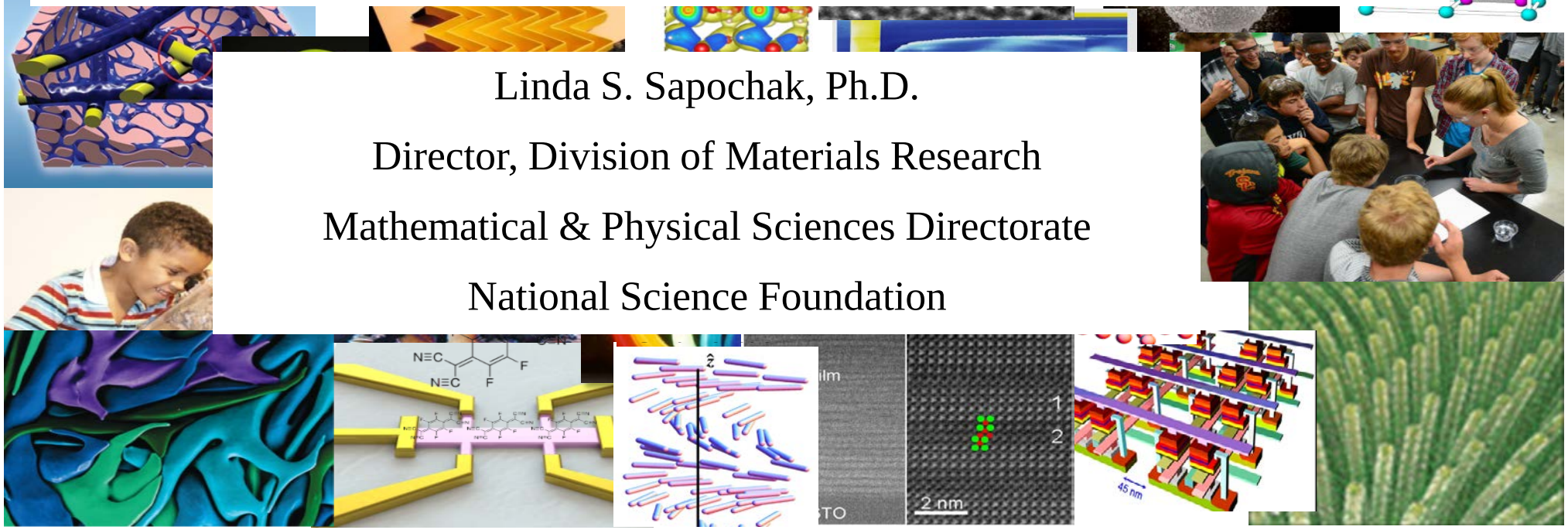
# NSF Division of Materials Research (DMR)


Linda S. Sapochak, Ph.D.

Director, Division of Materials Research

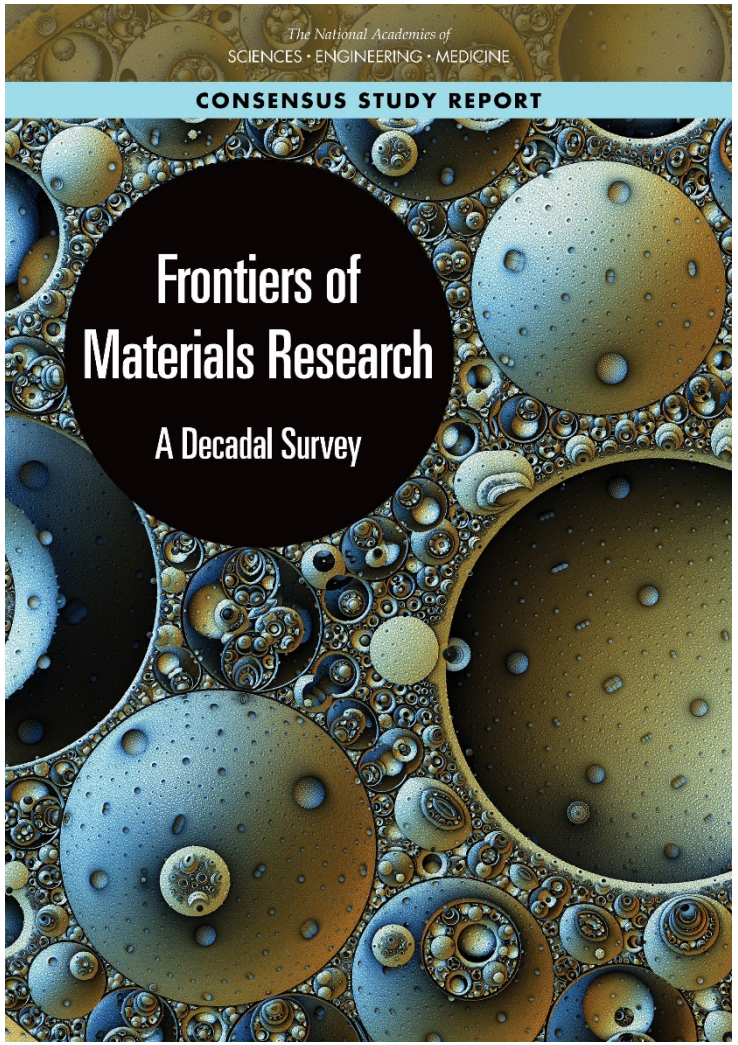
Mathematical & Physical Sciences Directorate

National Science Foundation

## Where Materials Begin & Society Benefits!

# NSF & DOE Sponsored Materials Research Decadal Survey




Laura Greene, Chief Scientist, NHMFL

Matt Tirrell, Univ of Chicago & ANL

Tom Lubensky, Univ of Penn

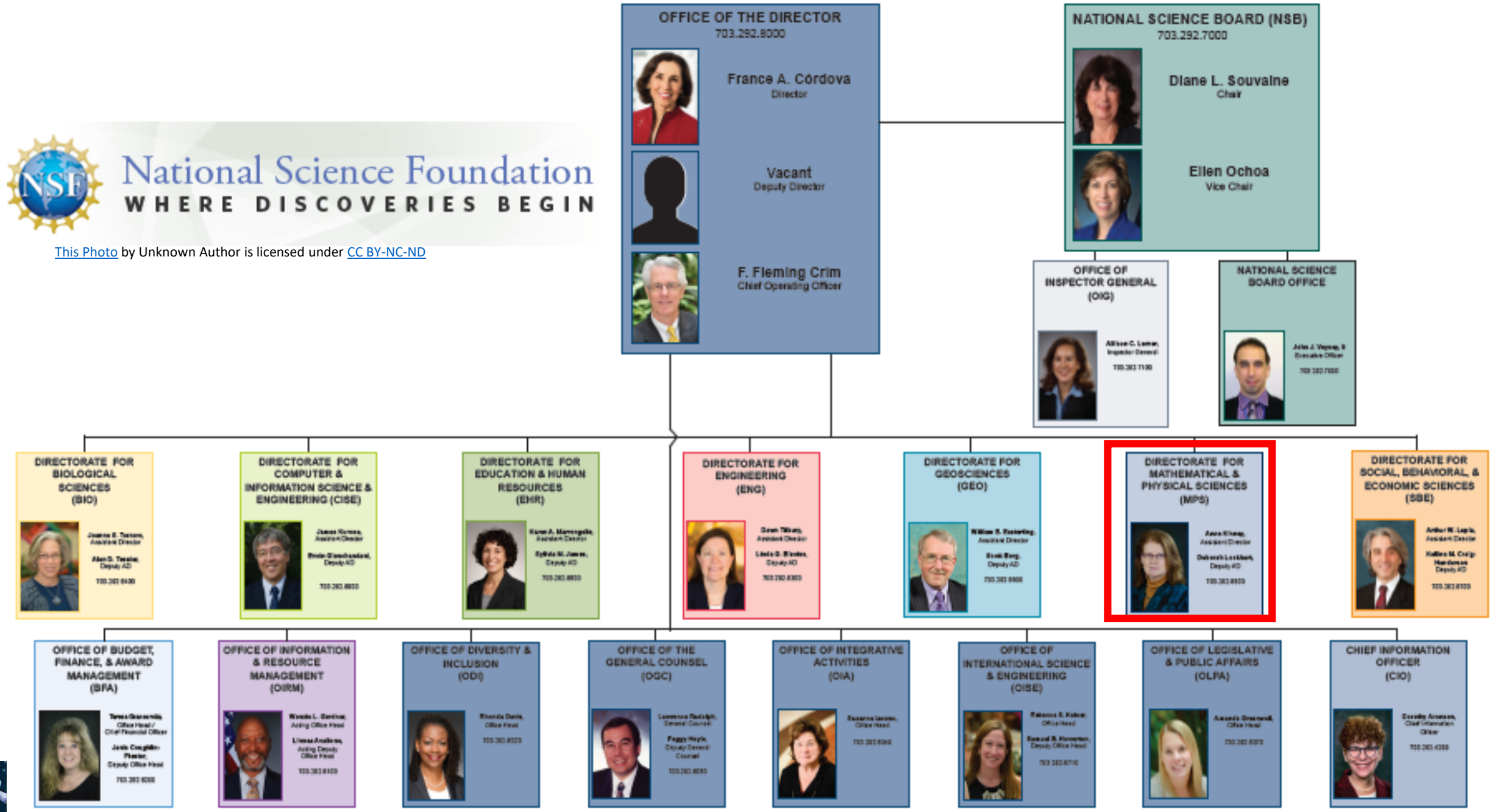
- Industry perspectives
- Research community input

- Strongest influencers: *MGI & NNI*

- NEW this decade: *topological materials, high entropy alloys, 2D materials, vitrimers, architected materials, additive manufacturing….*

Broad Recs:

- Increased coordination across all sectors – especially industry
- Mid-scale infrastructure
- Sustainable Material Development
- Computation and Data Science
- High-throughput syn/characterization
- **Quantum Materials**
- Hybrid/Composite Materials
- Advanced Manufacturing



# Division of Materials Research (DMR)

## OFFICE OF THE DIVISION DIRECTOR

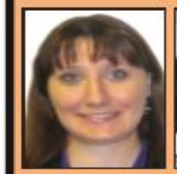

**Linda Sapochak**
Division Director


**Clark Cooper**
Acting Deputy Division Director


**Neila Odom-Jefferson**
Operations Specialist


**Velma Lawson**
Program Support Manager

## ADMINISTRATIVE UNIT


**Meghan Ackerman**
Program Specialist


**Benita Fair**
Program Specialist


**Claudia Johnson**
Contractor


**Allison Smith**
Program Specialist


**Aubrie TenEyck**
Contractor

## Program Directors

### National Facilities and Instrumentation


**Leonard Spinu**


**Guebre X. Tessema**


**Charles Ying**

### Materials Research Science and Engineering Centers


**Daniele Finotello**

### PREM


**Debasis Majumdar**

### Designing Materials to Revolutionize and Engineer our Future


**John Schlueter**


**Eva Campo**

### Condensed Matter Physics


**Tomasz Durakiewicz**


**Germano Iannacchione**

### Electronic and Photonic Materials


**Tania Paskova**


**Robert Opila**

### Condensed Matter and Materials Theory


**Daryl W. Hess**


**Alex Kloronomos**

### Solid-State and Materials Chemistry


**Birgit Schwenzer**


**Catherine Oertel**

### Metals and Metallic Nanostructures


**Gary Shiflet**

### Polymers


**Andrew J. Lovinger**

### Biomaterials


**Germano Iannacchione**


**Hsin-Chiao (Daniel) Ou-yang**

### Ceramics


**Lynnette Madsen**

### Cross-Cutting Activities

**Divisional**

### Additional Scientific Staff


**Freddy Khoury**


**Krystle Wilson**


**Lisa Lewis**

Last Updated: 3/1/2019

# DIVISION OF MATERIALS RESEARCH (DMR)

## Topical Materials Research Programs (TMRPs)

Biomaterials
**Ceramics**
Electronic & Photonic Materials
Metals and Metallic Nanostructures
Polymers

**Condensed Matter & Materials Theory**
Condensed Matter Physics
Solid State and Materials Chemistry

**Other types of Proposals: EAGER, RUI, GOALI (and CAREER*)**

## Cross-Cutting Activities

Diversity

International

Education

## Centers & Teams

Jul 2019 — Materials Research Science & Engineering Centers **(MRSEC)**

Jan 2021 — Partnerships in Research & Education in Materials **(PREM)**

Jan 2019 — Designing Materials to Revolutionize & Engineer our Future **(DMREF)**

## National Facilities & Instrumentation (NaFI) Program

Cornell High Energy Synchrotron Source (CHESS)

National High Magnetic Field Laboratory (NHMFL)

Center for High Resolution Neutron Scattering (CHRNS)

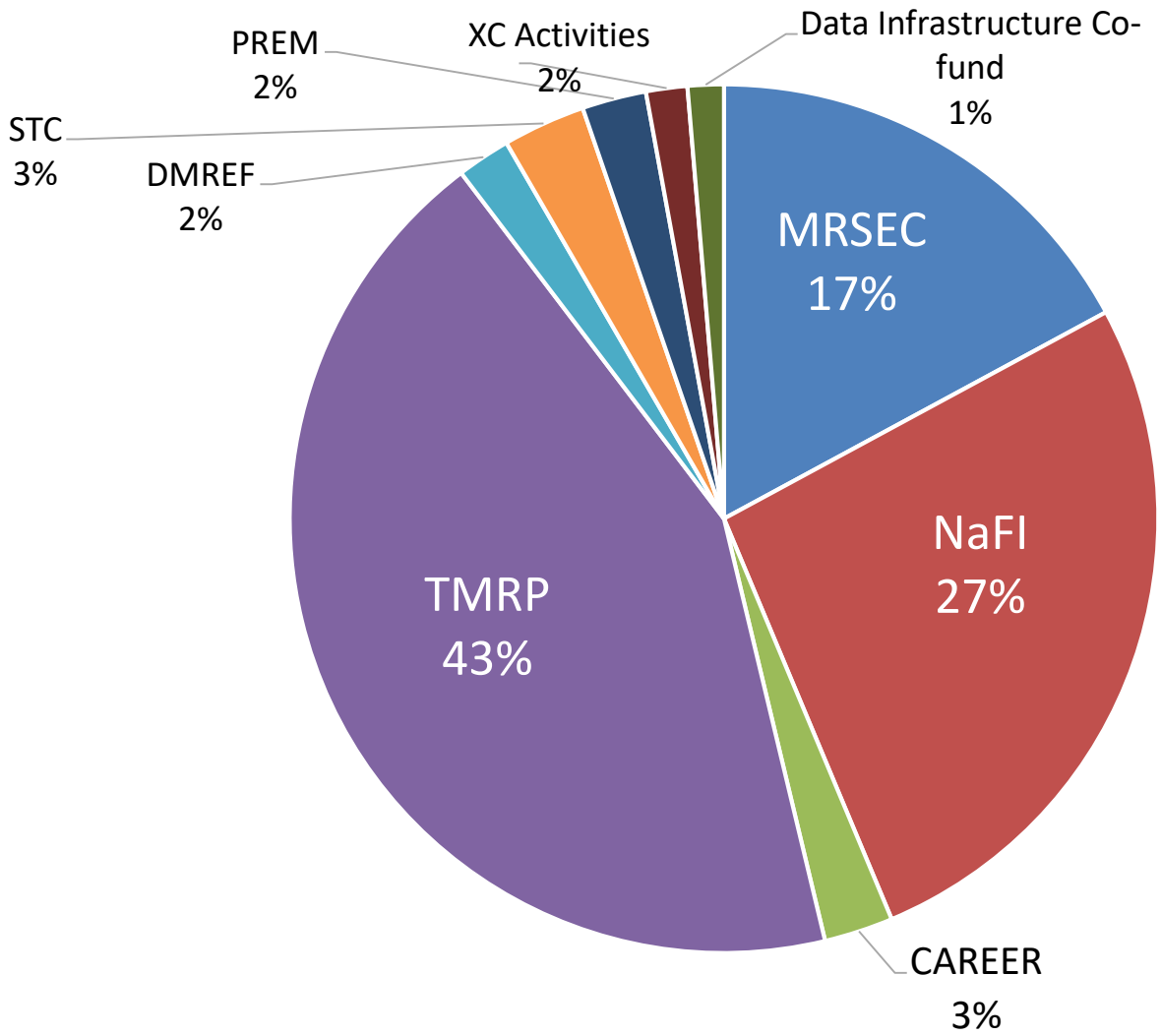
National Nanotechnology Coordination Network (NNCI)

April 2019 — **Materials Innovation Platforms (MIP)**

User Facilities

# DMR Budget

**FY 18: $337.14M**




These charts do not include Foundation-wide programs such as IGERT, MRI and GRF.

# Materials Research Science and Engineering Centers (MRSEC)

## PROGRAM SOLICITATION
## NSF 19-517

## REPLACES DOCUMENT(S):
## NSF 16-545

**National Science Foundation**

Directorate for Mathematical & Physical Sciences
Division of Materials Research

National Science Foundation
MRSEC
Materials Research Science and Engineering Centers

**Preliminary Proposal Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

June 24, 2019

**Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

November 26, 2019

By invitation only

Specifically, it should be stressed that DMR plays an important role in the following NSF Big Ideas:

- *Harnessing the Data Revolution;*
- *The Future of Work at the Human-Technology Frontier;*
- *Understanding the Rules of Life;*
- *The Quantum Leap.*

In addition, potential research topics to broaden the current MRSEC portfolio include, but are not limited to:

- Use of supervised and unsupervised *Machine Learning* addressing materials science complex problems, and in particular as applied to traditional materials science problems in *ceramics, metals, metallic alloys* and others.

Finally, a few additional strategic research areas of DMR interest have also been identified:

- *Synthetic Materials Biology*: in such an effort biologists and system engineers work with materials scientists to identify materials challenges hindering advancements of Synthetic Biology, as well as to generate new Synthetic Biology approaches to materials development i.e., "Materials Biology";
- *Structural Materials under Extreme Conditions*: this effort addresses fundamental challenges in ceramic, metallic, and polymeric materials and their composites for applications under extreme conditions;
- *Recyclable Plastics and Alternative Materials for Sustainable Development*: these efforts could include the development of intrinsically recyclable polymers, a better understanding of mechanical properties of recycled plastic products, strategies to improve the properties of recycled plastics, and materials alternatives for plastics.

Dan Finotello

Leonard Spinu

Birgit Schwenzer

# Designing Materials to Revolutionize and Engineer our Future (DMREF)

## PROGRAM SOLICITATION
NSF 19-516

## REPLACES DOCUMENT(S):
NSF 16-613

**National Science Foundation**

Directorate for Mathematical & Physical Sciences
- Division of Materials Research
- Division of Mathematical Sciences

Directorate for Engineering
- Division of Civil, Mechanical and Manufacturing Innovation
- Division of Electrical, Communications and Cyber Systems
- Division of Chemical, Bioengineering, Environmental and Transport Systems

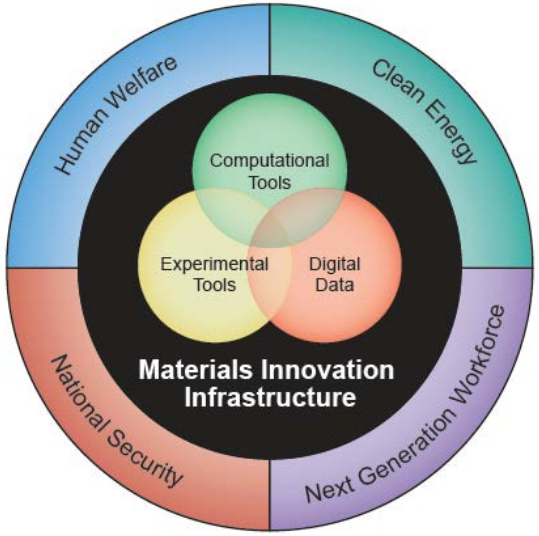
Directorate for Computer & Information Science & Engineering
- Office of Advanced Cyberinfrastructure
- Division of Computing and Communication Foundations
- Division of Computer and Network Systems
- Division of Information & Intelligent Systems

**Submission Window Date(s)** (due by 5 p.m. submitter's local time):

January 28, 2019 - February 04, 2019

**Over 500 proposals (300 projects)**

**NSF's response to MGI!**




- Awards are now 4 year duration, up to $1,750,000.
- Opportunity for PIs to engage Google Cloud resources
- Strategic Areas of Interest: Synthetic Materials Biology, Structural Materials Under Extreme Conditions, Recyclable Plastics & Alternative Materials for Sustainable Development, Robotic Materials.

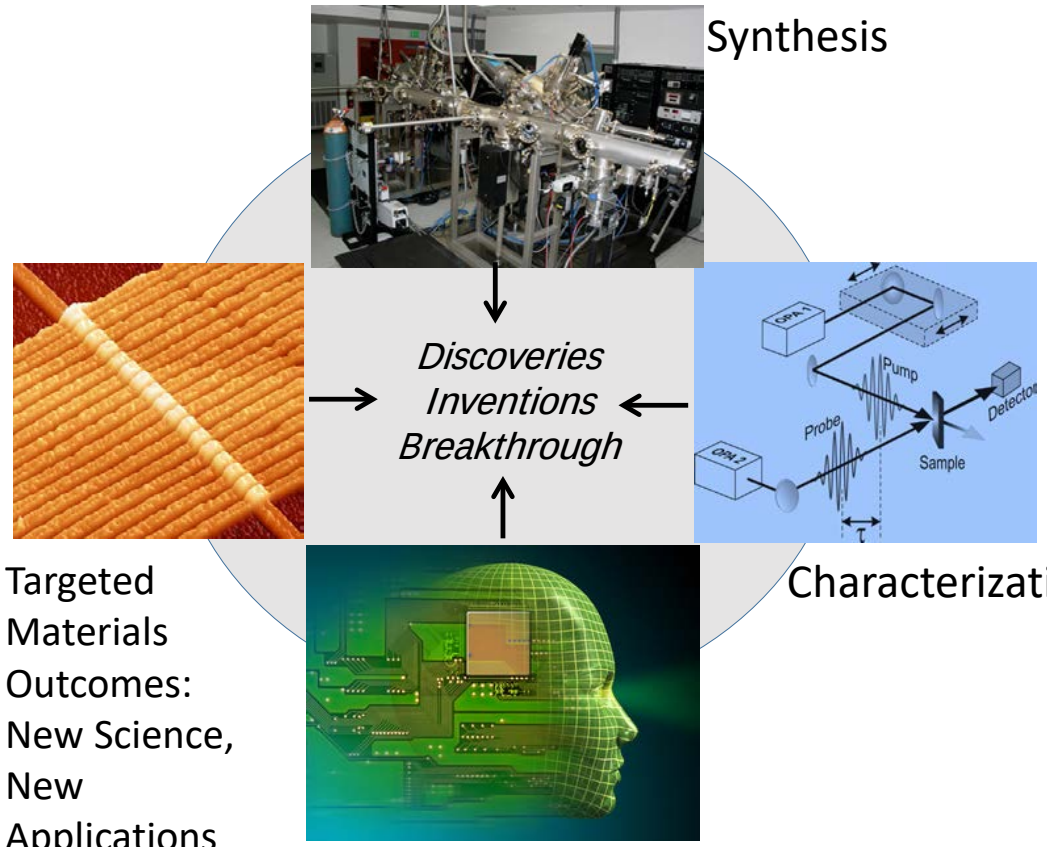
**John Schlueter**

**Eva Campo**

# Materials Innovation Platforms (MIP)

Charles Ying

DMREF “pumped up”




PennState Materials Research Institute

2DCC-MIP 2 Dimensional Crystal Consortium NSF Materials Innovation Platform

Chalcogenide 2D materials with a focus on providing new bulk crystal chalcogenides and improving existing and new 2D chalcogenide thin films for electronic applications.

https://www.mri.psu.edu/mip

Cornell University

PARADIM

Oxide-based hetero-interfaces with a range of 2D material systems such as oxides, chalcogenides and graphene for novel electronic and magnetic functionality.

http://paradim.cornell.edu/

*From the MPS AC Report: Closing the Loop Materials Instrumentation*

# Materials Innovation Platforms (MIP)

**MIP Concept: Combine a focused research effort in an interactive feedback loop together with a mid-scale user facility open to the community in order to accelerate advancement of a materials research topic of national importance.**

**Materials Innovation Platforms (MIP)**

**PROGRAM SOLICITATION**
**NSF 19-526**

**REPLACES DOCUMENT(S):**
**NSF 15-522**

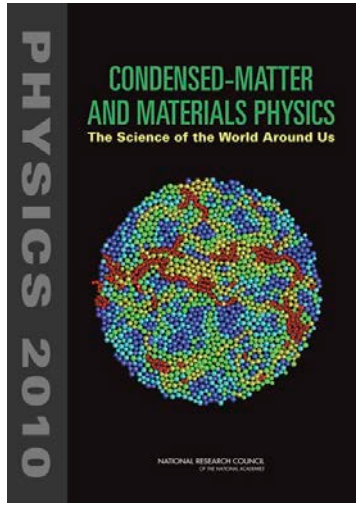
National Science Foundation

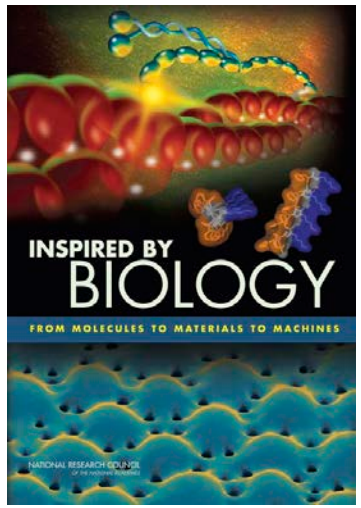
Directorate for Mathematical & Physical Sciences
Division of Materials Research

**Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

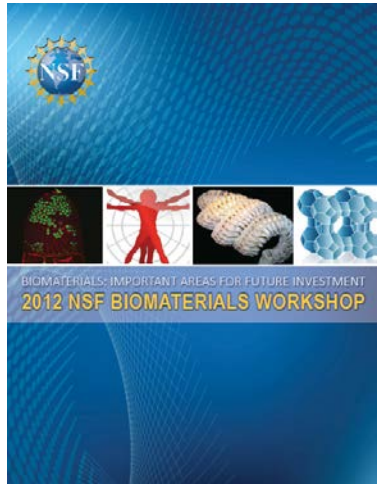
February 04, 2019 Postponed to April 26, 2019

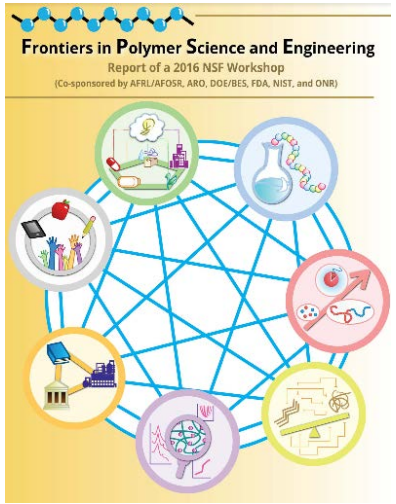
***Focus:*** advancing convergence of materials research with biological sciences for developing new materials.




Also see 2016 Biomaterials Midscale Tools Workshop Report at www.biomatworkshop.org



Synthetic and Systems Biotechnology 3 (2018) 105–112

Contents lists available at ScienceDirect

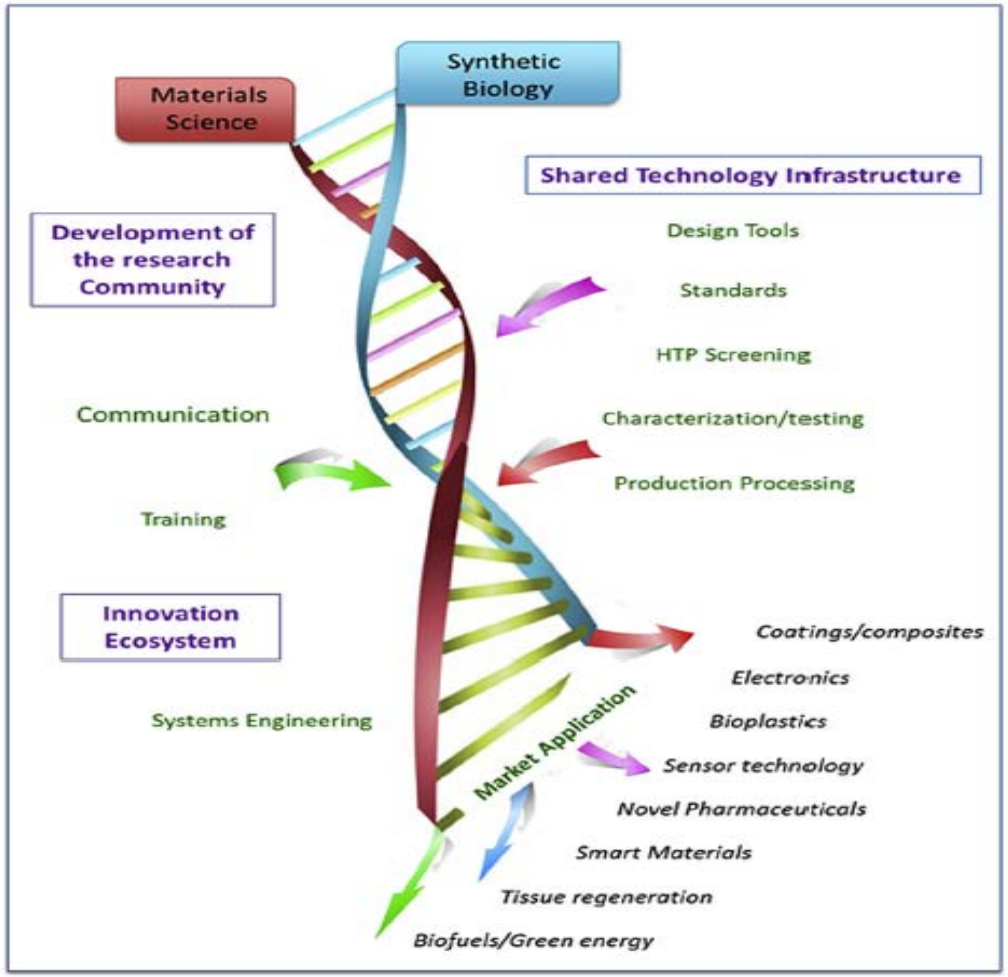
Synthetic and Systems Biotechnology

journal homepage: http://www.keaipublishing.com/en/journals/synthetic-and-systems-biotechnology/


# A living foundry for Synthetic Biological Materials: A synthetic biology roadmap to new advanced materials

Rosalind A. Le Feuvre [a, b, **], Nigel S. Scrutton [a, b, *]

[a] BBSRC/EPSRC Manchester Centre for Synthetic Biology of Fine and Speciality Chemicals (SYNBIOCHEM), Manchester Institute of Biotechnology, The University of Manchester, Manchester M1 7DN, United Kingdom
[b] School of Chemistry, The University of Manchester, Manchester M1 7DN, United Kingdom

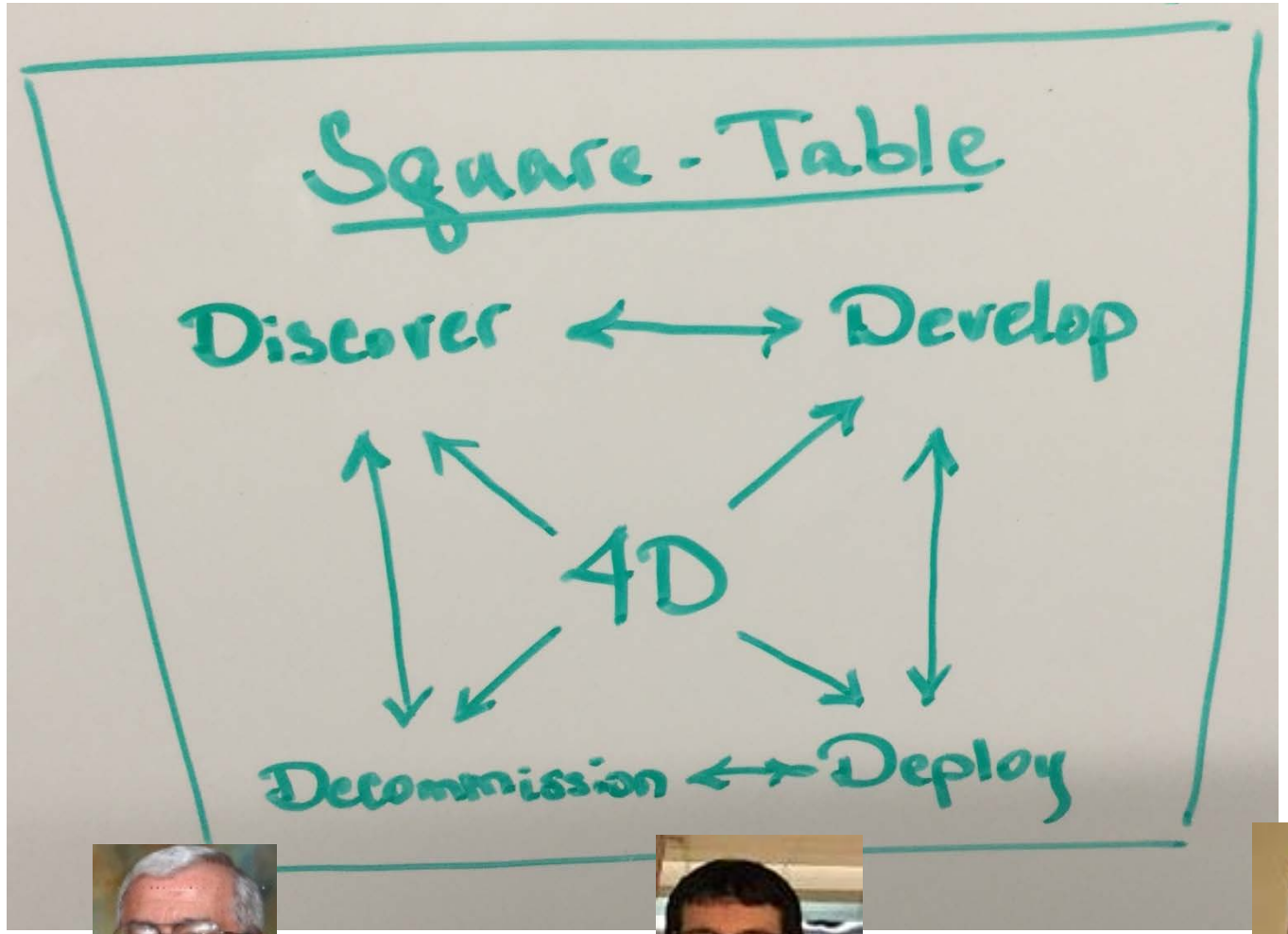



"By harnessing the power of SynBio, existing materials discovery platforms and fabrication technologies can be augmented to widen the materials development space and define a new materials paradigm – Synthetic Biological Materials"

Workshop Support: Naval Research Global, Defense Science & Technology Laboratory

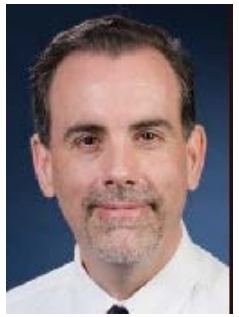
# Square Table Workshop on Synthetic Biology and Biomaterials

**Overall theme**: How do we evolve a material? And what would you do with this capability?




Wilhelm T.S. Huck, Radboud Univ.

M.G. Finn, Georgia Tech



Germano Iannacchione, NSF

Mohan Srinivasarao, NSF

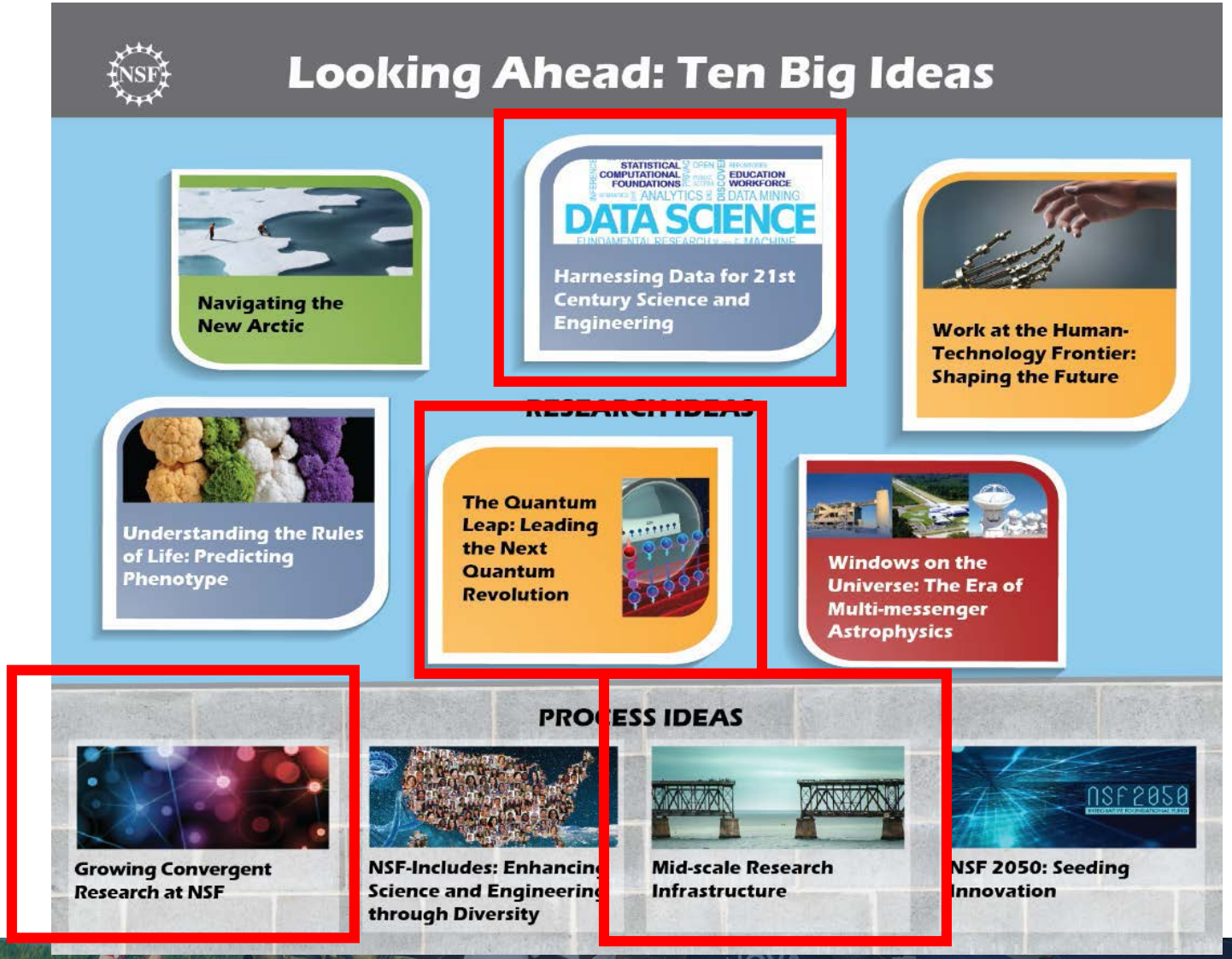
Alex Simonian NSF

David Rampulla, NIH

Dinesh Patwardhan, FDA

# NSF's Big Ideas for Future NSF Investments

- *Bold questions that will drive NSF's long-term research agenda*
- *Catalyze investment in fundamental research*
- *Collaborations with industry, private foundations, other agencies, universities*
- *Solve pressing problems and lead to new discoveries*



## Mid-scale Research Infrastructure-1 (Mid-scale RI-1)

### PROGRAM SOLICITATION
NSF 19-537

National Science Foundation

**Preliminary Proposal Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

February 19, 2019

**Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

May 20, 2019

By invitation only.

**$4 - $20M projects**

## Mid-scale Research Infrastructure-2 (Mid-scale RI-2)

### PROGRAM SOLICITATION
NSF 19-542

National Science Foundation

**Letter of Intent Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

February 14, 2019

**Preliminary Proposal Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

March 11, 2019

**Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

August 02, 2019

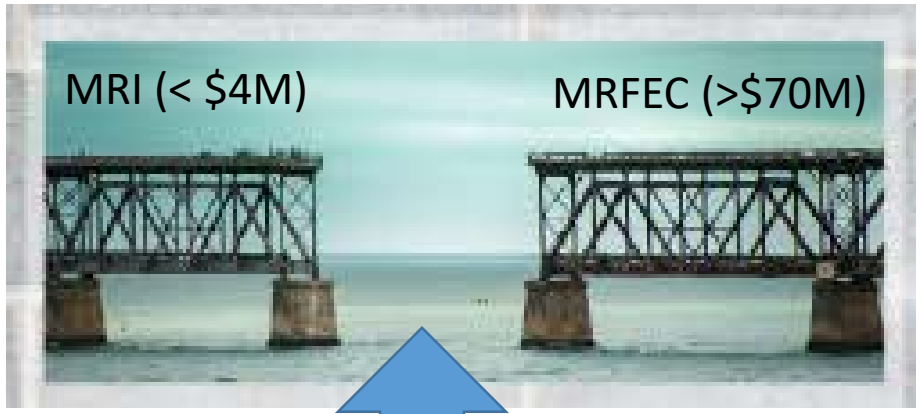
Submission by invitation only.

**$20 - $70M projects**

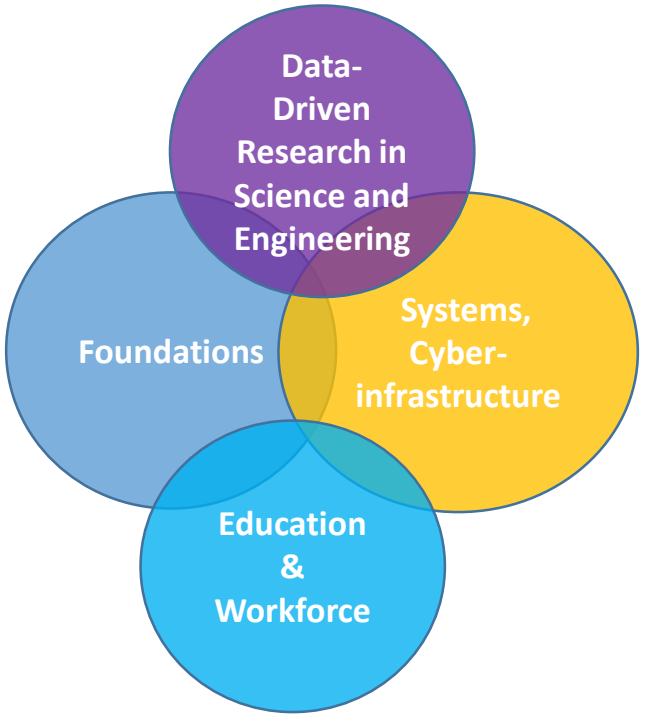
Tessema Guebre

Leonard Spinu

Charles Ying



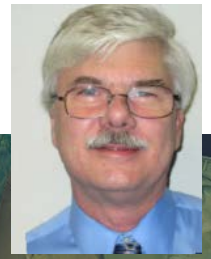

# Harnessing the Data Revolution



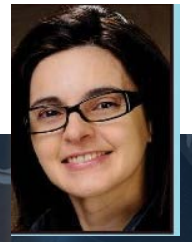

**Ecosystem of Interrelated Activities**


- Transdisciplinary Research in Principles of Data Science (**TRIPODS**)
  - Theoretical Computer Scientists + Statisticians + Mathematicians
  - 12 Institutes funded
- TRIPODS + Science & Engineering [**TRIPODS + X**]
  - Partnerships with science and engineering
- Cyberinfrastructure for Sustained Scientific Innovation (CSSI)
  - Support for data and software cyberinfrastructure

**HDR FY2019 – go to NSF Big Ideas page to see all new opportunities in HDR and others.**

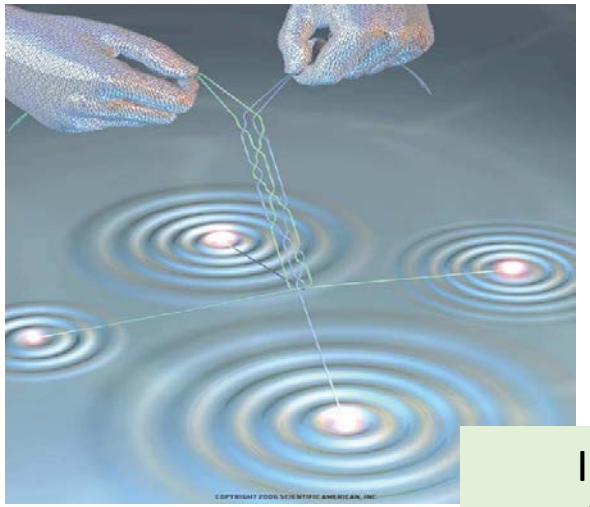


Daryl Hess



Eva Campo

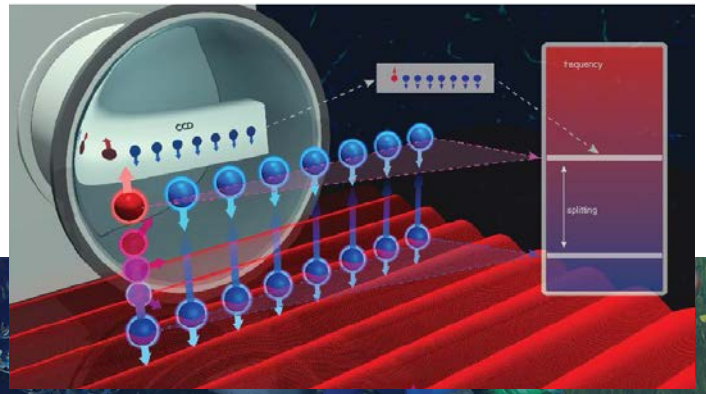
# NSF Big Idea - The Quantum Leap (QL): Leading the Next Quantum Revolution

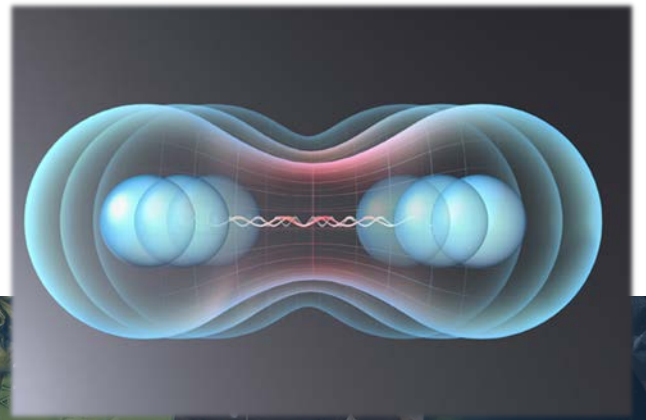


**NSF is planning to exploit transdisciplinary approaches that build on decades of investment in quantum science & engineering.**

**Promoting convergence** of physical sciences, mathematics, computer science, engineering, biology, education, and social sciences into a transformative enterprise that **answers deep questions about microscopic quantum behavior and develops the means of manipulating quantum systems at a macroscopic scale.**

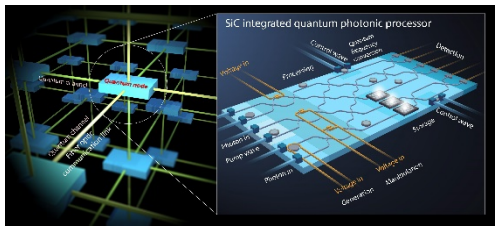
In its execution, it couples together experiment, computation, theory and data to attack fundamental questions, instill quantum thinking, and **develop the quantum workforce.**



# The Quantum Leap: Realizing Ambitious Goals!

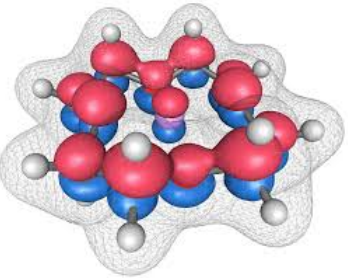
Technologies and devices



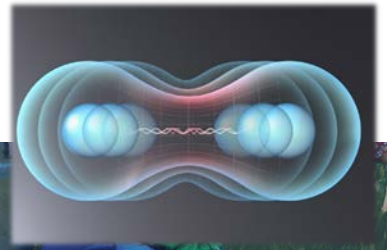

Materials, metrology, sensing, secure communications, computing

Understanding natural and engineered quantum systems

Complexity, simulation, emergent behavior, theory, quantum/classical



Fundamental science



Entanglement, coherence, squeezing

# FY2019 NSF Quantum Leap Solicitations

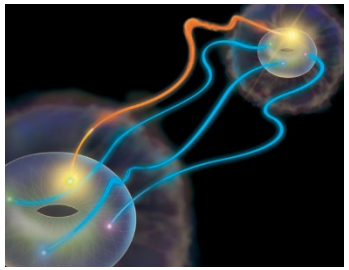
**Q-AMASE-I -** Enabling Quantum Leap: Convergent Accelerated Discovery ***Foundries*** for Quantum Materials Science, Engineering and Information (NSF 18-578)

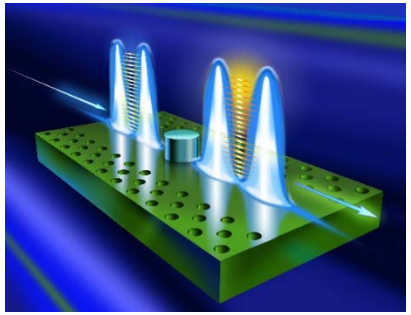
***Foundries***: up to $25M over 6 years

**All require convergence across multiple disciplines**

**QII – TAQS -** Enabling Quantum Leap: Quantum Idea Incubator for Transformational Advances in Quantum Systems (NSF 19-532)

***Small teams***: up to $2M for 3 to 5 years





**QLCI -** Quantum Leap Challenge ***Institutes*** (NSF 19-559)

***Institutes***: up to $25M over 5 years, FY2020 funding

**This session was THE MOST SUBSCRIBED of about 900 sessions at APS MM 2019**

APS March Meeting 2019;
Monday, Session D51: Enabling Quantum Leap: National Quantum Initiative Special Outreach Session

Sponsoring Units: DCMP DMP
Chair: Tomasz Durakiewicz, National Science Foundation; Room: BCEC 253A

7:30PM - 7:50PM D51.00001: Expanding American Leadership in Quantum Information Science
Invited Speaker: **Jacob Taylor**

7:50PM - 8:10PM D51.00002: Developing our Quantum Future
Invited Speaker: **Krysta M Svore**

8:10PM - 8:30PM D51.00003: Physics community input to federal QIS legislation
Invited Speaker: **Francis Slakey**

8:30PM - 8:50PM D51.00004: Enabling Quantum Leap
Invited Speaker: **Linda Sapochak**

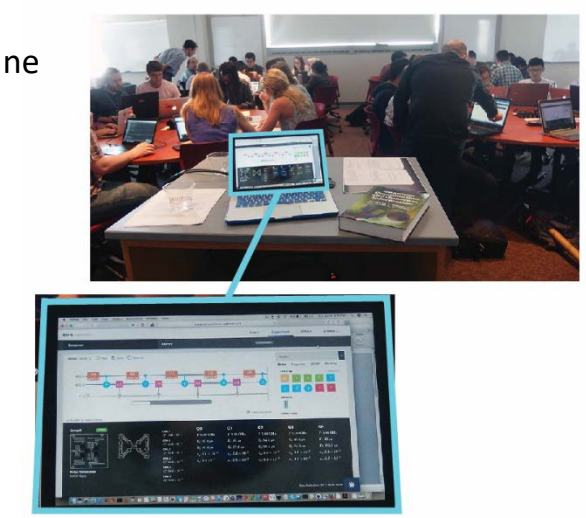
8:50PM - 9:10PM D51.00005: Opportunities at the entanglement frontier
Invited Speaker: **John Preskill**

9:10PM - 9:40PM D51.00006: Round Table Discussion

# NSF/DOE/AFOSR Quantum Science Summer School

- Convergence QL: NSF/DOE Quantum Science Summer School" DMR-1743059 (Funded by: NSF; DOE/BES, DOE/ASCR, and AFOSR)
  - First school held: Johns Hopkins University, 5-16 June 2017
  - Second school: Cornell Univ., 10-22 June 2018,
  - Next: Penn State (2019), TBD (2020)

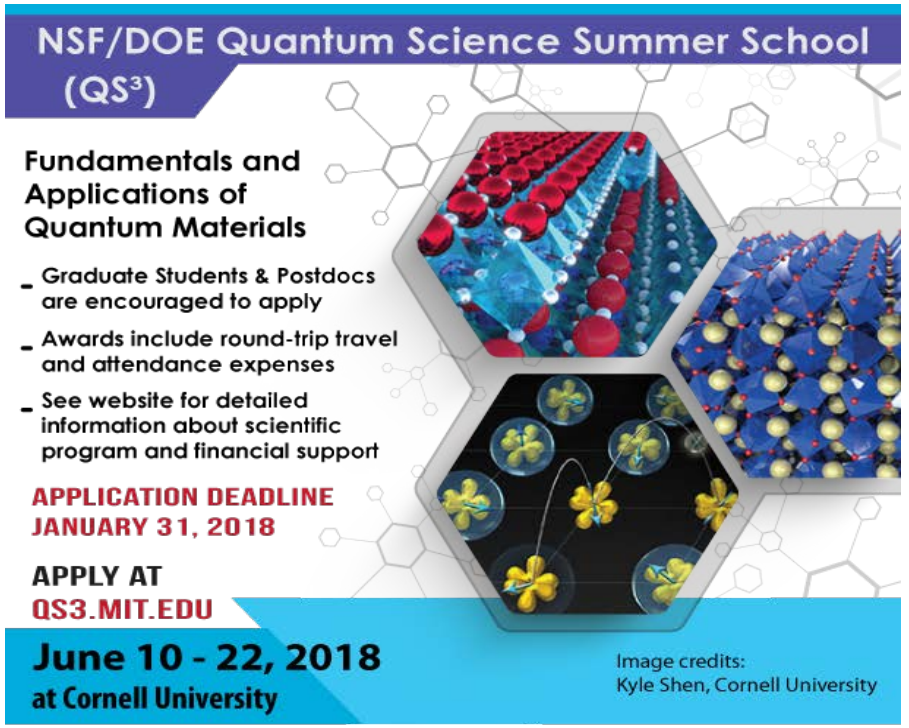
QS3, June 2017



IBM Quantum Experience: programming a quantum computer

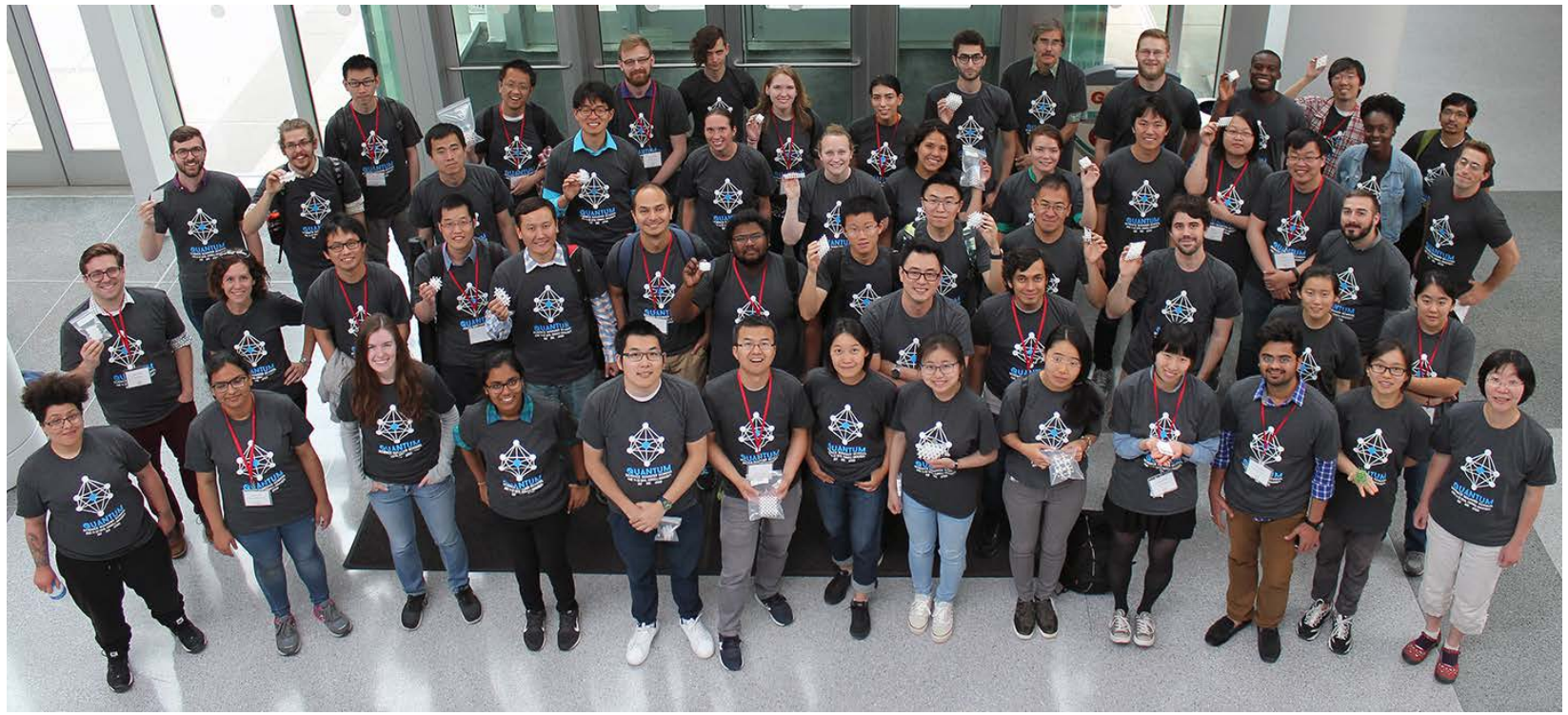
QS3, June 2018

Design and visualization of quantum materials using VR technology



# Quantum Science Summer School

$$\left|\text{Quantum Scientist}\right\rangle = c_1\left|\text{Materials \& Chemistry}\right\rangle + c_2\left|\text{Engineering}\right\rangle + c_3\left|\text{Physics}\right\rangle + c_4\left|\text{Computer Science}\right\rangle$$



**QS$^3$ in 2018**

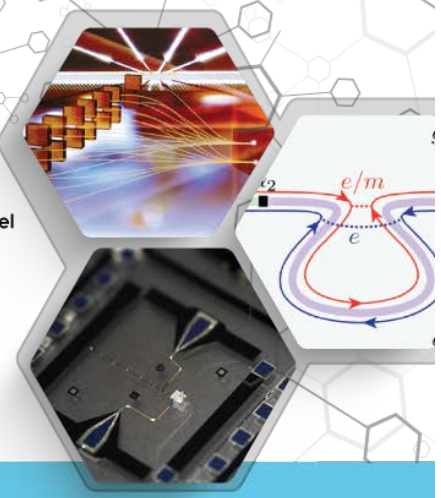
# NSF/DOE Quantum Science Summer School (QS³)

## Fundamentals and Applications of Quantum Computing

- Graduate Students & Postdocs are encouraged to apply
- Awards include round-trip travel and attendance expenses
- See website for detailed information about scientific program and financial support

**APPLICATION DEADLINE**
**MARCH 31, 2017**

**APPLY AT**
**QS3.MIT.EDU**




**June 5 - 16, 2017**
**at Johns Hopkins University**

Image credits:
(top) Emily Edwards, JQI and University of Maryland
(right) Jason Alicea, Caltech
(bottom) John Martinis, Google/UCSB

### Faculty Speakers:

- J. Alicea (Caltech)
- A. Aspuru-Guzik (Harvard)
- D. Freedman (Northwestern)
- S. Girvin (Yale)
- J. Martinis (Google/UCSB)
- D. McClure (IBM)
- C. Monroe (UMD)
- S. Pakin (LANL)
- D. Weiss (PSU)

### Organizers:

- Joe Checkelsky (MIT)
- Natalia Drichko (JHU)
- Liang Fu (MIT)
- Kyle Shen (Cornell)
- Jun Zhu (PSU)

The QS³ is an annual summer school with the mission of training graduate students and postdocs in condensed matter, materials, and related fields for the next "quantum revolution." The aim is to provide students an interactive learning experience with both theoretical and experimental leaders in the field and a connection to new technology. The 2017 school is focused on Quantum Computing. QS³ is supported by the National Science Foundation and the Department of Energy.

### School Topics:

- Superconducting, Spin and Topological Qubits
- Cold Atom and Ion Trap Approaches
- Quantum Simulation
- Industrial Progress

QS3.MIT.EDU

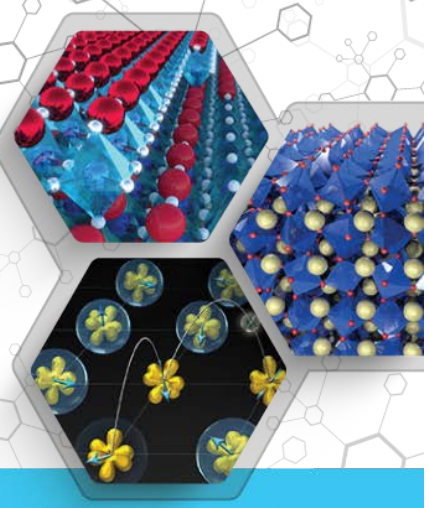
# NSF/DOE Quantum Science Summer School (QS³)

## Fundamentals and Applications of Quantum Materials

- Graduate Students & Postdocs are encouraged to apply
- Awards include round-trip travel and attendance expenses
- See website for detailed information about scientific program and financial support

**APPLICATION DEADLINE**
**JANUARY 31, 2018**

**APPLY AT**
**QS3.MIT.EDU**



**June 10 - 22, 2018**
**at Cornell University**

Image credits:
Kyle Shen, Cornell University

### Faculty Speakers:

- Peter Armitage (JHU)
- Leon Balents (UCSB)
- Judy Cha (Yale)
- Seamus Davis (Cornell/BNL)
- Feliciano Giustino (Oxford)
- Jacob Ruff (Cornell)
- Darrell Schlom (Cornell)
- John Tranquada (BNL)
- Inna Vishik (UC Davis)

### Organizers:

- Joe Checkelsky (MIT)
- Natalia Drichko (JHU)
- Liang Fu (MIT)
- Kyle Shen (Cornell)
- Jun Zhu (PSU)

The QS³ is an annual summer school with the mission of training graduate students and postdocs in condensed matter, materials, and related fields for the next "quantum revolution." The aim is to provide students an interactive learning experience with both theoretical and experimental leaders in the field and a connection to new technology. The 2018 school is focused on Quantum Materials. QS³ is supported by the National Science Foundation and the Department of Energy.

### School Topics:

- Correlated Electrons
- 2D Materials
- Superconductivity
- Topological Materials

QS3.MIT.EDU

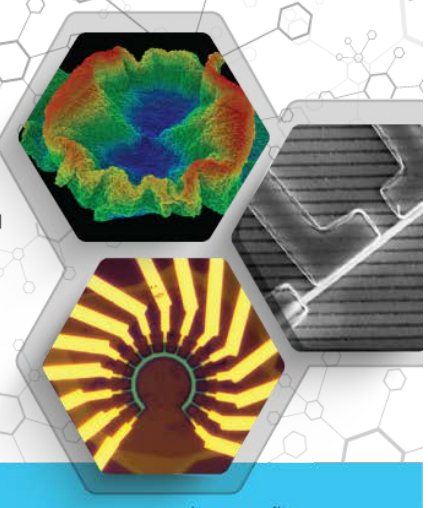
# NSF/DOE/AFOSR Quantum Science Summer School (QS³)

## Fundamentals and Applications of Quantum Devices

- Graduate Students & Postdocs are encouraged to apply
- Awards include round-trip travel and attendance expenses
- See website for detailed information about scientific program and financial support

**APPLICATION DEADLINE**
**JANUARY 31, 2019**

**APPLY AT**
**QS3.MIT.EDU**



**June 3 - 14, 2019**
**at Penn State University**

Image credits:
Top: 2DCC, Penn State
Right: Sergey Frolov, Pitt
Bottom: Jim Hone, Columbia

### Faculty Speakers:

- Scott Crooker (LANL)
- Sergey Frolov (Pitt)
- Dale van Harlingen (UIUC)
- Jim Hone (Columbia)
- Evelyn Hu (Harvard )
- Ania Bleszynski Jayich (UCSB)
- Katja Nowack (Cornell)
- Mikael Rechtsman (Penn State)
- Nitin Samarth (Penn State)
- Andy Stern* (Weizmann)

* tentative

### Organizers:

- Joe Checkelsky (MIT)
- Natalia Drichko (JHU)
- Liang Fu (MIT)
- Kyle Shen (Cornell)
- Jun Zhu (PSU)

The QS³ is an annual summer school with the mission of training graduate students and postdocs in condensed matter, materials, and related fields for the next "quantum revolution." The 2019 school is focused on Quantum Devices. QS3 is supported by the National Science Foundation, Department of Energy, and the Air Force Office of Scientific Research.

### School Topics:

- Majoranas
- Photonics
- Spintronics
- Superconductors
- 2D Materials
- Heterostructures

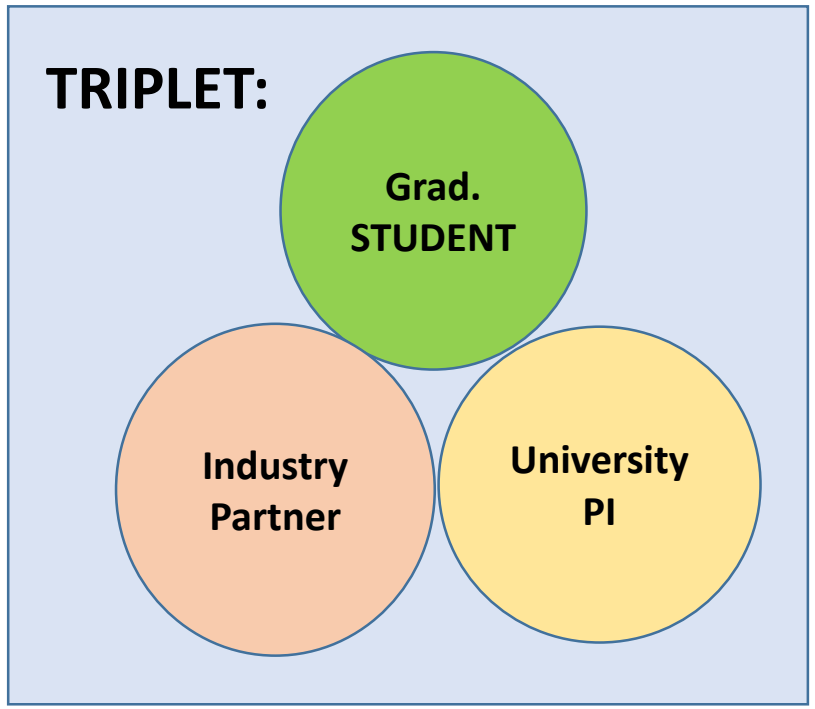
QS3.MIT.EDU

# Quantum Leap: Triplets

Quantum Information Science and Engineering Network" of "triplets" of students, faculty, industry partners to work on Quantum Leap challenges (nine NSF Divisions participating)

| *University* | *Partner* |
|---|---|
| Columbia U | Raytheon BBN |
| Georgia Tech | IBM Watson |
| MIT | Sandia Labs |
| U. Maryland | IonQ Inc. |
| MIT | Google |
| U. Maryland | IBM Watson |
| UW-Madison | Google |
| Georgetown | IBM Almaden |
| Georgia Tech | IBM |
| Dartmouth | Google |

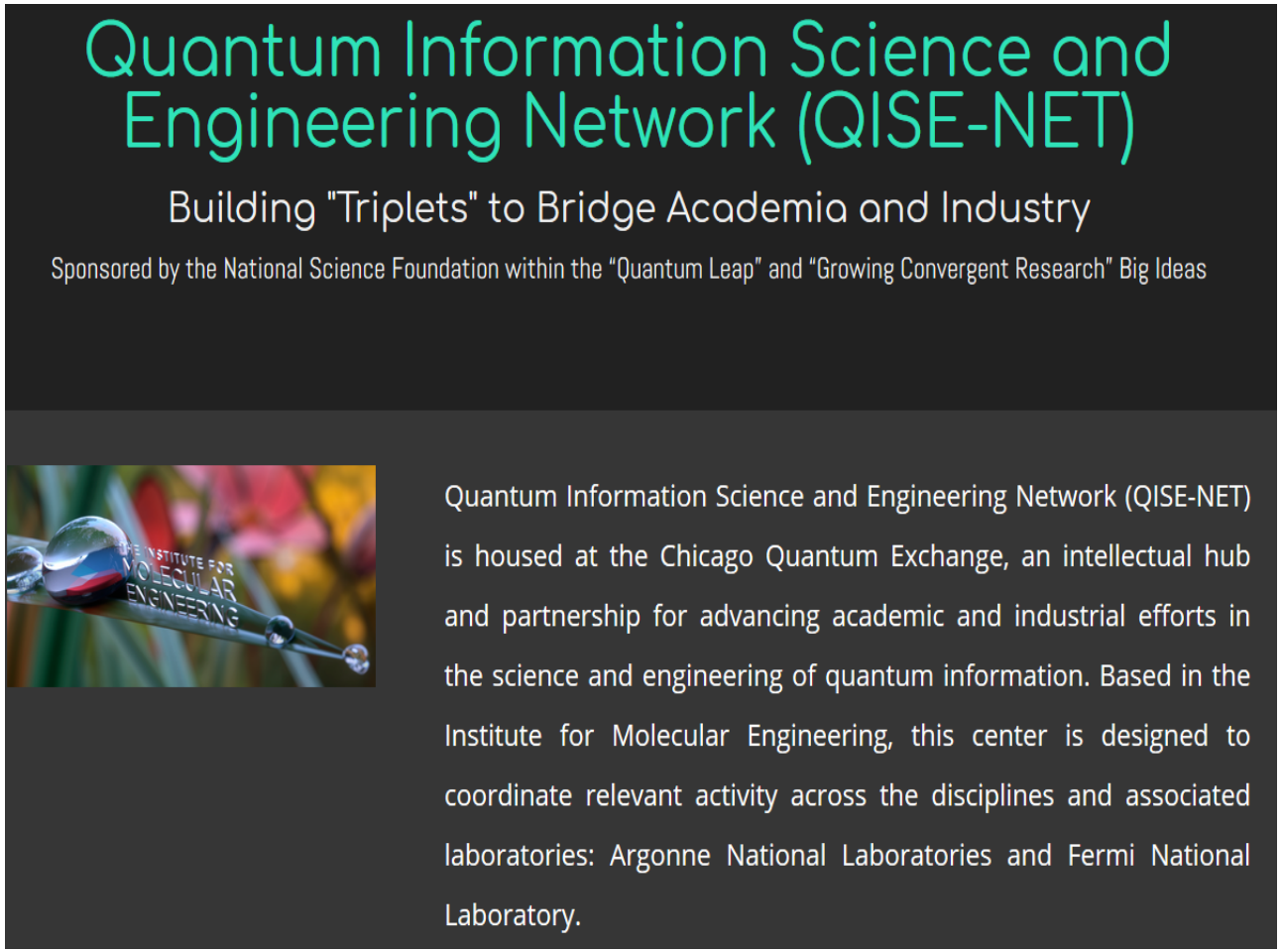
| *University* | *Partner* |
|---|---|
| U. Chicago | IBM |
| UCSC | Argonne |
| UT Austin | NIST |
| Caltech | IBM |
| Caltech | Google |
| U. Pitt. | IBM |
| U. Illinois | NIST |
| Vanderbilt | ORNL |
| Sony Brook U. | BNL |
| UW Madison | Adamas Nano. |
| MT State | MT Instruments |



# Workforce development for Quantum Leap: Triplets

Quantum Information Science and Engineering Network" of "triplets" of students, faculty, industry partners to work on Quantum Leap challenges **(**OIA, DMR, CHE, PHY, ECCS, CCF, OAC, SES, OMA)

- UChicago News: *"Nationwide program launches to train new generation of quantum engineers. NSF-funded project pairs graduate students with industry, academia"*
- *"Approximately 20 students will receive four years of funding under the first edition of the program."*




http://news.uchicago.edu/article/2018/05/08/nationwide-program-launches-train-new-generation-quantum-engineers24


# THANK YOU!

Questions? Concerns?

Want to be on the DMR mailing list?

Contact me:

**lsapocha@nsf.gov**

## Where Materials Begin & Society Benefits!

# Our NSF Approach

## *The 3 C's*