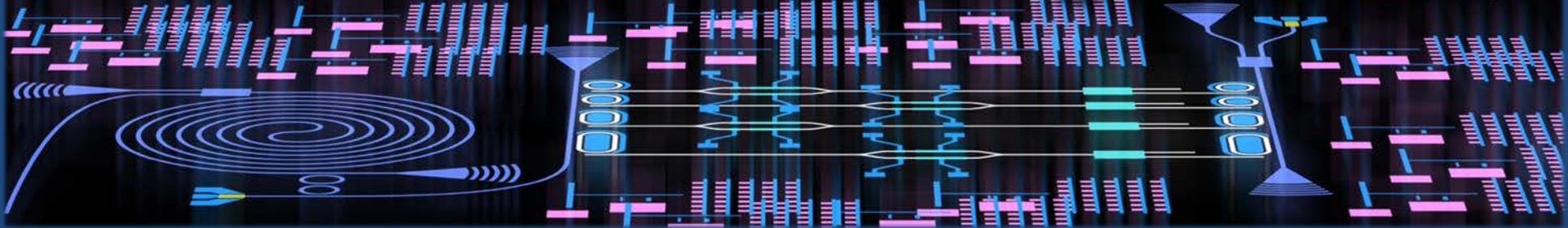


INTEGRATED PHOTONICS

INSTITUTE for MANUFACTURING INNOVATION



Integrated Photonics Institute for Manufacturing Innovation (IP-IMI)

Dev Shenoy, Ph.D

Advanced Manufacturing Office, EERE

U. S. Department of Energy

1000 Independence Ave., SW 20585

Email: Devanand.Shenoy@ee.doe.gov

Acknowledgements: Dr. Peter Goetz, Government Chief Scientist, IP-IMI

ARPA-E Workshop on Optical Interconnects, July 28-29, 2015

National Network for Manufacturing Innovation

- National network of Institutes focused on advanced manufacturing to revitalize American manufacturing
- Industry, academia, government and other stakeholders working together to support manufacturing
- Federal funds matched 1:1 by non-federal funds
- Currently 6 Institutes, including the IP-IMI



Institutes in the NNMI

- **America Makes** – Additive manufacturing (3D printing)
- **Digital Manufacturing & Design Innovation Institute (DMDII)** – Integrated digital design & manufacturing
- **LIFT** – Lightweight Technology (primarily metals)
- **Power America** – Wide bandgap semiconductors
- **The Institute of Advanced Composites Manufacturing Innovation (IACMI)** – Advanced Fiber-reinforced polymer composites
- **IP-IMI** – Institute for Photonics Manufacturing



IP-IMI Timeline

- **October 3, 2014: President Obama announced the IP-IMI.**
- November 5, 2014: AFRL released FOA on behalf of OSD/MIBP, requesting Concept Papers.
- December 19, 2014: Concept Papers due.
- March 31, 2015: Full Proposals from Invited Proposers due.
- July 28, 2015: Institute winner announced - RF-SUNY.
- **Institute's operations will begin approximately January 2016. Federal funds run for 5 years.**



Definition of Integrated Photonics

“Integrated photonics generally is the integration of multiple lithographically defined photonic and electronic components and devices (e.g. lasers, detectors, waveguides/ passive structures, modulators, electronic controls and optical interconnects) on a single platform with nanometer-scale feature sizes.

U.S. Integrated Photonics: Current Status

- Some of the best capabilities for Integrated Photonic Circuits reside in the USA *but...*
 - Access to U.S. foundries is **proprietary, limited, & expensive**
 - Outside groups must develop their own fabrication processes & customized components
 - *Component* development with low yield and quality
 - Lack of standardization
 - Duplication of effort, Market fragmentation
- **Slow progress & high costs**

Why do we need an IP-IMI?

- **We need an Ecosystem capable of delivering a Manufacturable Product that:**

- incorporates a diverse group of Materials/Foundries (Si, InP, SiN, GaAs, LiNbO3, Glass, etc)
- has a common approach to CAD & simulation tools
- includes a rapid prototyping capability
- is able to coordinate Test, Assembly and Packaging across multiple technologies/foundries
- grants access to a wide variety of “customers”

-> We need this IP-IMI to function as if it were being done by a Single Vertically-Integrated Company

IP-IMI Stated Goal

“...**provide access** to all elements of the integrated photonic manufacturing technology innovation ecosystem, with the goal of establishing processes that will lead to a more responsive and integrated domestic manufacturing industrial base, to include **standardization** of component modules, and advances in design tools, assembly, testing and packaging.”



Integrated Electronics Solution: MOSIS

- MOSIS was built around 3 main ideas:
 - **Standard building blocks** for components & circuits
 - **Share costs** by putting multiple projects from various users on a single mask set
 - **Give government labs & universities access** to foundries

“The Birth of the Microchip”

<http://www.longviewinstitute.org/projects/marketfundamentalism/microchip/>

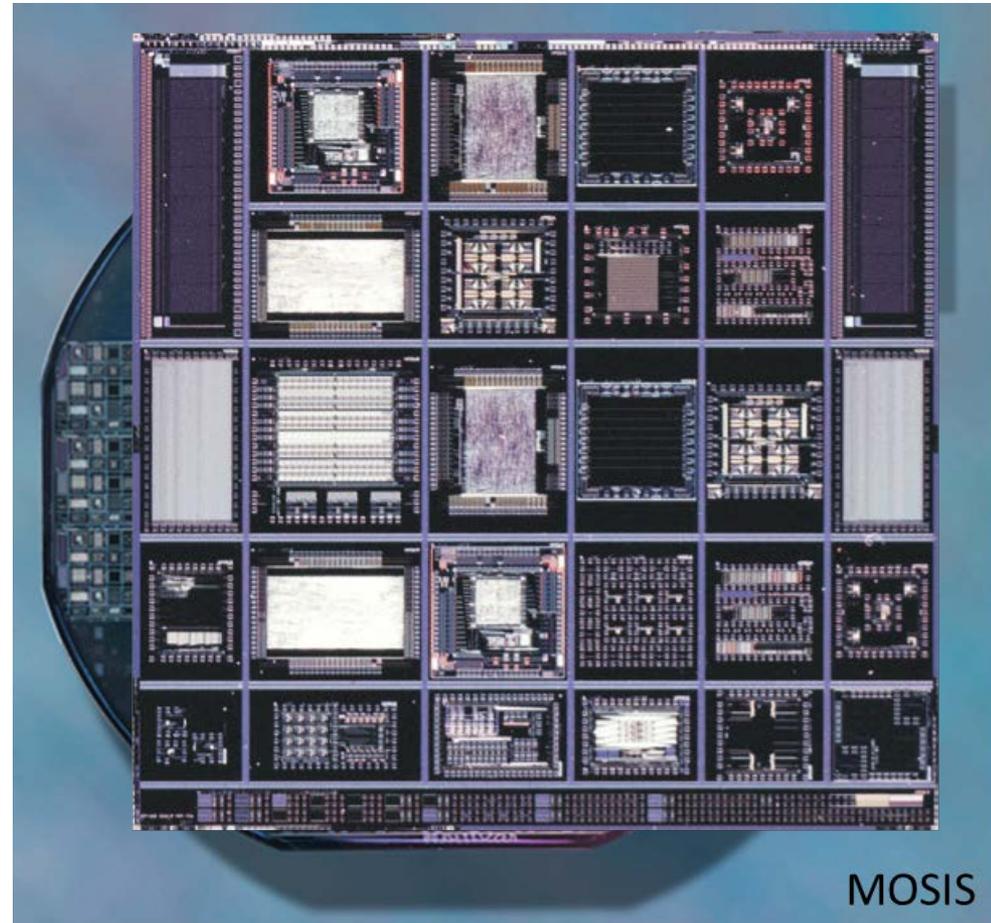
“Funding a Revolution”

<http://ai.eecs.umich.edu/people/conway/Impact/FundingaRevolution.html>



Cost sharing: Multi-Project Wafers (MPW)

- Mask & processing costs shared amongst many users
- Multiple projects per wafer
- Each user gets many copies of **their own die**

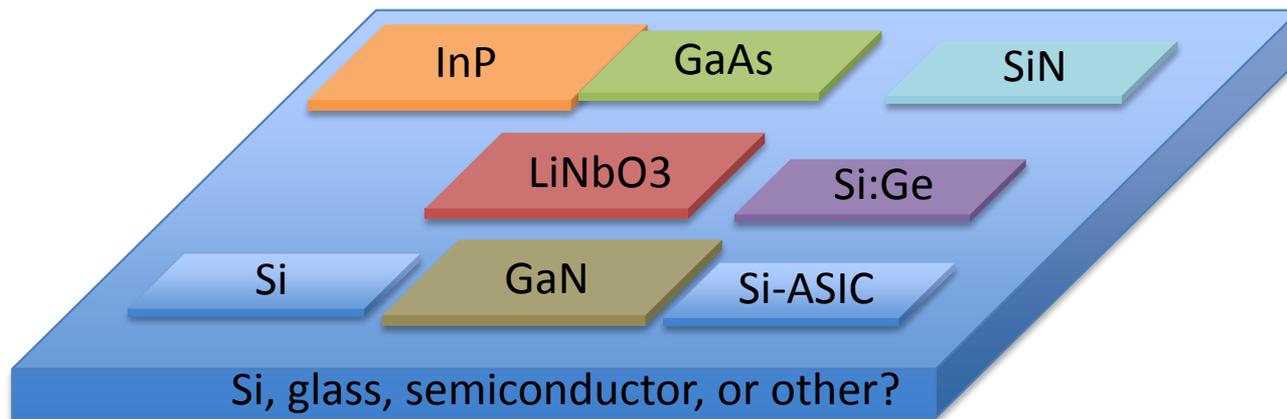


Impact of MOSIS on Electronics Industry

- Government labs, universities & small-to-medium enterprises (SMEs) have access to state-of-the art integrated **electronics** foundries
- Cooperation between academia & industry (uncommon prior to MOSIS)
- Academia provides industry w/graduates familiar with industry's tools and techniques
- Greatly reduces costs of novel designs
- Simplifies path to production, enabled fabless companies
- Widely credited for helping U.S. regain its lead in microelectronics

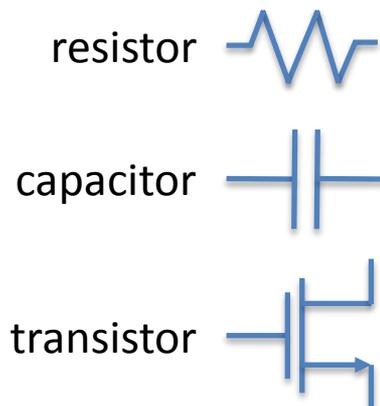
Integrated Photonic Systems can be “Material Diverse”

- **Goal: Diverse material systems, utilizing both electrical and optical chips, analog and digital chips/techniques, must be incorporated to increase functionality, reduce size and cost, to yield innovative solutions within a volume manufacturing process.**



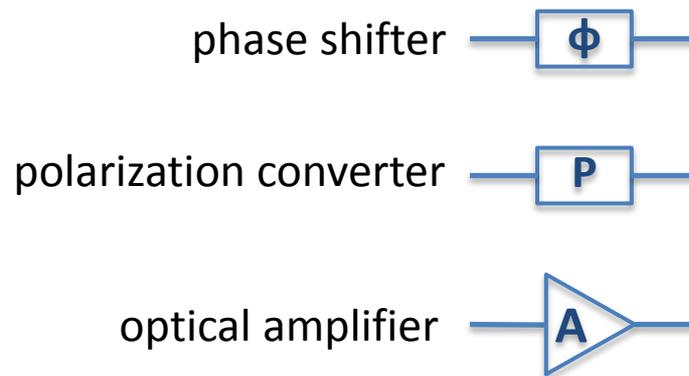
Electronic ICs Analogy to Photonic ICs

Basic Electronic Elements



**Electronic ICs are
connected by metal traces**

Basic Photonic Elements

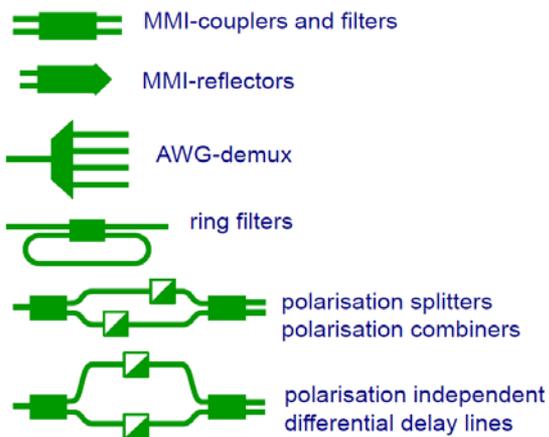


**Photonic ICs are
connected by waveguides**

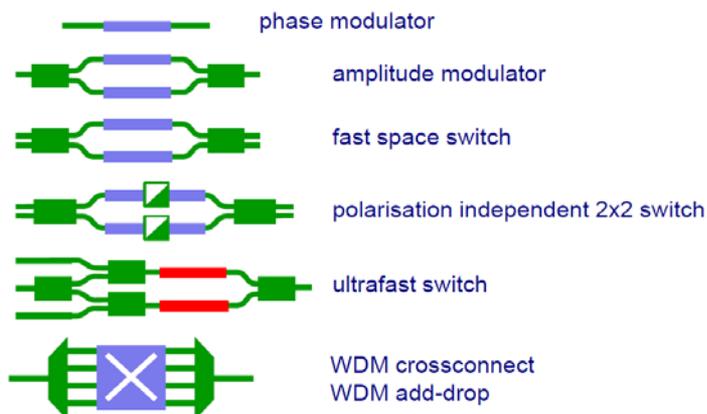
Devices are processed in parallel, creating Integrated Circuits

Photonic Integration w/Basic Building Blocks

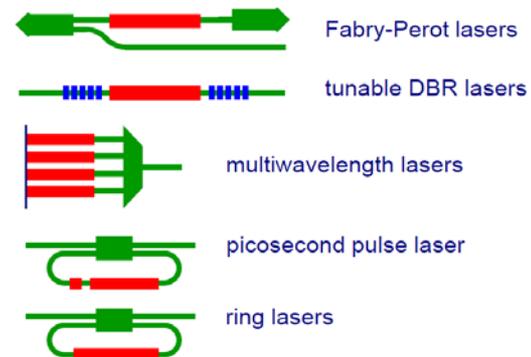
Passive Devices



Devices w/Phase Modulators (Switches, Modulators)



Devices w/Optical Amplifiers (Lasers)

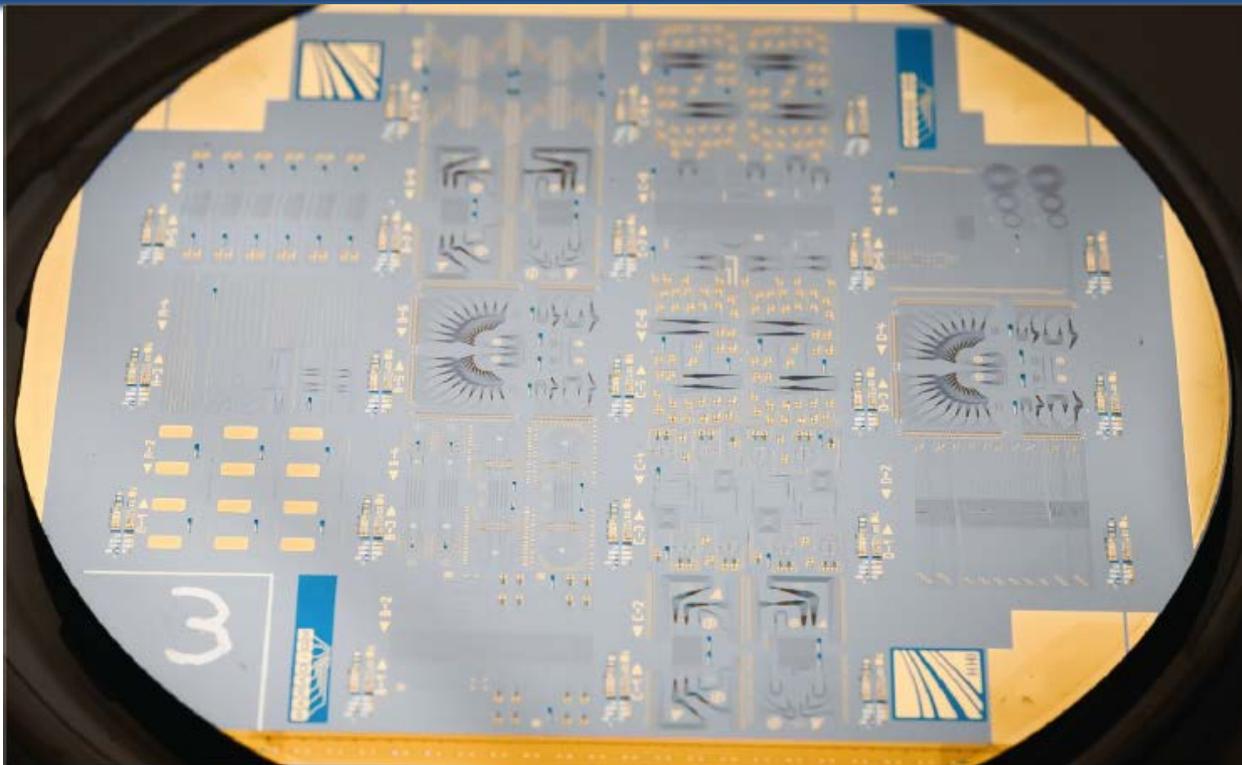


From "Generic Integration Technology," Photonics Integrated Circuits Workshop 2014, Meint Smit

Libraries are created from combinations of components. Designs are optimized and reused. Simulations models are verified over many runs.

Process Design Kits (PDKs) to allow designers to use these libraries.

Photonic Integrated Circuits Wafer

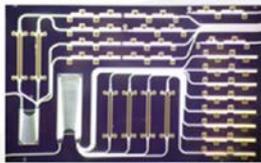


*100-Channel WDM Rx-Type PIC on InP for Use of Low-Cost and Low Power Consumption Electronics
M. Baier(1), R. Broeke(2), F. Soares(1), M. Gruner(1), A. Seeqer(1), M. Moehrle(1), N. Grote(1), M. Schell(1)*

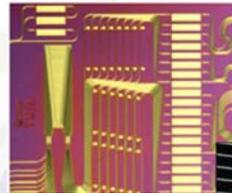
Photonic Integrated Circuits can be processed in the same foundries as Electronic Integrated Circuits

Sample Integrated Photonic Circuits

Fiber to the Home
Wireless



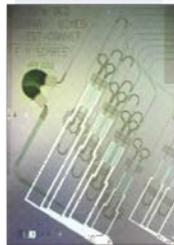
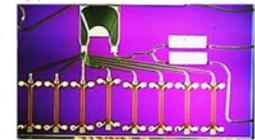
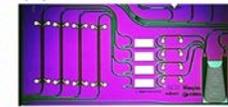
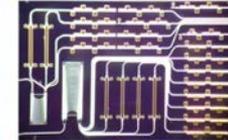
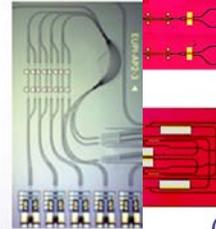
Medical
Bio-imaging



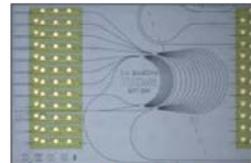
Datacom
Switching



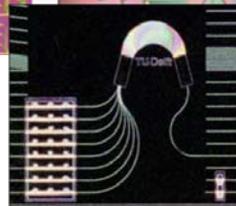
Sensor
Readouts



WDM-TTD switch



Cascaded WDM



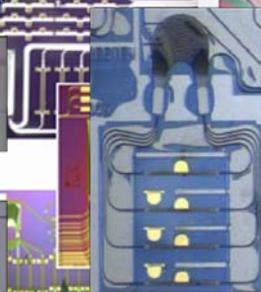
multiwavelength laser



tunable multiwavelength laser



picosecond pulse laser



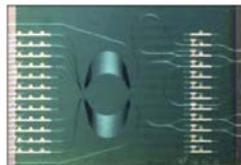
WDM ring laser



optical crossconnect



optical crossconnect



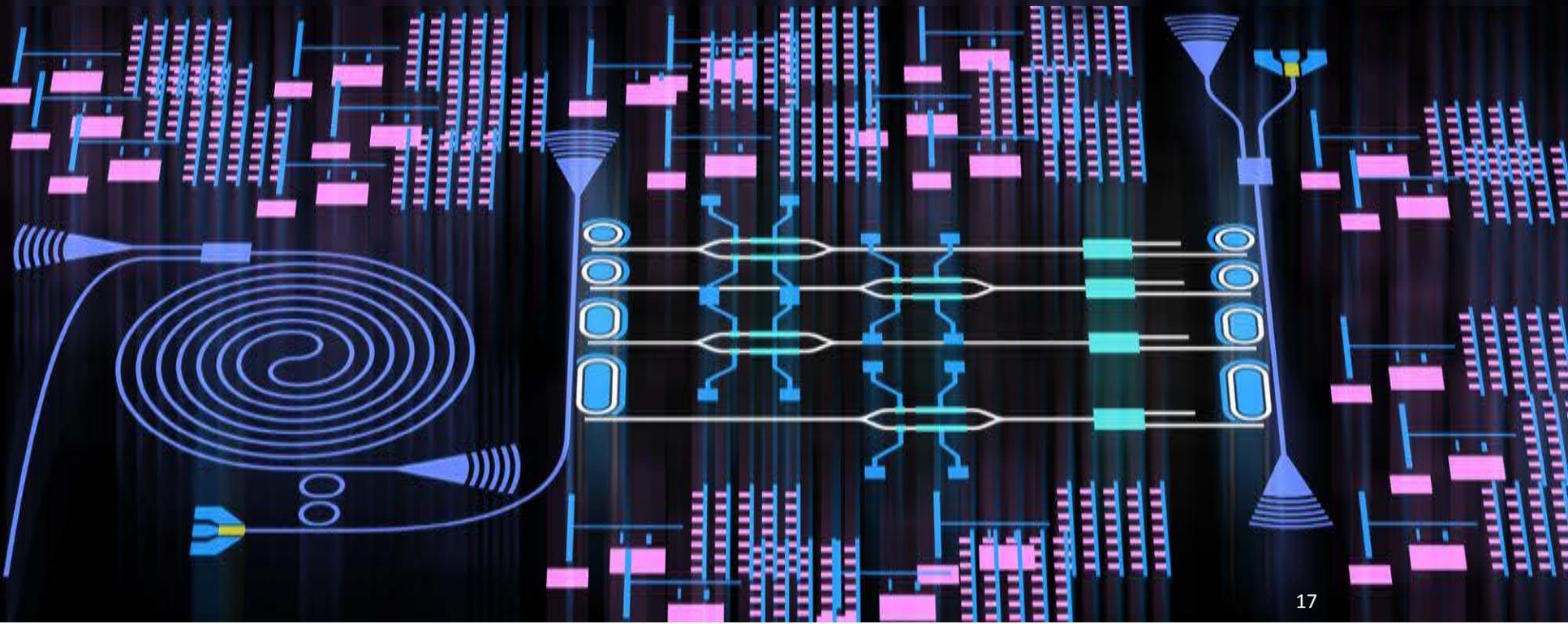
wavelength converter

JePPIX processed designs

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Process Design Kits (PDKs)



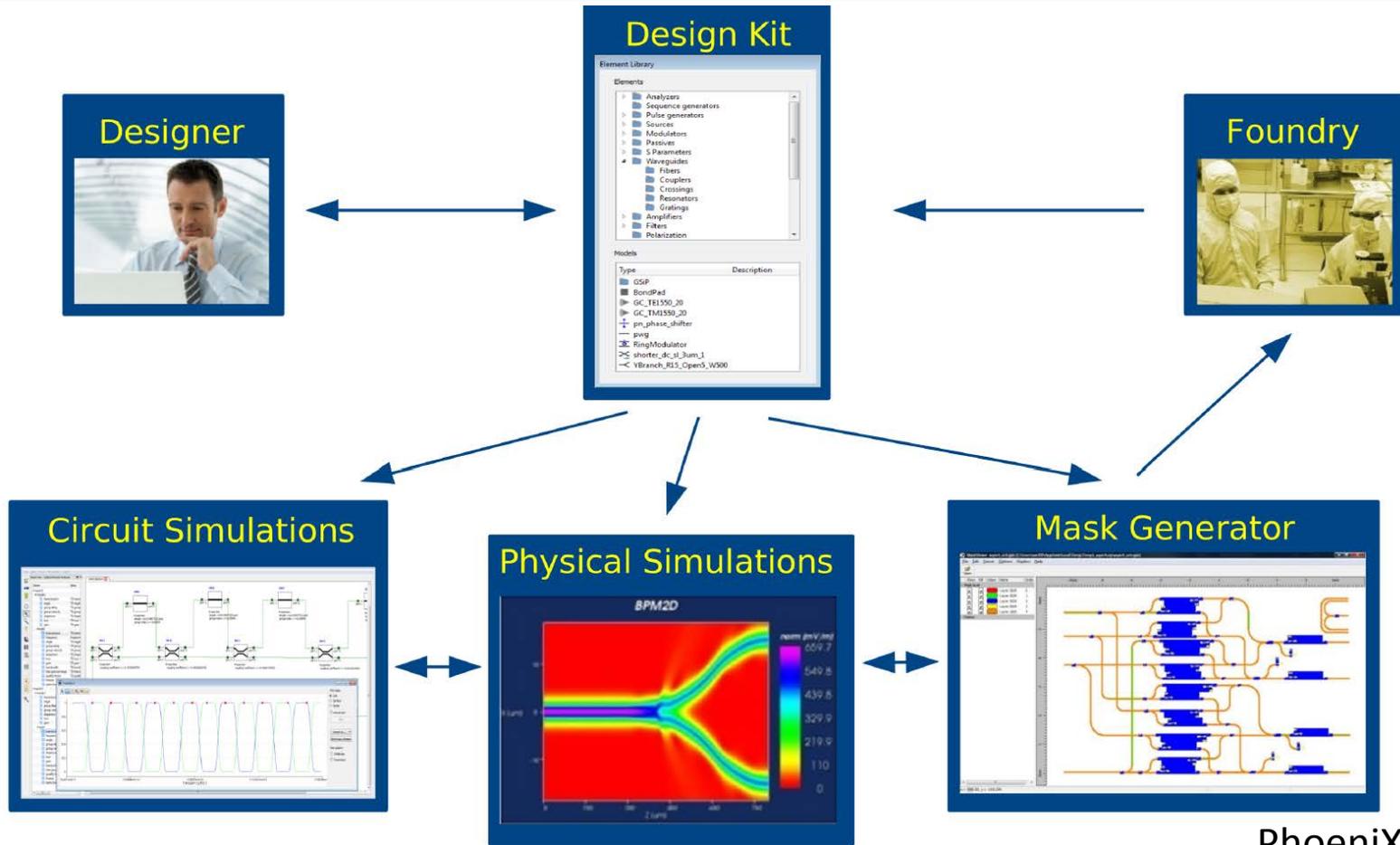
Process Design Kits (PDKs)

- PDKs: information about a fab's building blocks and process for design, layout, and simulation
- IBM, Intel, Infinera, Luxtera, etc. each have unique PDKs
- Allow efficient interaction between designer & fab:
 - Re-use existing building blocks
 - Translates design intent into Clean Layout for manufacturability
 - Simulate designs for process variation/functional performance
 - Allows both **physical model simulations** & **compact circuit models (S-parameter style)** for complex circuitry

Benefits of Using PDKs

- Reduces design time and cost
- Allows complex designs to be successful on the 1st run (Iteration could add a year!!!)
- Allows Foundries to maintain proprietary designs (black box components)
- Simplifies porting designs from one foundry to another
- Reduces level of education/training required to create sophisticated designs
- Gives easy access to **standardized packaging**

PDK Functions



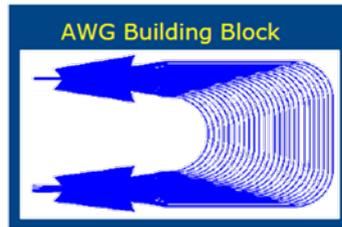
Phoenix Software

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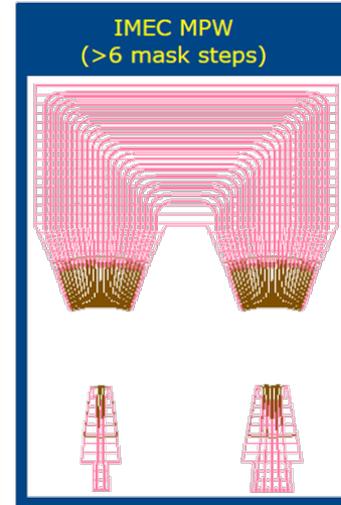
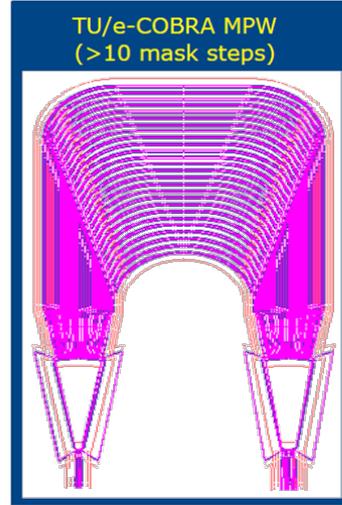
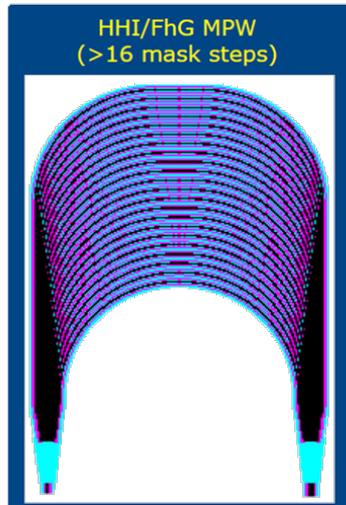
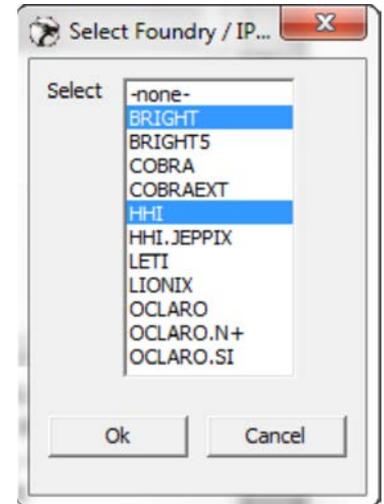


Photonics Design Flow with PDKs

1) Build circuit w/Parametric Building Blocks



2) Select Foundry PDK



3) PDK deals with creating foundry's mask levels & conforming to design rules

What will the IP-IMI provide?

- Federal funding: \$110 million (to be matched at least 1:1)
- **Access** to world-class foundries and packaging houses (both small-scale for research & large-scale for manufacturing)
- **Standardization** of components, modules, assembly, testing, and packaging
- **Packaging & Testing development** for manufacturable products
- **Education & Training** (Design training, Fab-resident training)
 - Pool of educated designers creating new applications & companies, forming the basis for self-sustainment of the Institute

Standardization

- + **Reduced design time & cost** by eliminating need for re-designing basic components and packaging
 - + **Guaranteed functionality**
 - + **Increased 1st run success** through decreased process variations & validated simulations
-
- **Reduced flexibility**, some designs not possible

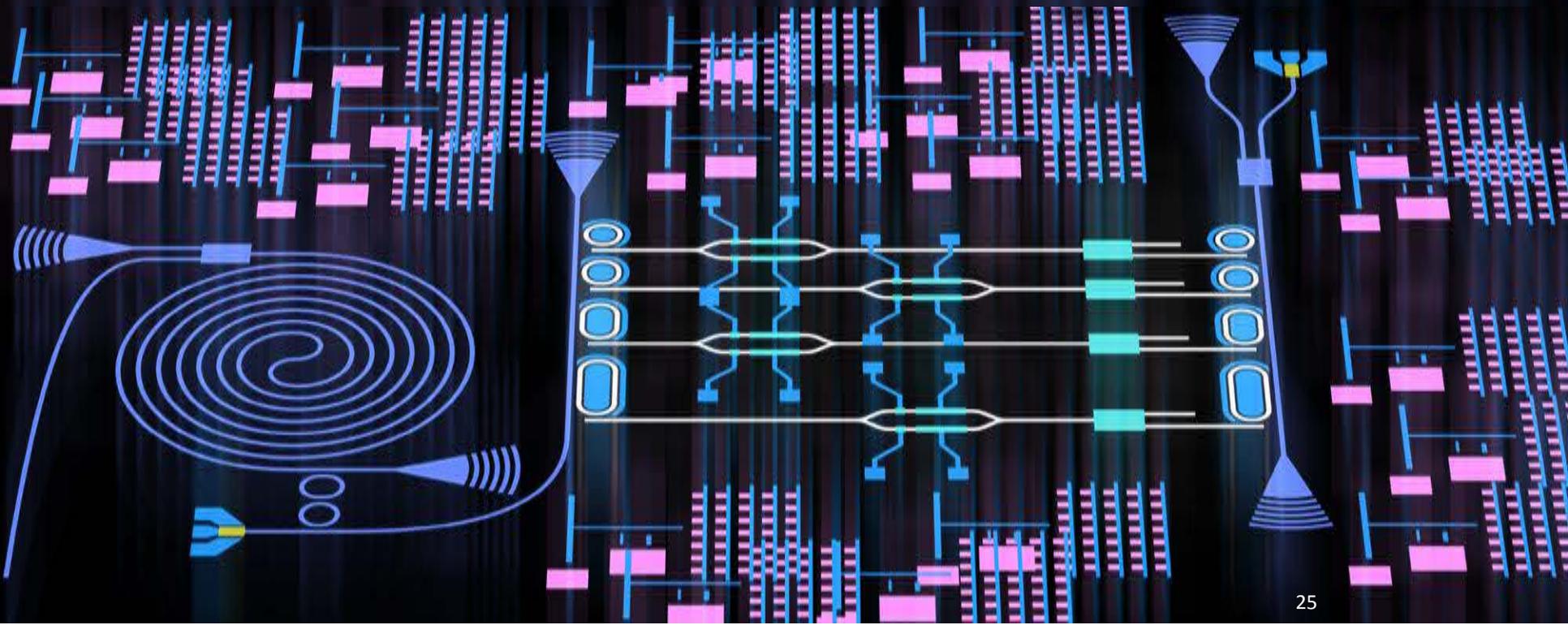
Standardization is primarily addressed through **PDKs**

Collaboration and Membership

- Institute creates structure for competitors to pool resources and collaborate
- Membership provides legal framework for Intellectual Property management



IP-IMI Projects



3 Core Technical Areas Required

1. **Digital** data and communication links
2. **Analog** RF applications
3. **Sensors** (chemical, biological, and/or physical)

All of these should be **producibile at high volume.**
Packaging and Testing are critical!



Types of Institute Projects

The Institute will have 2 distinct types of projects:

1. Project calls
2. Customer projects



Project Calls

- Throughout the life of the Institute, research projects that support goals of the Institute will be solicited, selected, and awarded.
- **These must provide benefit to the entire Institute Membership**—not closed to other Institute Members
- **Sharing of results & costs with the Institute is required**
- **Publication of some results encouraged**
- **Institute shares costs with Members**
Awardee leads (w/Institute input)

Customer Projects

**The Customer pays and leads
Income helps support Institute**

- Customers can be
 - Institute members
 - Non-members
 - Government agencies (e.g. DARPA)
 - Companies (large companies, SMEs, start-ups)
- Projects may include
 - Open projects (e.g. academic R&D)
 - Closed/proprietary projects
 - Mixed work (open and closed)

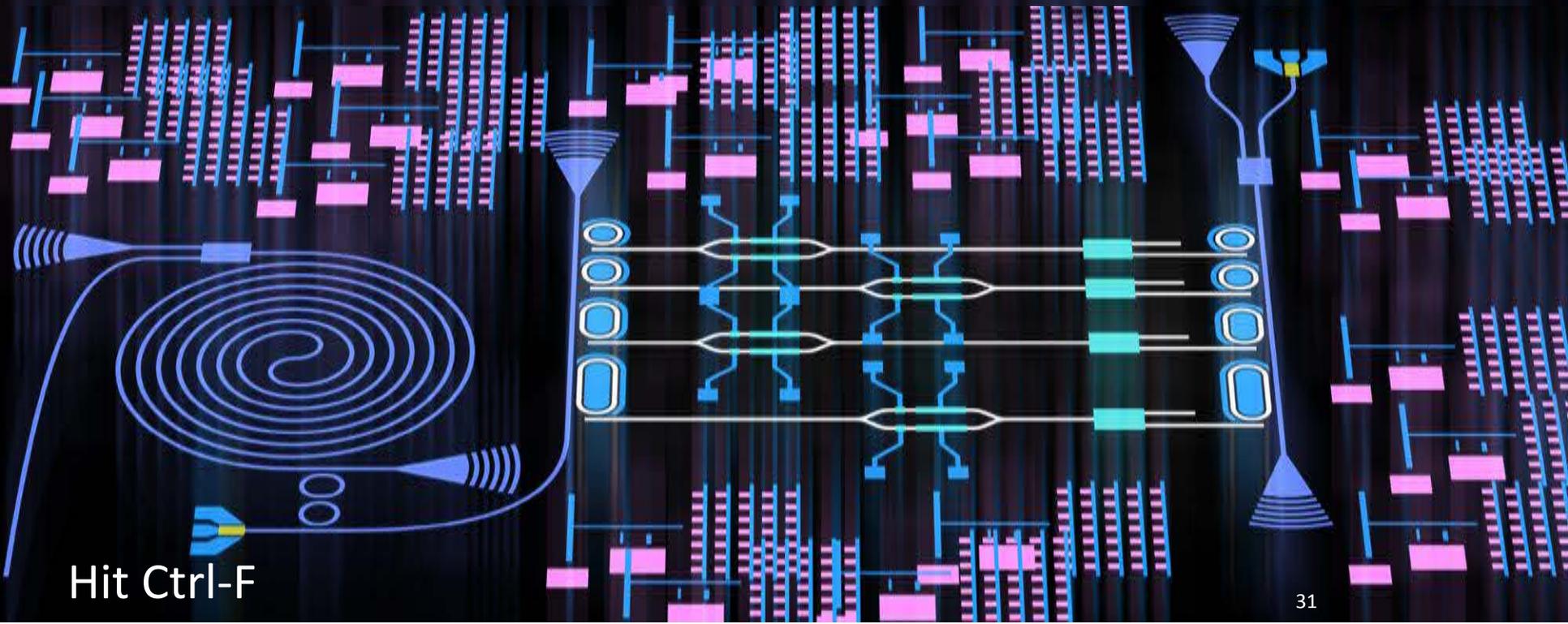
How do I Join a Project?

How other NNMI Institutes do Project Calls:

- Project Call topic determined by Institute Leadership
- If your organization is an Institute member, you will be eligible to bid on project calls, typically as part of a **team**.
- If not an Institute member, you can team & propose as part of a team, but you can't lead. You will be required to become a member if your team wins.



[http://manufacturing.gov
/ip-imi.html](http://manufacturing.gov/ip-imi.html)



Hit Ctrl-F