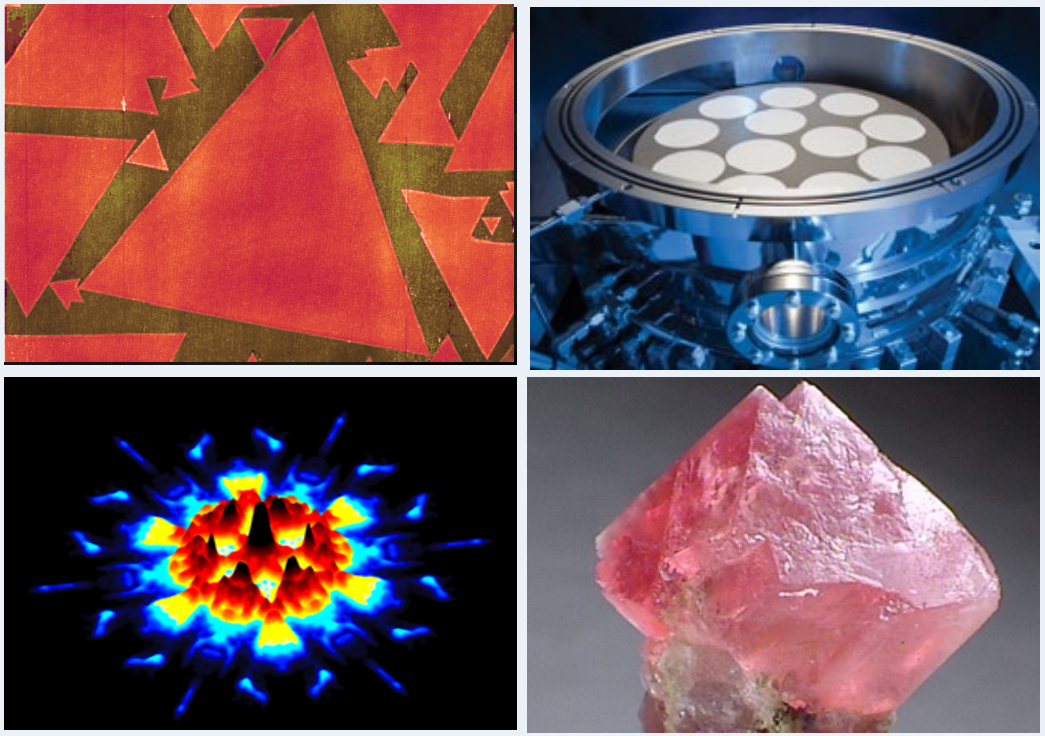
# Materials Innovation Platforms (MIP):

## NSF *Mid-scale Instrumentation and User Program to Accelerate The Discovery of New Materials*



2016 MRSEC Directors Meeting

Sean L. Jones, Charles, Ying, Guebre X. Tessema, and Leonard Spinu
Division of Materials Research
National Facilities and Instrumentation (NaFI) program

# Reminder: National Facilities & Instrumentation (NaFI) Program Portfolio

**Stewardship:** National Facilities program provides high cost and unique experimental capabilities to the DMR community:

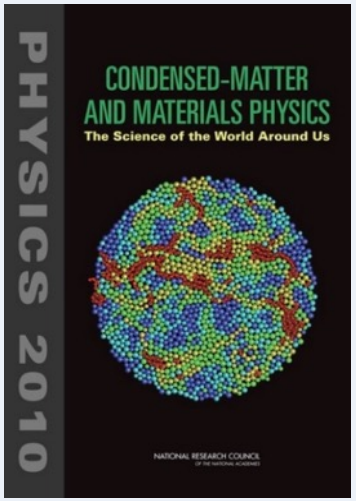
- **Cornell High Energy Synchrotron Source (CHESS)**
- **National High Magnetic Field Laboratory (NHMFL)**
- **Materials Innovation Platforms (MIP)**

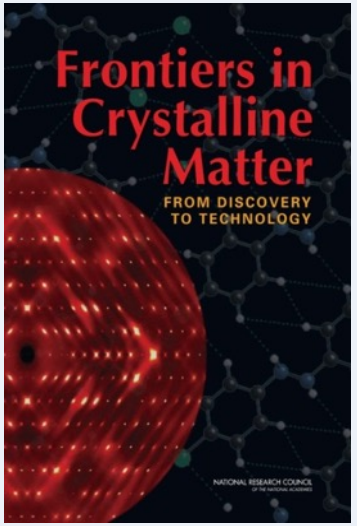
**Partnership:** National Facilities program partners:

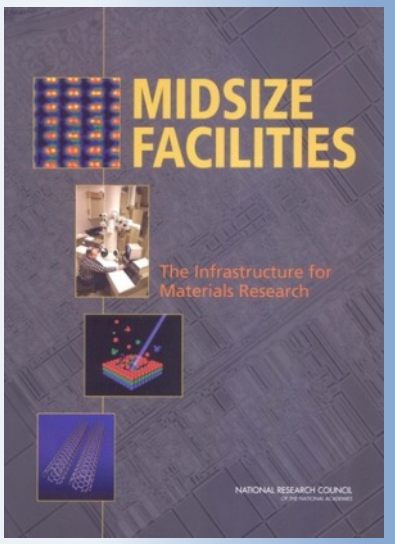
- NIST: **The Center For High Resolution Neutron Scattering (CHRNS)** at the NIST Center for Neutron Research
- NSF/Chem: **ChemMatCARS Beamline** at the Advanced Photon Source
- NSF/ENG: **National Nanotechnology Infrastructure Network (NNIN)**
- NSF/OIA: **Major Research Instrumentation (MRI)** program – division leads in instrumentation development efforts.

# DMR Mid-scale Facilities

- The need for Mid-scale Facilities has been highlighted in several reports: MidSize Facilities (2006), Frontiers in Crystalline Matter (2009), CMMP Report (2010), DMR COV (2011), and Materials 2022 (2012).
- Most recent reports recommend NSF consider regional facilities to enhance materials-related infrastructure in the U.S.
- Mid-scale user facilities focused on a science topic, not an instrumentation type.
- Include instrument development and cross-disciplinary training of users and students.
- Support for technical staff is key.



# Materials Innovation Platforms (MIP)

**July 2014: MPS AC Study – *Closing the Loop***
Cherry Murray and George Crabtree, co-Chairs
*Graphic courtesy of Charles Anh*

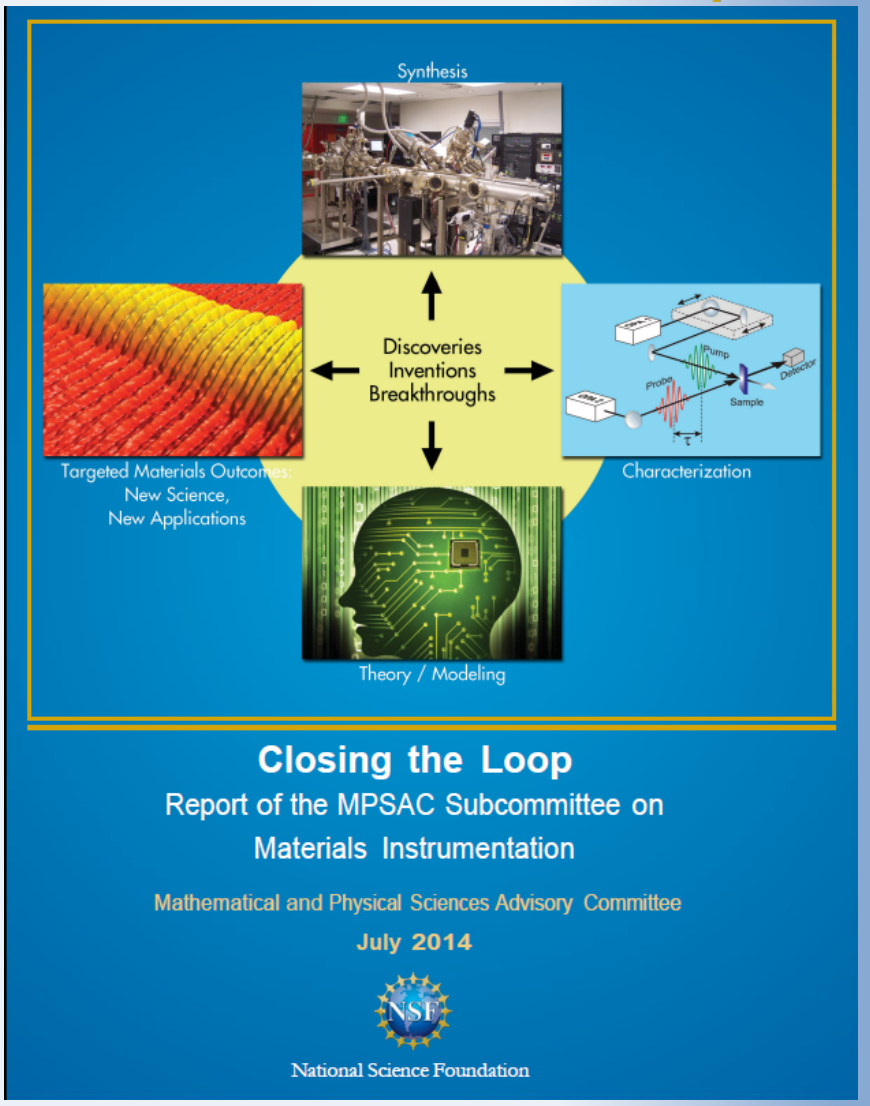
Need *Materials Innovation Platforms* focused on targeted national priorities (**MIP**).

Mid-scale facility focused on a science topic, not an instrumentation type.

With flat budgets, DMR's investments in facilities should be for "unique capabilities".

Adopt MGI/DMREF strategy and combine synthesis, characterization, theory and computation – accelerate materials discovery.

Need national materials synthesis capabilities.



# Last Year at the Director's Meeting…

## MIP Solicitation: NSF 15-522

- 5 year award: $10,000,000 – 25,000,000 with a 5 year renewal based on performance. 10 years maximum – sunset.
- 1 to 3 awards, depending on the availability of funds
- 1st competition focuses on the synthesis of bulk/thin film crystalline inorganic materials: 2009 National Academy report - *Frontiers in Crystalline Matter: From Discovery to Technology*.

- Received 50 proposals; 4 Returned Without Review
- 46 proposals reviewed in 2 Topical Panels
- 4 invited for a Reverse Site Visit
- 2 awards made March 4, 2016
- Panel recommended investment in 2D materials for electronic applications

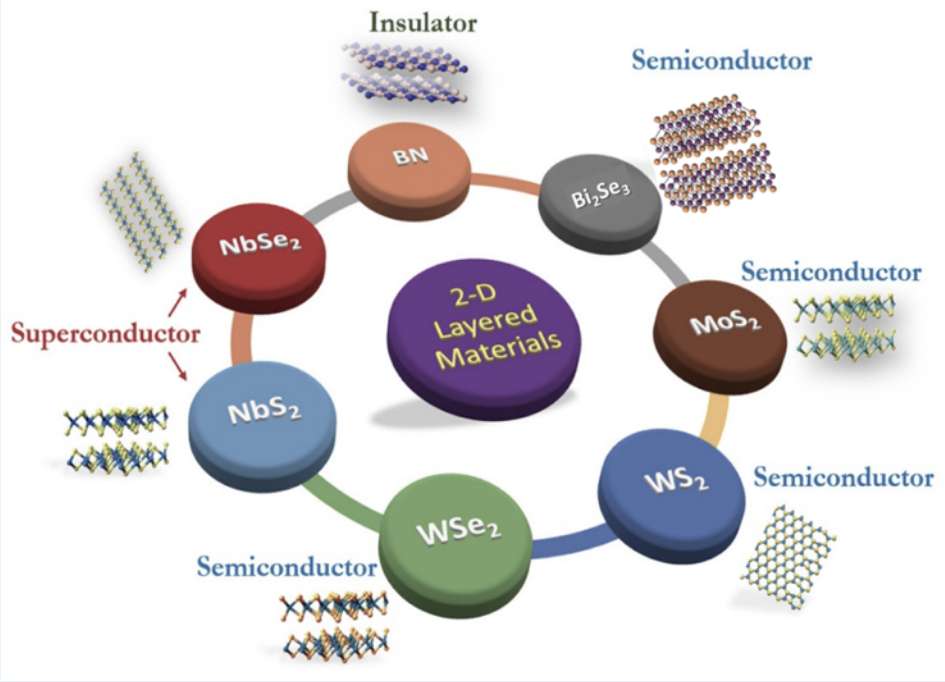
# 2D Crystal Consortium

**NSF** Materials Innovation Platform

PennState

NSF

2D chalcogenide monolayers, surfaces and interfaces are emerging as a compelling class of systems with transformative new science that can be harnessed for novel device technologies in next-generation electronics.




- Fundamental growth processes of 2D systems
- Conformal and uniform coverage of 2D systems
- Large area growth

**Hybrid MBE**
**Chalcogenide MOCVD**
**CVT, Bridgman**

*In-situ measurement*

*insights into growth*

**STM/AFM**
**ARPES**
**4-probe**
**Raman, PL**

*characterization & interpretation*

**DFT**
**Reactive FF**
**Monte Carlo**
**Phase field**

Find the 2DCC at www.mip.psu.edu

PARADIM

Cornell University

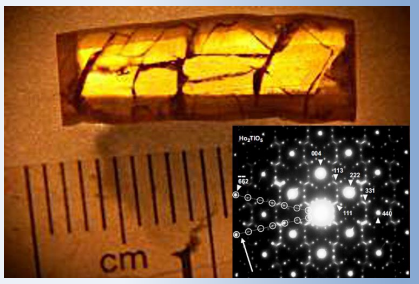
PRINCETON UNIVERSITY

JOHNS HOPKINS UNIVERSITY

CLARK ATLANTA UNIVERSITY

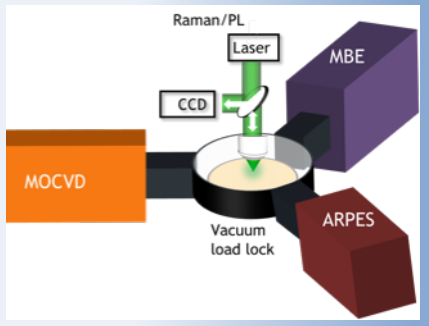
NSF

Oxide-based multi-layer structures with a range of 2D material systems such as oxides, chalcogenides and graphene for novel electronic and magnetic functionality. Major bulk crystal growth effort.



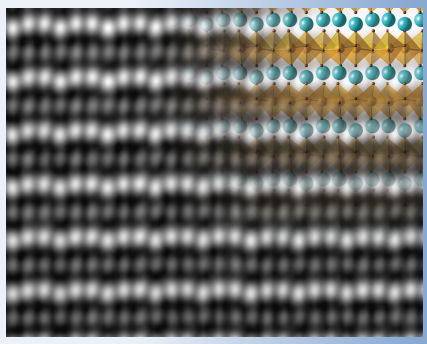

High-pressure 300+ ATM (supercritical fluid) floating-zone growth

Mass spectrometry and computed tomography *during* bulk crystal growth




Integrated MOCVD + MBE + ARPES

High sensitivity, high dynamic range pixel array detector for quantitative mapping of ***E*** and ***B*** fields with sub-nm resolution



Stable cryo-stages for STEM and STEM-EELS at 20 K and 80-1200 K

www.paradim.org

# 5 Key Elements of a Materials Innovation Platform (MIP)

New Model for DMR – focused research effort and mid-scale user facility together.

- Focused research targeting an area of national importance.
- User Facility – open access to tools, expertise, **data**, and new materials. You can get free samples! User proposal driven, vetted by external experts.
- Team of researchers in the 3 areas of synthesis, characterization, theory/modeling in a closed-loop and iterative collaboration leading to advances in each mode of research.
- Advances in materials discovery are excepted by focused efforts of both in-house researchers and external users – "Community of Practitioners".
- Education and Outreach – further advances the mission of the Platform.

# What can I do at a MIP?

- Use the FACILITY to grow, measure, study 2D!
- Work with theorists on designing new materials.
- Work with experimentalists to grow new bulk or thin film materials.
- Work with characterization experts to analyze your materials.
- Obtain samples – for free. Taking requests now!
- Make devices or conduct sophisticated and detailed studies in conjunction with other facilities available to Platforms (NNCI, MRFN, National Facility, etc).
- Envision and grow new substrate materials.
- Utilize or share/store data from/to the MIP– Platforms are community resources to advance materials discovery!
- Partner with a Platform with new capabilities (Work In Progress).
- Send students, post-docs and colleagues for training at the Platforms in crystal growth, characterization, theory, etc. (pending 2DCC October webinar, PARADIM 2017 workshops online now).

www.mip.psu.edu www.paradim.org

# Next Competition?

- Platform competitions will be conducted on a periodic cycle.
- Second competition expected to start in 2017.
- Expect a solicitation early spring.
- Structure of a MIP unlikely to change substantially.
- Focused topic: processing input from the community and NSF priorities like the NSF 10 Big Ideas.

# Research: Focused Area

Conducts research in an area of national importance, addressing a bottleneck or missing capability.

Within this priority area, the research topic is focused, targeted, and seeks to advance a specific scientific or technological outcome. *Not seeking multiple research thrusts/themes.*

The chosen area will benefit from an approach involving the iterative and closed-looped collaboration between synthesis, characterization, and theory; and

The problem being addressed is of a scale and significance that requires a mid-scale level investment in equipment and a user facility to engage the external community to further advance the proposed area of research.

MIPs differ from Materials Research Science and Engineering Centers (MRSECS) by conducting research that is very focused and targeted, leading to technological outcomes in an area of national importance and significance.

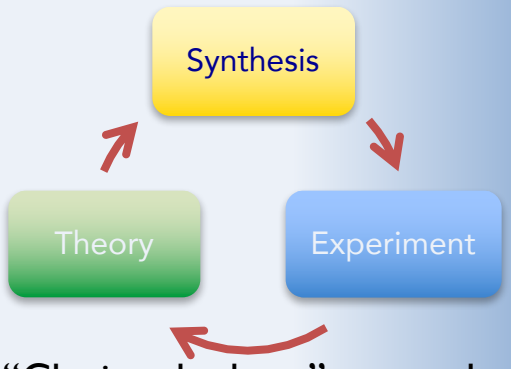
# Research: Accelerated Discovery

Research is conducted by clearly defined experts in synthesis, characterization, and theory/computation (S,C,T).

To accelerate materials discoveries, it is expected that each area of expertise guides the other in an iterative closed-loop process.

This team should be of an appropriate size.

Advances in each area – (S,C,T) are expected.




"Closing the loop" must advance or accelerate materials design

What materials design or development problems can I solve with the experimental, theoretical and computational tools at my disposal? What new "tools" do I need to develop?

# User Facility

The user facility is a key aspect of a MIP, with instrumentation and capabilities that are unique and enabling making it a national resource.

The facility is of a scale and emphasis that it meets the research interests and needs of a larger community, not just the local group of researchers and their collaborators.

It is open a significant fraction (~50%) of the time to external users who further advance the focused research area at no cost to academic users to utilize the equipment purchased under the MIP award.

Access to all aspects of the MIP are expected – expertise in (S,C,T) as well as the equipment and outputs of the Platform.

**The combination of tools/capabilities will be unique that you cannot openly access anywhere else.**

# User Facility: Access to "Products"

The ability to manufacture and give access to samples is a major consideration of a MIP.

MIPs will have robust data management plans for the curation and access to the samples, data, and codes.

Samples, data, and codes will be *accessible*, even to researchers who may never formally connect with MIP PIs or staff.

Support for individuals and/or resources to make products of the MIP available is allowable in MIP budgets.

**The materials community at-large will benefit from the large amounts of samples and data being generated by both the in-house team and the external researchers?**

# Instrumentation

Invests in mid-scale equipment > $4M in tools.

Tools (or the suite of tools) acquired or developed are novel and/or unique and go beyond the scope/scale of tools acquired through other NSF modes of support, such as the Major Research Instrumentation (MRI) program.

Substantial support allowed to employ research associates and technicians to manage equipment, interact with users of the facility, and engage in MIP-related research.

Students will be supported, but this is a unique opportunity to allocate budget resources towards research associates, technicians, and equipment.

**The budget supports the acquisition and development of unique and enabling tools along with technical resources.**

# Broader Impacts

The new materials being developed and provided by a MIP should be compelling, rare/hard to obtain, and transformational in nature.

A MIP should train the next generation diverse scientific workforce which is equipped with the scientific and technical depth/breadth to work in a team tackling emerging challenges.

A MIP engages in an appropriate number of impactful and MIP-focused education and outreach activities.

A MIP engages in novel and innovative approaches to transferring the knowledge generated by the in-house research and MIP user community.

**The education and outreach activities will amplify the MIP's broader impact on new materials discovery.**

# Summary

5 Key Elements to a Platform:

- Focused research targeting an area of national importance.
- Team of researchers in the 3 areas of synthesis, characterization, theory/modeling in a closed-loop and iterative collaboration leading to advances in each mode of research.
- User Facility – open access to tools, expertise, data, and new materials.
- Advances in materials discovery are excepted by focused efforts of both in-house researchers and external users.
- Education and Outreach – further advances the mission of the Platform.

Thank you for your attention!

***Questions?***

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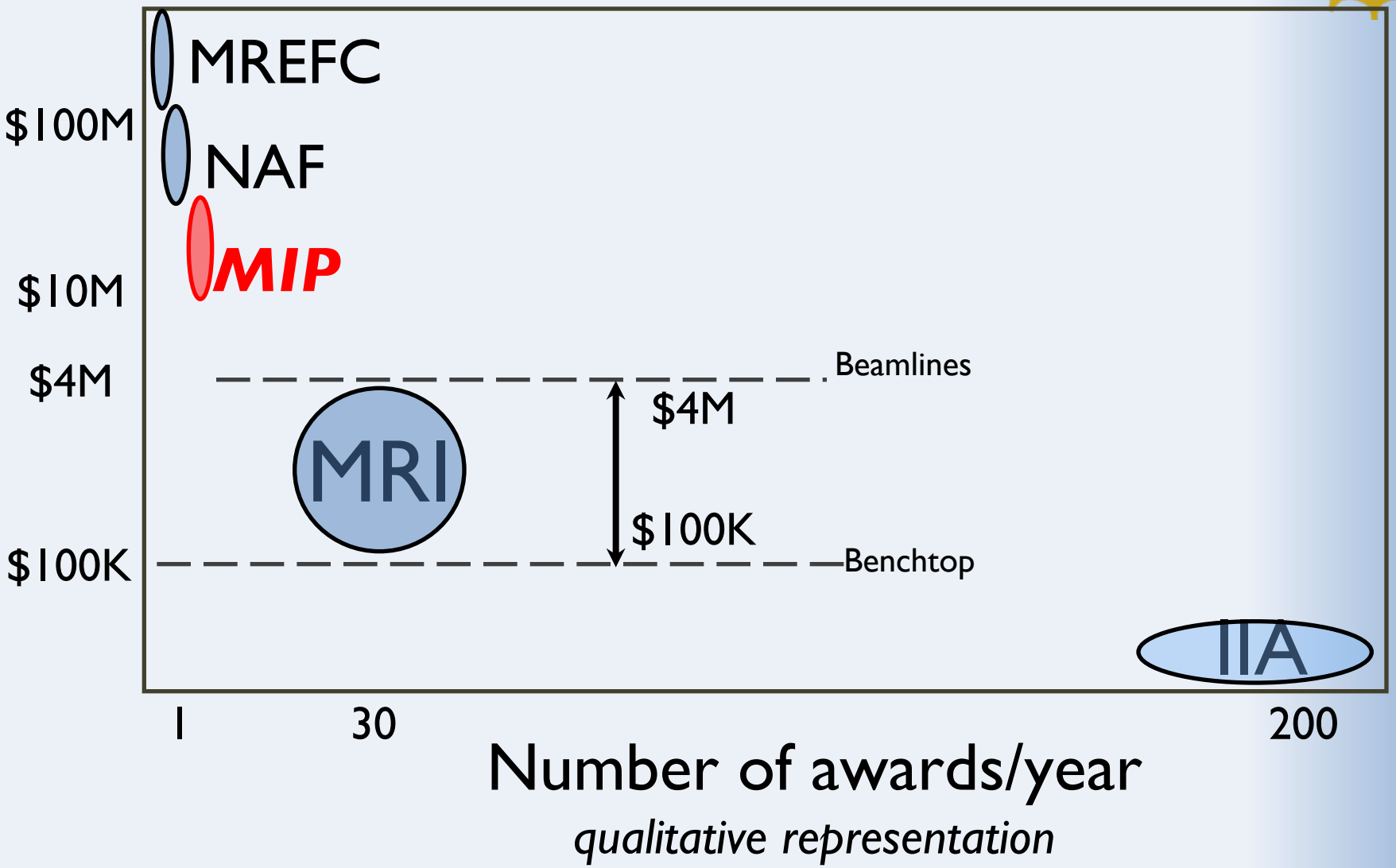
www.mip.psu.edu www.paradim.org

# Scale of Instrumentation Investments




*qualitative representation*