaN, InGas, and other III-V materials)
    - Significant leveraged shared access and cost reductions for each participant
  - ***Attract entire supply chain (tool, materials,…) for complete R&D center to benefit participants***
  - ***Accelerate technology commercialization by providing solutions to technology and capability gaps***
    - Across multiple technology fields (Universal Smart Sensors, Photonics, Advanced Energy,…)

ICAMR

Technology Platforms – Phase 1

ICAMR will be the central foundation for four Manufacturing Development Centers located in Florida and have two functional platforms:

1. Advanced Materials Development Line
   - Designed to support a broad range of industries (biomedical, agriculture, environmental,...)
   - GaN, GaAs, InGaAs and SiGe MOCVD deposition tools – utilizing 8" silicon substrates
   - Universal Smart Sensors, Advanced Photonics Devices, and III-V materials
     - Multipurpose product applications (ionic, molecular, gas–chemFETs sensor, w/ wireless communication)

   Note: Total market for Advanced Devices components expected to reach $47.5B by 2017

2. Advanced Packaging, Test, and Device Integration Development Line
   - Back-end processing and packaging line for prototype development and commercialization
     - Biomedical, Oil and Gas, Aerospace/Defense, Environmental, Agriculture, Environmental Sensors
   - Advanced Optics and photonics Devices – wide range of advanced applications (SIP)

Note: Overall sensor market expected to reach $116B in 2019

Key performance attributes of these advanced materials for emerging technologies:

- ***High sensitivity***
- ***Low Power***
- ***Harsh environments performance***

ICAMR Platforms

Manufacturing Development Centers (MDFs)

ICAMR infrastructure designed to support four phases of emerging technology manufacturing development

Phase I

MDF for Materials, Sensors, Packaging & Testing

Advanced Devices on Si - Universal Smart Sensors:
- Sensor / Photonics Device integration and prototyping

Adv Materials Development:
- Support a broad range of Emerging Technologies (BioMed, Environmental, Oil & Gas, Aerospace/Defense,…)

Adv Packaging Integration Development Line
- New materials
- Additive Manufacturing
- Device/Sys Reliability Testing

Advanced Energy Center

PV Programs

Next Gen PV (cSi & other)

Solar Systems & Power Elect

Smart Grid & Utility Solutions

Test & Certification (World Leader)

Energy Storage

Nanotechnology in Energy

Other renewables:
- Fuel cells
- Wind

Manufacturing Competitiveness Centers

Manufacturing Hubs/Programs
- Industry/Technology-driven initiatives

Next Generation Manufacturing Pilot lines:
- Photonics & Optics
- Packaging & Reliability
- Additive Manufacturing
- NEMS/MEMS/MOEMS
- Biomedical/Microfluidics

International Emerging Technologies

Emerging Tech Programs

Cyber Security

BioMed Technologies

ESH

Nanotechnologies

Simulators & Models

Roadmaps & Standards

Joint University Centers

Workforce Development

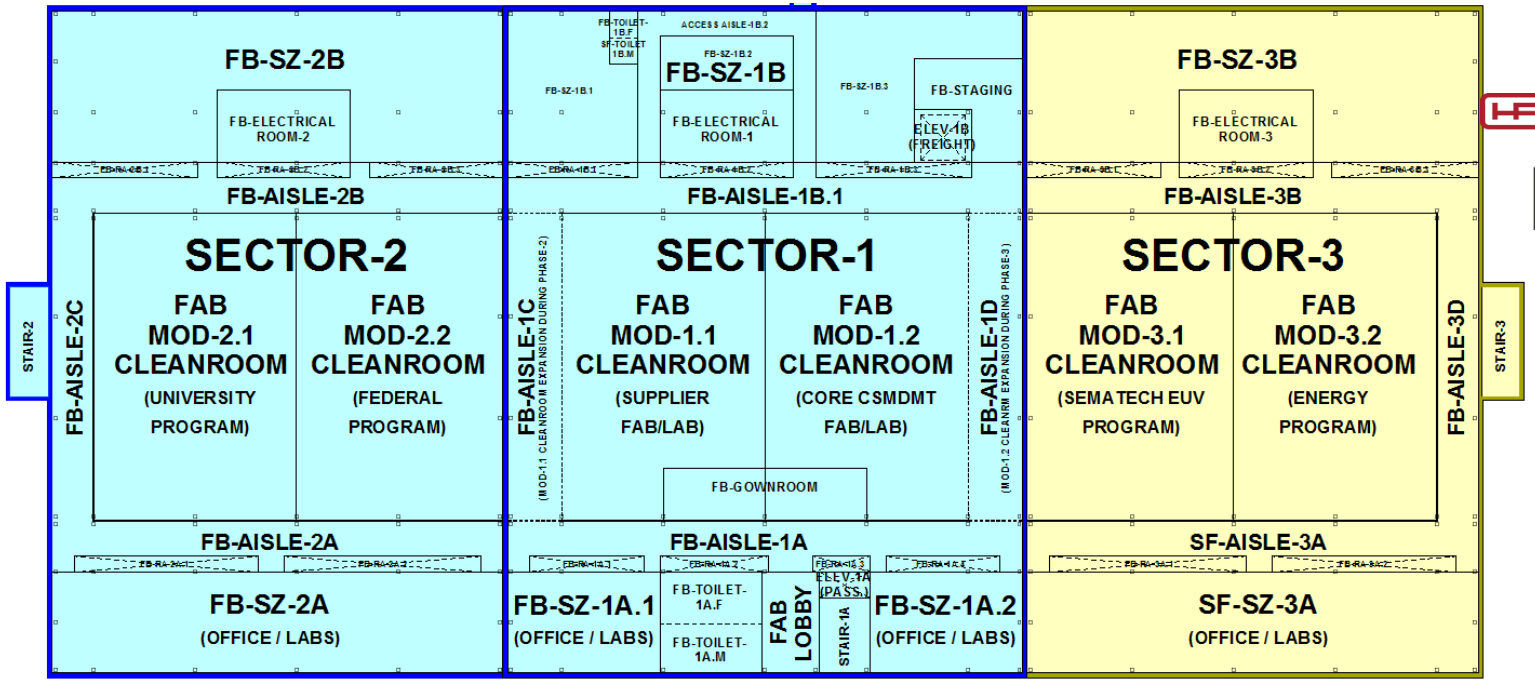
Incubator Centers

iCAMR

Regional Manufacturing Development Centers Partnership Opportunities

- Manufacturing technology roadmapping and standards
- Manufacturing development, prototyping and technology transfer - commercialization
- Materials characterization, integration and manufacturing protocols
- Process and metrology equipment development
- Production scale-up and cost modeling
- ESH and sustainability
- Certification/test/reliability – quality
- Policies/codes/permitting
- University, national labs, and international programs
- Member company application-specific support programs
- Internships and educational/workforce training programs

Building Layout



HENSEL PHELPS
Plan. Build. Manage.

Page/

iCAMR – 100,000 sqft two level state-of-the-art R&D lab/fab facility - ~$125M

- 43,000 sqft of cleanroom
- 30,700 sqft of elevated waffle slab / sub fab
- 15,000 sqft of lab / office area (plus addition building support areas – services, loading dock,..)
- Site located on a new dedicated 220 acres research park
- All utilities (electric, water, wastewater) available to site

ICAMR

Florida ICAMR Site

ICAMR

Initial Program Development Platforms

- **CREO**
  - UCF Center for Research & Education in Optics and Lasers (College of Optics & Photonics)
- **MIST NSF Hub**
  - UCF MIST Center – Multi-functional Integrated Systems Technology
- **UCF Materials Characterization Facility (MCF)**
- **Florida High-Tech Corridor (UCF, USF, UF)**
  - Joint economic development initiative
- **Novati fab**
  - Initial 200mm processing support
- **Equipment supplier partner labs**
- ***Others to be established by Q4, 2014***

iCAMR

UCF Partnership CREOL – The College of Optics & Photonics

Center for Research & Education
in Optics and Lasers
Founded, 1987
College of Optics & Photonics
Founded, 2004

28 faculty
14 joint faculty
32 research scientists
31 visiting scientists

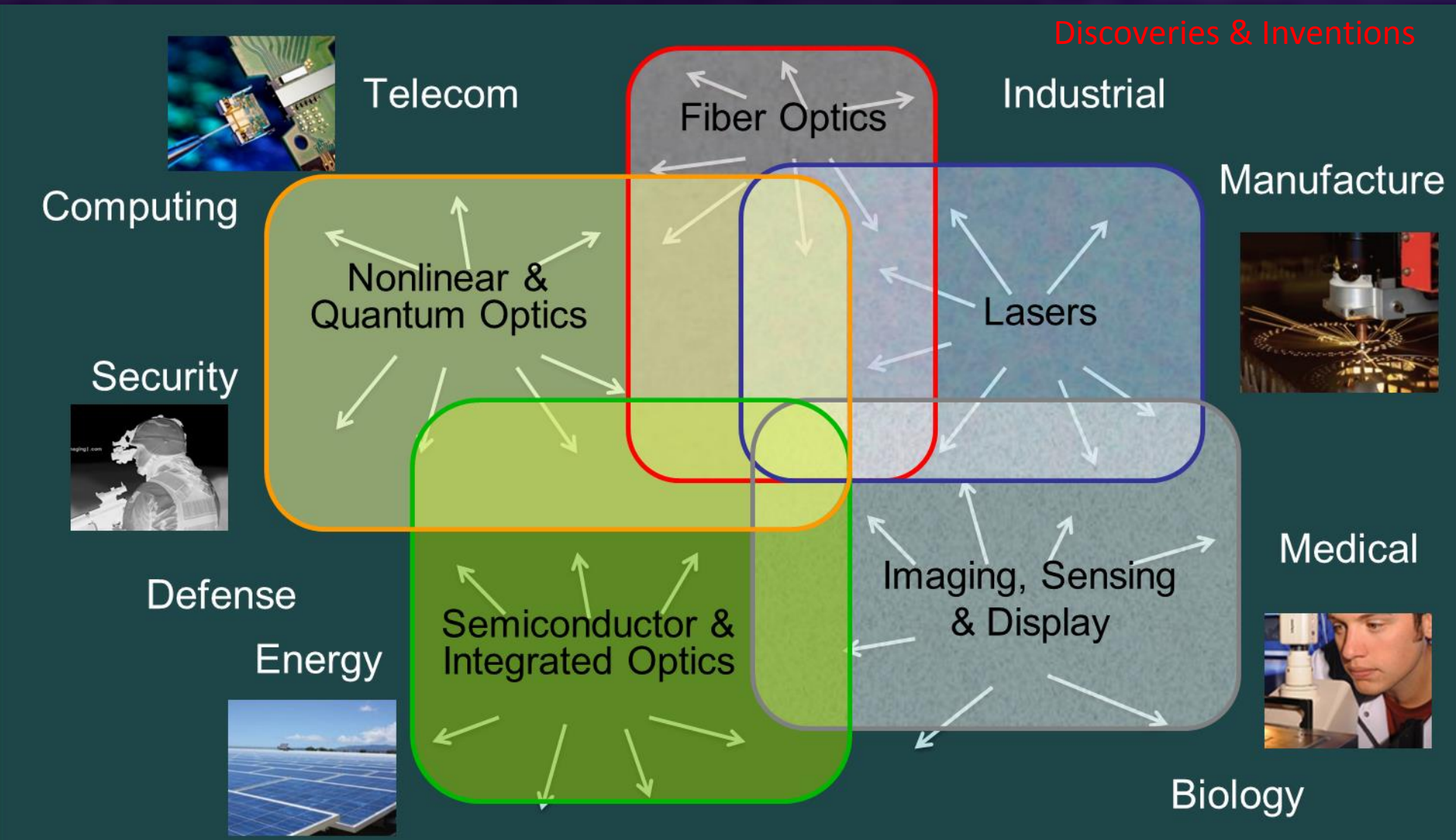
108 PhD students
26 PhD degrees
27 MS students
17 MS degrees
54 BS students

70 Industrial affiliates
6 Incubated companies

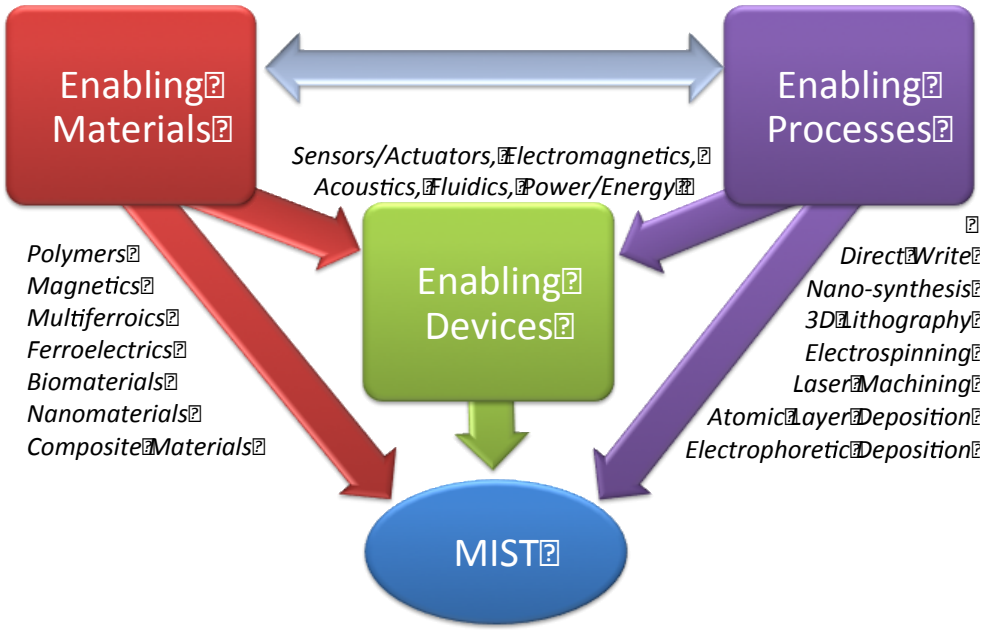
190 Journal papers 2013
19 Patents issued 2013
$15M External grants

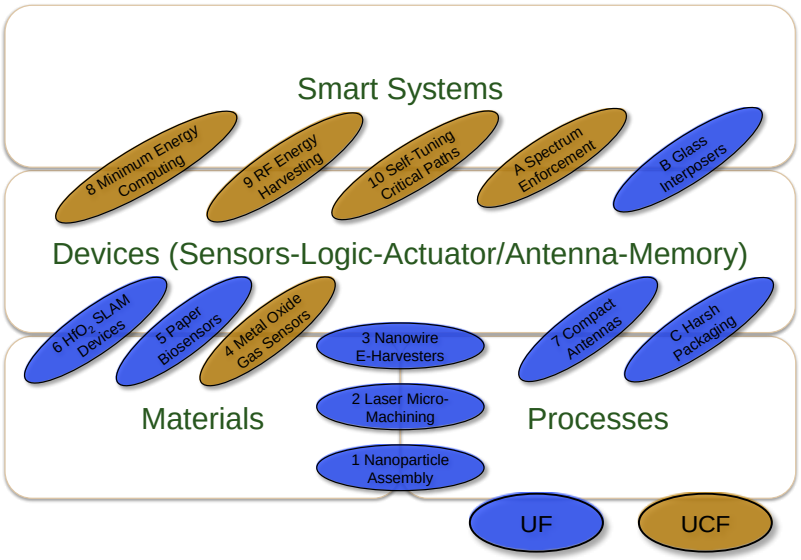
iCAMR

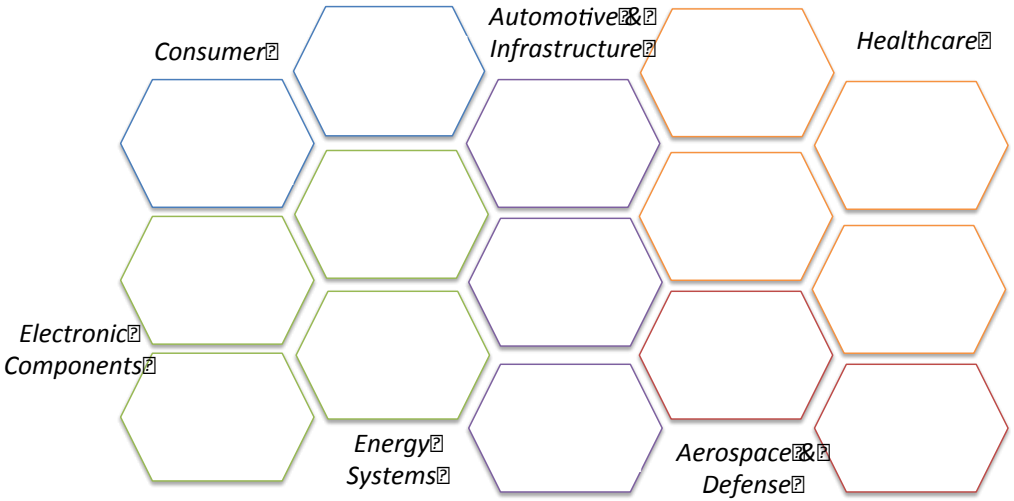
UCF Partnership CREOL – Research: Fundamental Science & Applications

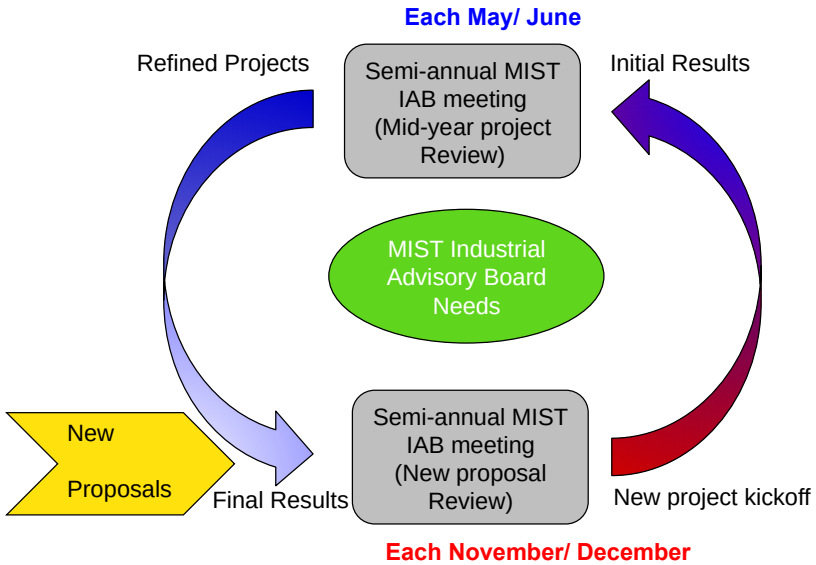


MIST Center – Multi-functional Integrated Systems Technology





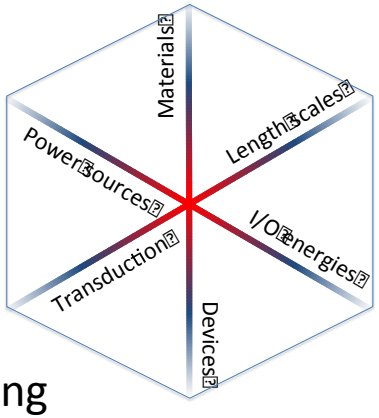




National Science Foundation (NSF) initiative – in partnership with International Industries, universities, and research centers

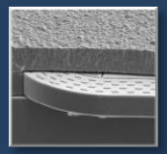
- **Led by UF and UCF in partnership with the ICAMR**
- **Vision: To pioneer the "More than Moore" era by developing materials, processes, and advanced devices that enhance the functionality of integrated systems**
- **Approach: Industry/University partnership to explore new integrated sensor multi-functionality through diverse Center expertise: materials, length scales, I/O energies, devices, transduction, and power sources**
- **Expertise: 27 faculty in 6 departments/colleges (ECE, MAE, MSE, BME, CHE, Photonics) at the University of Florida and the University of Central Florida**
- **Value Proposition: The Multi-functional Integrated System Technology (MIST) I/UCRC serves as an intersectional innovation hub for the 'More than Moore' (MtM) and Internet of Things (IoT) era, providing research, recruiting, and relationship value to its members**

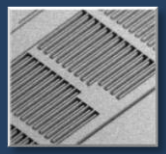
- **Initial projects (Top 5)**
  - Technology Development for Advanced Sensors
    - chenFETs, Photonics, High Sensitivity and Harsh Environment Microsensors
  - Compact Array Antennas with High Gain and High Electromagnetic Proof Characteristics
  - Development of Metal Oxide (MOx) Semiconductor Gas Sensors
  - Laser Micromachining of 3-D Miniature Parts in Hard Materials
  - Directed Nanoparticle Assembly by Electrophoretic Deposition



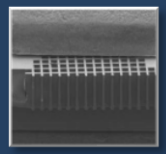
- **Additional projects**
  - Energy harvesting from ferroelectric nanowires
  - Laminated paper-based analytical devices (LPAD) for health monitoring
  - Ferroelectric HfO2 for Multi-Functional Sensor-Logic-Actuator-Memory Devices
  - Large-Scale Multi-Modal Data Representation through Stochastic Device Switching
  - RF Energy Harvesting Circuit Design and Reliability Analysis
  - Self-tuning Critical Paths for Nanometer-scale CMOS Aging and PVT Mitigation
  - Spectrum Enforcement using Interference Fingerprints
  - Glass Interposer Technology as High Frequency System-In-Package Platform

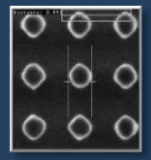
The Center of Innovation

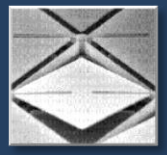

Resonator

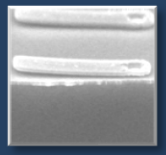

Accelerometer


Deep Trench Isolation

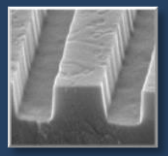

Wells in Silicon


MRAM


Mirror Arrays


Cantilever


Resonator


Channels in Quartz


Carbon Nanotubes


DSiE Vias


Cu Metalization


45nm


MuGFET

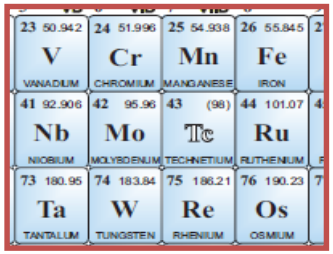

3D Memory

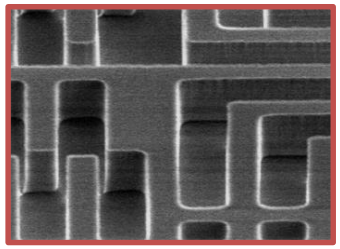
Novati is enabling novel nanotechnology development in:

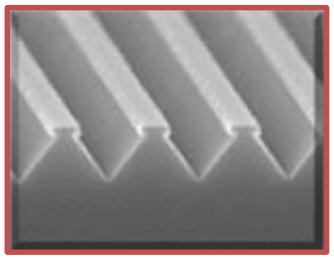
- **MEMS/NEMS**
- **Microfluidics**
- **Silicon Photonics**
- **III-V on Silicon**
- **2.5D/3D Integration**
- **Non-Volatile Memory**
- **High Voltage & RF**
- **Image Sensors**

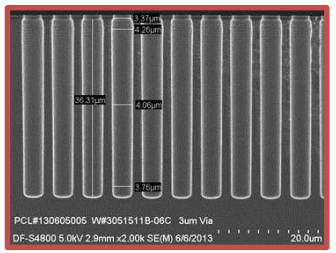
Novati
- Creating Value Through Innovation

End-to-End Strategy Focused on Five Technology Areas





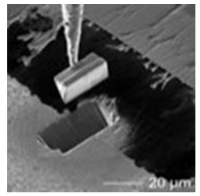


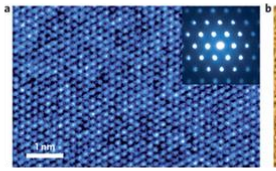
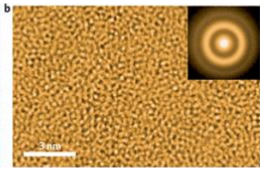


Novel Materials	MEMS & Microfluidics	Silicon Photonics	III-V on Silicon Integration	2.5-D & 3-D Packaging
• More than 60 elements from periodic table • More than 4 times the number of materials than other fabs	• Sensors • Oscillators • Microphones • Microbolo-meters • Camera Lenses • Inkjet Heads • Lab-on-a-chip	• Modulators • Transceivers • Avalanche Photo Detectors (APD's) • Waveguides • Couplers	• DARPA (COSMOS & DAHI) • InP & GaN • RF, Power & Photonics • Monolithic and Hybrid integration	• Licensed Ziptronix - ZiBond® and DBI® technology • TSV's • Wafer Lids • Tezzaron - FaStack® technology

UCF Materials Characterization Facility (MCF)

- **Began as Partner/Back-Up Facility for Lucent Technologies in late 1990's**
- **Continuous Update on Instrumentation and Capability**
- **Expanded User-base to:**
  - Materials Science and Engineering
    - Metals and Alloys
    - Ceramics
    - Polymers
    - Semi-Conductors/Thin Films
    - Composites
  - Nanoscience and Technology
  - Physics and Chemistry
  - Optics and Photonics
  - Civil, Biology, and Biomedical





- **Supported by 1 Faculty Associate Director, 3 Technical Staff and 1.5 Administrative Staff.**
- **Annual User-base of Over 200 (15% External)**

iCAMR

UCF Materials Characterization Facility (MCF)

• **SEM (Scanning Electron Microscope)**	**Zeiss Ultra 55 with E-and SA-BSE, STEM, e-Litho** **JEOL 6480LV with BSE, EDS and EBSD** **Hitachi S3500N VP-SEM with BSE and EDS**
• **TEM (Transmission Electron Microscope)**	**Tecnai F30 300KeV with EDS, STEM, HAADF** **JEOL 1011 TEM with EDS**
• **FIB (Focused Ion Beam)**	**Zeiss CrossBeam 1540EsB with SE, BSE, EDS, In-Situ Lift-Out** **FEI 200TEM with In-Situ Lift-Out**
• **SIMS (Secondary Ion Mass Spectroscopy)**	**CAMECA IMS-3F and PHI 6300**
• **RBS (Rutherford Backscattering Spec)**	**1.7MV Tandetron TBS Accelerator**
• **AES (Auger Electron Spectroscopy)**	**Physical Electronics 600**
• **XPS (X-ray Photoelectron Spectroscopy)**	**Physical Electronics 5400 ESCA**
• **EPMA (Electron Probe Micro-Analysis)**	**JEOL 733 with Four Crystals**
• **XRD**	**Rigaku DMAX-B wih Laue Back Reflection Pattern Capability** **Rigaku DMAX-B Thin Film Capability** **New Unit (TBD) will be Acquired via Recent ONR-DURIP Award**
• **Specimen Preparation**	**Gatan PECS (Coating System), Ion Milling, Ultra Microtome,** **Sputter Coater, Vacuum Evaporator/Carbon Coater, Diamond,** **ElectroJet Polisher, Dimple Grinder, Allied Polisher, Buehler VibroMet**

Potential Participants

- **International Consortium potential partners**
  - imec, HOLST, TNO, Fraunhofer, Leti, Philips
- **Potential U.S. program partners** (European partners to be identified)
  - Harris Corporation, Lockheed Martin, Jabil, DRS Technologies, TI, Boeing, Intersil, BAE Systems, Johnson Controls, GE, Valleo, Honeywell, Johnson & Johnson, Shell, BP, Schlumberger, Northrop, TriQuint, Medtronic, St. Jude, and many others
- **Supply chain potential partners**
  - ASMI, TEL, Applied Materials, Aixtron, KLA-Tencor, many others
- **Processing, Technology and Infrastructure Support**
  - imec, ASMI, Novati, TNO / HOLST, Leti, Page, Hensel Phelps, others
- **Universities and Institutes**
  - UCF, University of Florida, University of South Florida, University of Texas, many others
  - Florida Medical Centers, Texas System Medical Center, Methodist Research Hospital
  - International universities, institutes, and medical centers
- **Other key potential partners**
  - DARPA / DOD, NIST, NSF / National Labs, Florida Power and Light, Duke Energy, others

All Four Development & Manufacturing Centers

iCAMR Projected Funding Requirements

Centers ($K)	Funding: Industry**	Supply Chain**	Gov Agencies	Florida	Total
* CSMDMT [Phase I]	25,000	25,000	25,000	226,000	$301,000
Advanced Energy	15,000	15,000	15,000	5,000	$50,000
Manufacturing Competitiveness	20,000	20,000	30,000	5,000	$75,000
International Emerging Tech Ctr	20,000	20,000	30,000	5,000	$75,000
Total	$80,000	$80,000	$100,000	$241,000	$501,000

Investment ($K)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Industry (Mfrs / Supply Chain)	2,000	20,000	35,000	50,000	53,000	$160,000
Government Agencies	3,000	15,000	20,000	25,000	37,000	$100,000
Florida	116,000	50,000	25,000	25,000	25,000	$241,000
Total	$121,000	$85,000	$80,000	$100,000	$115,000	$501,000

Use of Funds ($K)***	Year 1	Year 2	Year 3	Year 4	Year 5	Total
CSMDMT [Phase I]	116,000	61,000	39,000	41,000	44,000	$301,000
Advanced Energy	2,000	12,000	12,000	12,000	12,000	$50,000
Manufacturing Competitiveness	1,000	6,000	14,000	22,000	32,000	$75,000
International Emerging Tech Ctr	2,000	6,000	15,000	25,000	27,000	$75,000
Total	$121,000	$85,000	$80,000	$100,000	$115,000	$501,000

* Phase I ICAMR launch is foundational for substantial development growth and the creation of three additional centers

** Program Participation, Equipment Donations, Equipment Discounts, Intellectual Property, Fab / Lab Usage, Assignees from Participants, Industry Contracts (focus on Florida), International Programs, Emerging Technologies, Start-ups Support

*** Program Spending includes labor, processing, lab costs, direct project costs, OVHD, IP, computing, and consortia/operations support

ICAMR

Status and Next Steps

- ✓ Year 1 infrastructure and operational funding secured, >$125M
- ✓ Initial ICAMR building design complete, construction procurement process started
- ✓ Core consortium management team secured
- ✓ Launched initial efforts to attract government funding with two major U.S. Department of Defense submissions for $150M
- ✓ Public announcement and official launch planned for August
- Secure international research institution and processing partner(s)
  - Align efforts to best leverage ICAMR and partnership programs and infrastructure
- Engage / recruit US and international industry
  - Key sensor industry product and equipment manufactures, supply chain and end-users
- Establish consortium governance team
- Launch roadmapping initiative – standards activities to follow
- Define and launch initial programs (Initial work to be accomplished at partner/member sites)
- Develop internships and educational/training programs
- Expand funding channels (state, national hubs, industry, JDPs,.)

ICAMR

International Collaboration to Solve the Many Challenges

- Success in emerging technologies is driven by development and innovation that lead to advances in manufacturing
- Success depends on comprehensive national and international collaborations
  - Challenges are global, and cut across industry ecosystem
  - Solutions require significant investment, leveraged funding

- The regions of the world that have the wisdom and confidence to spearhead these collaborations will be the leaders in manufacturing of the future disruptive and revolutionary devices and systems
- ICAMR well positioned for the multi-trillion dollar next-generation emerging technology market
  - Sensors, photonics, advanced materials & emerging technologies industries are key to the world's economies
  - Federal Government interested in further utilizing consortium model for key technologies & manufacturing
  - Consortia model is strong - critical need for accelerated and collaborative R&D in the emerging technology

Back - up

Targeted Industry Markets and Technologies

- **Enhance strong international collaboration in sensors/photonics/materials sectors**
  - ➔ ***Florida making substantial investment in infrastructure and industry-led consortium***
- **Global industry technology leaders (Intel, Samsung, TEL,…) and business analysis experts (Garner, VLSI Research,…) agree that the next disruptive market explosion will be "semiconductor-based" connected devices – led and enabled by the production of advanced sensor devices**
  - By 2017, smart sensors will be the dominant product for semiconductor manufacturing
  - Pervasiveness of sensors will be catalyst for growth & technology advances in nearly all industries

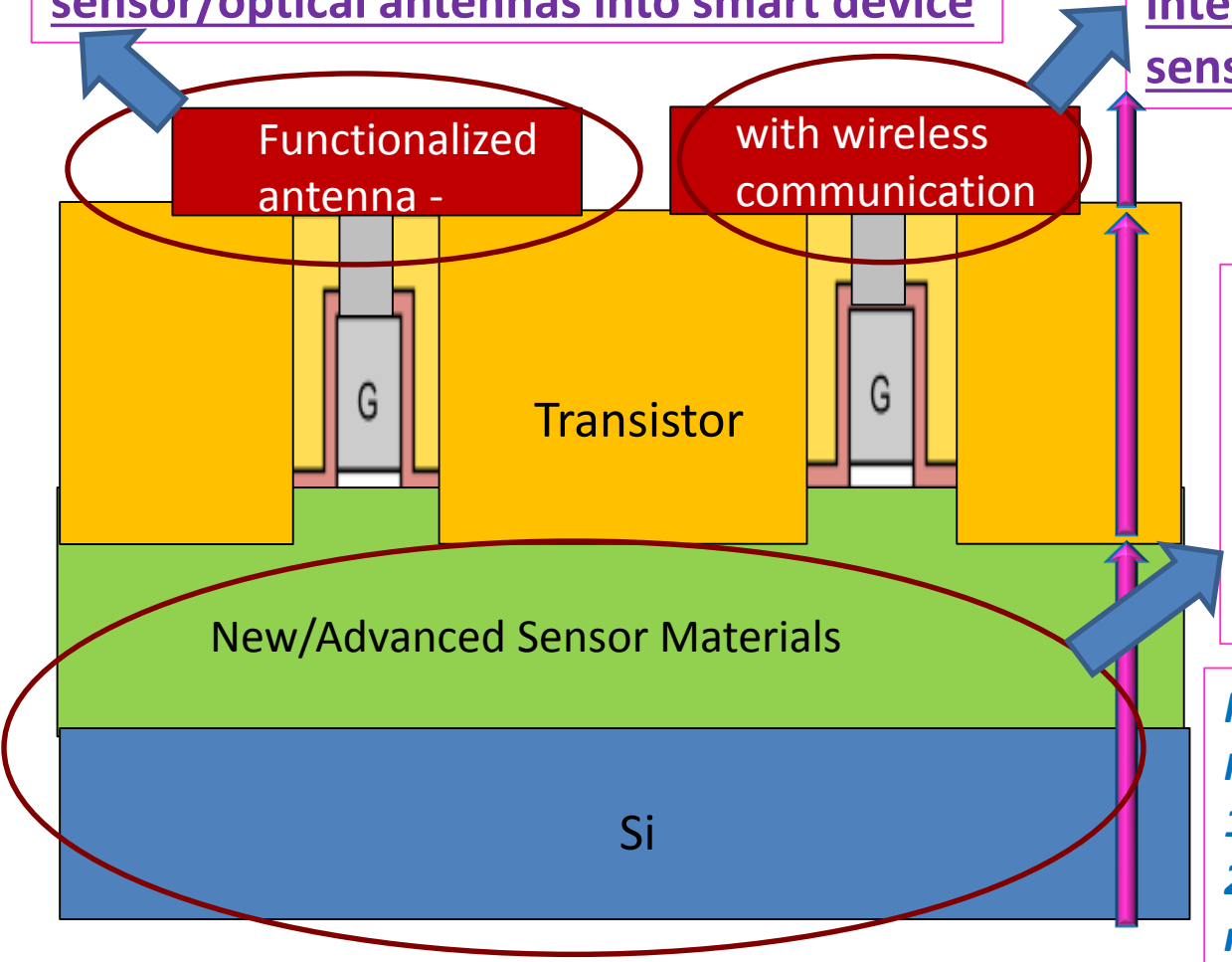
Aerospace and National Defense	Manufacturing
Oil and Gas	Health Care
Agriculture	Transportation
Communications	Banking and Securities

- **Pervasive computing / Internet of Things (IoT) represents a $1.9T (Gartner) opportunity by 2020 and a $100B (VLSI) opportunity for semiconductors … (a 30% expansion of the industry of the premier technology industry)**
  - By 2017, 50% of IoT will originate in startups less than 3 years old
  - The Internet of Things will have a broad scale impact across the economy, affecting consumers, enterprise, and government
    - ➔ ***By 2020 over 50 billion devices will be connected by sensors***

Universal Smart Sensor Fabrication Integration Strategy

2. Integration of functionalized sensor/optical antennas into smart device

3. Short range RF communication integrated into a universal smart sensor device



1. III-V materials deposited on 200mm/300mm Si substrates for cost effective manufacturing of advanced devices – sensors, photonics, etc.

Note:
ICAMD to include:
1) An advanced packaging line
2) Advanced testing and reliability labs