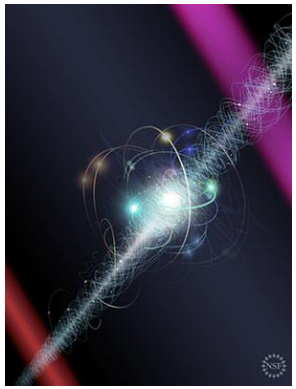
National Science Foundation Mathematical and Physical Sciences Update

Image credit: NSF/LIGO/
Sonoma State University/A. Simonnet

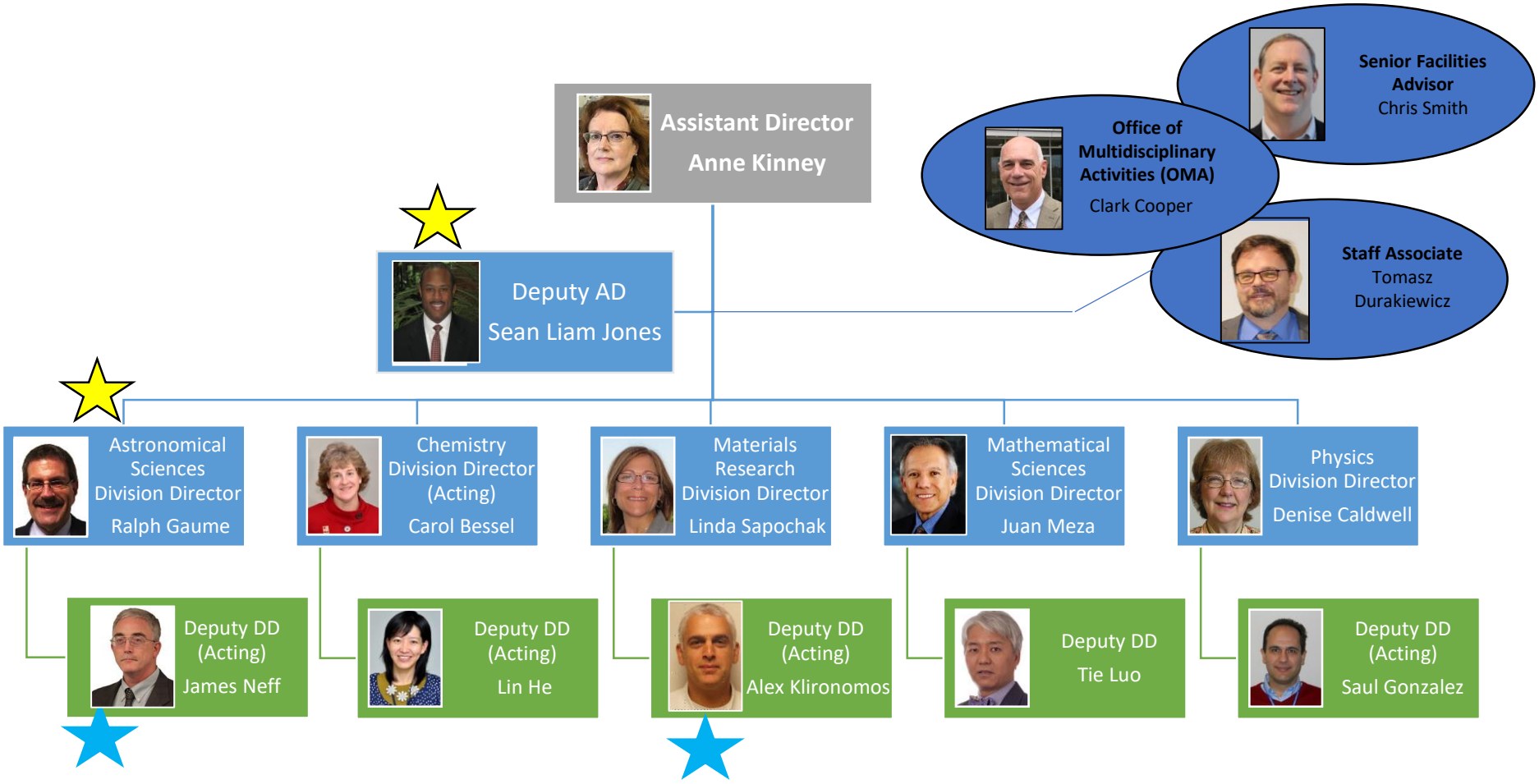
HEPAP Meeting
November 21, 2019



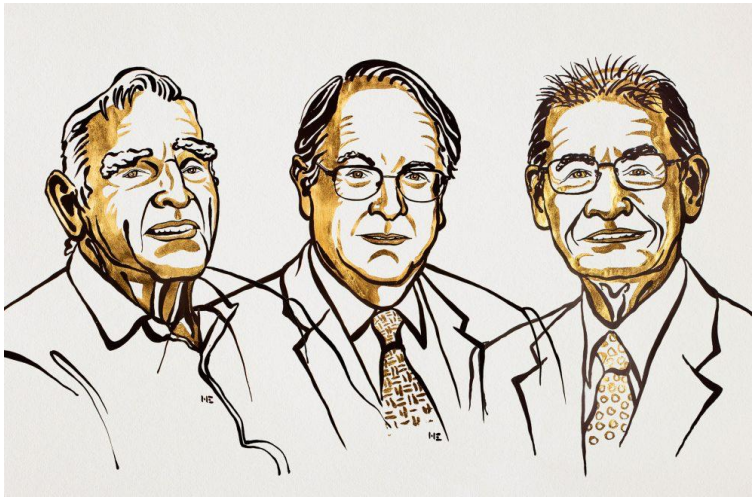
Credit: Nicolle R. Fuller/NSF

Denise Caldwell
Division Director, Physics
Directorate for Mathematical and Physical Science

Staff Changes in MPS



2019 Awardees Funded by NSF/MPS

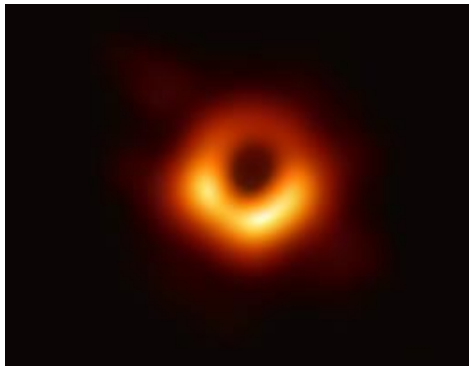


2019 Nobel Laureates in Chemistry

Nobel Prize in Chemistry
- John Goodenough, M. Stanley Wittingham

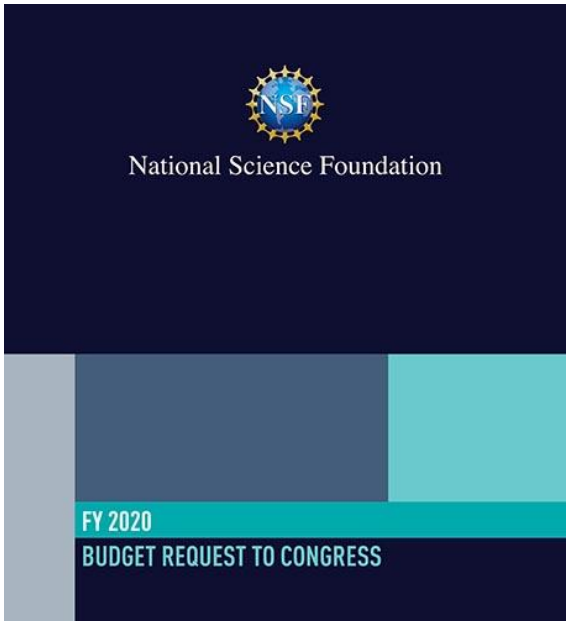
Nobel Prize in Physics
- James Peebles

Breakthrough Prize in Physics
- EHT Collaboration



Breakthrough Prize in Mathematics
- Alex Eskin

Budget



- FY 2019 Appropriation
  - $8.075 billion enacted for NSF
  - $1.465 billion for MPS
- FY 2020
  - *Continuing Resolution until 11/21/19*
  - NSF budget request = $7.226 billion
  - MPS budget request = $1.255 billion

SUMMARY TABLE
FY 2020 BUDGET REQUEST TO CONGRESS
(Dollars in Millions)

NSF by Account	FY 2018 Actual	FY 2019 Annualized CR[1]	FY 2019 Enacted[2]	FY 2020 Request	FY 2020 Request change over FY 2018 Actual Amount	Percent
BIO	$756.60	-	-	$683.36	-$73.24	-9.7%
CISE	960.80	-	-	883.04	-77.76	-8.1%
ENG	977.90	-	-	881.42	-96.48	-9.9%
Eng Programs	*767.92*	-	-	*686.27*	*-81.65*	*-10.6%*
SBIR/STTR, including Operations	*209.98*	-	-	*195.15*	*-14.83*	*-7.1%*
GEO	907.80	-	-	787.05	-120.75	-13.3%
MPS	1,503.41	-	-	1,255.82	-247.59	-16.5%
SBE	250.69	-	-	230.08	-20.61	-8.2%
OISE	48.98	-	-	46.24	-2.74	-5.6%
OPP	501.72	-	-	403.39	-98.33	-19.6%
U.S. Antarctic Logistics Activities	*71.13*	-	-	*71.00*	*-0.13*	*-0.2%*
Other Polar Programs	*430.59*	-	-	*332.39*	*-98.20*	*-22.8%*
IA	471.05	-	-	491.04	19.99	4.2%
U.S. Arctic Research Commission	1.43	-	-	1.52	0.09	6.3%
Research & Related Activities	**$6,380.38**	**$6,334.48**	**$6,520.00**	**$5,662.96**	**-$717.42**	**-11.2%**
Education & Human Resources	**$903.87**	**$902.00**	**$910.00**	**$823.47**	**-$80.40**	**-8.9%**
Major Research Equipment & Facilities Construction	**$186.30**	**$182.80**	**$295.74**	**$223.23**	**$36.93**	**19.8%**
Agency Operations & Award Management	**$328.51**	**$328.51**	**$329.54**	**$336.89**	**$8.38**	**2.6%**
National Science Board	**$4.30**	**$4.37**	**$4.37**	**$4.10**	**-$0.20**	**-4.6%**
Office of Inspector General	**$15.09**	**$15.20**	**$15.35**	**$15.35**	**$0.26**	**1.7%**
Total, NSF Discretionary Funding	**$7,818.43**	**$7,767.36**	**$8,075.00**	**$7,066.00**	**-$752.43**	**-9.6%**
Education and Human Resources - H-1B Visa	192.26	192.23	192.23	120.00	-72.26	-37.6%
Donations	29.22	71.76	71.76	40.00	10.78	36.9%
Total, NSF Mandatory Funding	**$221.48**	**$263.99**	**$263.99**	**$160.00**	**-$61.48**	**-27.8%**
Total, NSF Budgetary Resources	**$8,039.91**	**$8,031.35**	**$8,338.99**	**$7,226.00**	**-$813.91**	**-10.1%**

Totals exclude reimbursable amounts.

[1] Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

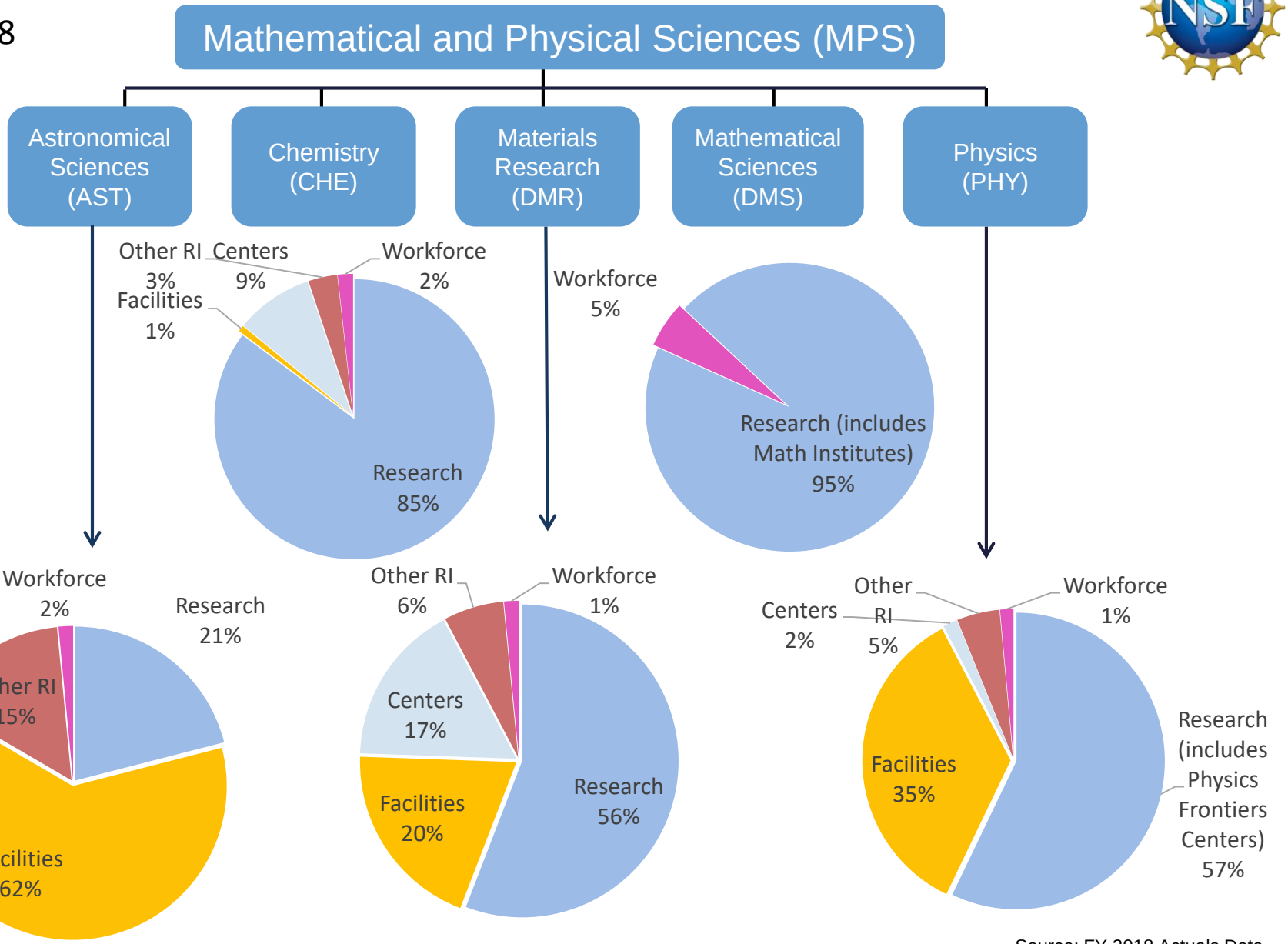
[2] Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.

President's FY 2020 MPS Request $1,256 M

MPS Funding					
(Dollars in Millions)					
	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual	
				Amount	Percent
Astronomical Sciences (AST)	$311.16	-	$217.08	-$94.08	-30.2%
Chemistry (CHE)	246.29	-	214.18	-32.11	-13.0%
Materials Research (DMR)	337.14	-	273.78	-63.36	-18.8%
Mathematical Sciences (DMS)	237.69	-	203.26	-34.43	-14.5%
Physics (PHY)	310.75	-	247.50	-63.25	-20.4%
Office of Multidisciplinary Activities (OMA)	60.39	-	100.02	39.63	65.6%
Total	$1,503.41	-	$1,255.82	-$247.59	-16.5%

$30 M Quantum Leap
$30 M Windows on the Universe

FY 2018



Source: FY 2018 Actuals Data

NSF's 10 Big Ideas

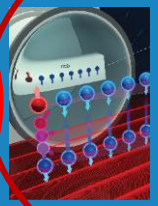
RESEARCH IDEAS

Harnessing Data for 21st Century Science and Engineering

Work at the Human-Technology Frontier: Shaping the Future

Navigating the New Arctic

Windows on the Universe: The Era of Multi-messenger Astrophysics



The Quantum Leap: Leading the Next Quantum Revolution

Understanding the Rules of Life: Predicting Phenotype

PROCESS IDEAS

Mid-scale Research Infrastructure

NSF 2026

Growing Convergence Research at NSF

NSF INCLUDES: Enhancing STEM through Diversity and Inclusion

NSF's Role in the National Quantum Initiative

Contribution to national strategy

NATIONAL STRATEGIC OVERVIEW FOR QUANTUM INFORMATION SCIENCE

Basic QISE research

31 'quantum' Nobel laureates funded since 1964

Quantum workforce development

Interagency collaboration

National Institute of Standards and Technology
U.S. Department of Commerce

https://www.nsf.gov/mps/quantum/quantum_research_at_nsf.jsp

NSF NQI Response – FY 2019 +

NSF 19-559 Quantum Leap Challenge Institutes (QLCI); Total Funding Amt. $94M; 18 Conceptualization Grants in FY 2019 ($3M); First full Institute awards in FY 2020; Second group in FY 2021

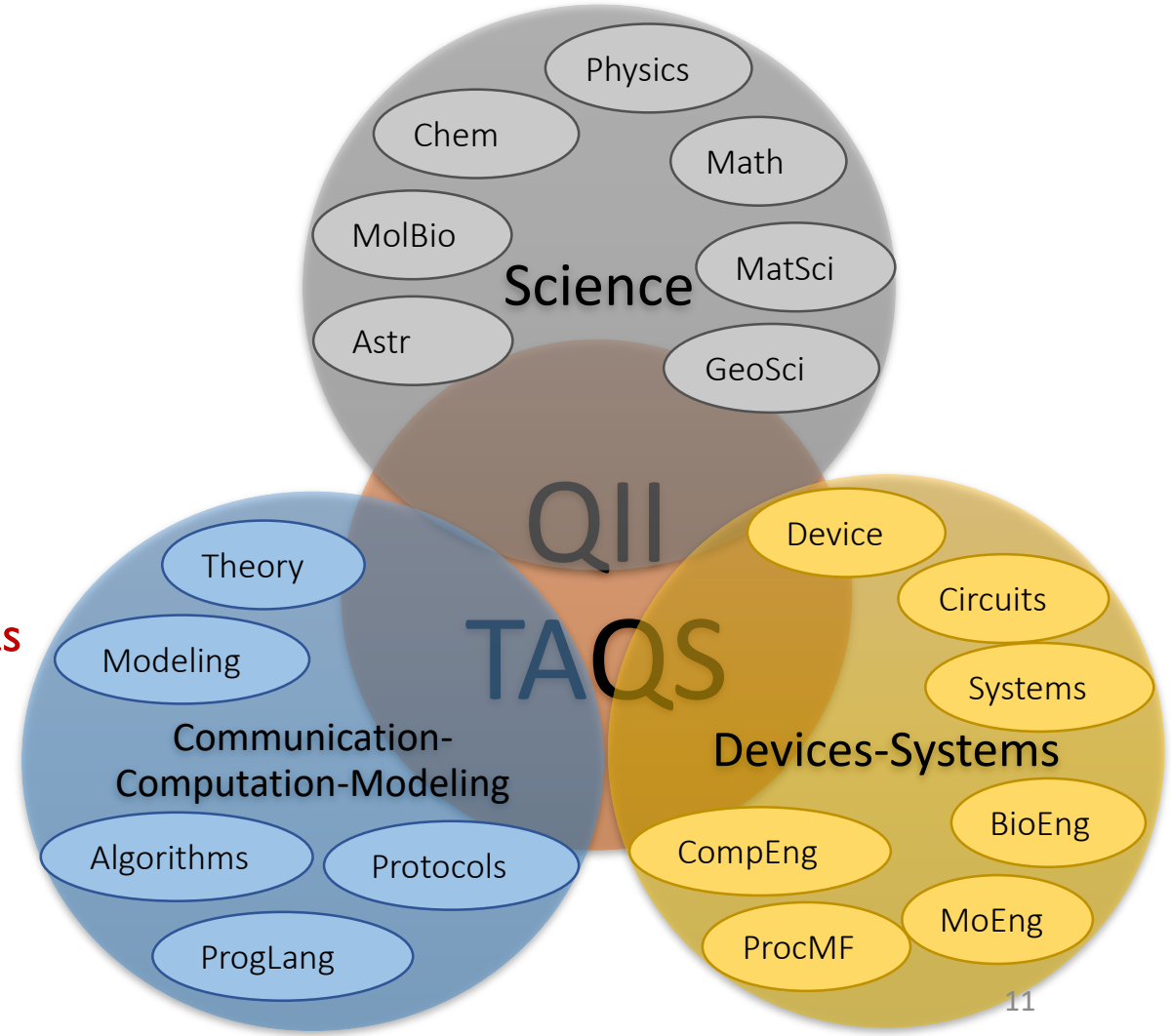
QII-TAQS Incubators: Transformational Advances in Quantum Systems; *Follow-on to extremely successful FY 2018 RAISE (TAQS) awards*; 19 Awards in FY 2019; $35.5 M over two years

Quantum Computing and Information Science Faculty Fellows (QCIS-FF) Two Awards in FY 2019, Each $250k per year for three years

Enabling Quantum Leap: Convergent Accelerated Discovery Foundries for Quantum Materials Science, Engineering and Information (Q-AMASE-i); Award 1906325 "Enabling Quantum Leap: Q-AMASE-i: Quantum Foundry at UCSB"; A. Bleszynski-Jayich; $25M over six years.

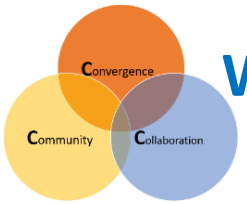
NSF 19-532: Quantum Idea Incubator - Transformational Advances in Quantum Systems (QII -TAQS)

- ***Concept:*** the Quantum Idea Incubator solicitation aims to support the process of translating innovative, original, and potentially transformative ideas into reality
- **Includes:** at least three research disciplines, which preferably come from at least two of the recommended thrust areas



QI-TAQS Awards

Title	PI	Organization
QII-TAQS: Quantum Devices with Majorana Fermions in High-Quality Three-Dimensional Topological Insulator Heterostructures	Vikram Deshpande	University of Utah
QII-TAQS: Characterizing and Utilizing 2D van der Wals Materials with Superconducting Qubits	William Oliver	Massachusetts Institute of Technology
QII-TAQS: Topological Quantum Devices from Nanoscale Mechanical Control of Materials	Stephen Wu	University of Rochester
QII-TAQS: Spatially and Temporally Resolved Ultrasensitive Magnetic Sensing of Quantum Materials	Gang Xiao	Brown University
QII-TAQS: Enhancing Quantum Coherence by Dissipation in Programmable Atomic Arrays	Sebastian Will	Columbia University
QII-TAQS: Solid State Integration of Molecular Qubits	Ezekiel Johnston-Halperin	Ohio State University
QII-TAQS: All-Photonic Quantum Network	Alexander Gaeta	Columbia University
QII-TAQS: Quantum Photonics at Telecommunications Wavelengths Based on Metal-Ion-Doped Materials	Rufus Cone	Montana State University
QII-TAQS: Chip-Scale Quantum Emulators Based on Polaritonic Lattices	Vinod Menon	CUNY City College
QII-TAQS: Quantum Circuits Through Symmetry-Driven Valley Optoelectronics	Ritesh Agarwal	University of Pennsylvania
QII-TAQS: Quantum Metrological Platform for Single-Molecule Bio-Sensing	Peter Maurer	University of Chicago
QII-TAQS: Quantum-Enhanced Telescopy	Paul Kwiat	University of Illinois at Urbana-Champaign
QII-TAQS: Simulating Entangled Quantum Chemical Abstract Machines	Srinivasan Iyengar	Indiana University
QII-TAQS: Majorana Nanomanipulation for Topological Quantum Computing	Jennifer Hoffman	Harvard University
QII-TAQS: Strongly Interacting Photons in Coupled Cavity Arrays: A Platform for Quantum Many-Body Simulation	Arka Majumdar	University of Washington
QII-TAQS: Suppressing and Correcting Errors in Hybrid Superconducting Qubit Systems	Eli Levenson-Falk	University of Southern California
QII-TAQS: A Chip-Scale Spin-Photon Memory Interface with Coherence Exceeding One Second	Chee Wei Wong	University of California-Los Angeles
QII-TAQS: Quantum Control of Ultracold Atoms in Optical Lattices for Inertial Sensing for Space Applications	Dana Anderson	University of Colorado at Boulder
QII-TAQS: Quantum Machine Learning with Photonics	Edo Waks	University of Maryland College Park



What are Quantum Leap Challenge Institutes (QLCI) ?

NSF 19-559

- The QLCI program will support **large-scale projects** driven by a ***cross-disciplinary challenge research theme*** for advancing the frontiers of quantum information science and engineering.

- Timely and bold research agenda aimed at making breakthroughs on compelling challenges in a 5-year period.

- Conceptualize, develop, and implement **revolutionary** new approaches and technologies for quantum information processing.

- Research will span the focus areas of **quantum computation**, **quantum communication**, **quantum simulation, or quantum sensing.**

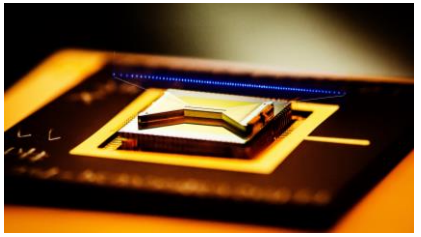


Image Credit: K. Hudek, IonQ&E; E. Edwards JQI

The QLCI program will support two types of awards:

Conceptualization Grants (CGs) funded at a level of $100,000-$150,000 for 12 months

Challenge Institute (CI) awards funded at a level of up to $5,000,000/year for 5 years

Two rounds of competition:

ROUND I (2019-2020): **CG or CI proposals** *but not both*
ROUND II (2020-2021): **CI proposals only**

Credit: Brad Baxley/JILA

CG awardees will have the opportunity to submit a CI proposal in Round II

Quantum Leap Challenge Institute Conceptualization Grant Program Concept

- Conceptualization Grants intend to **build capacity** among teams to plan for large-scale, interdisciplinary research projects that aim to advance the frontiers of quantum information science and engineering.
- Research at these Institutes will span the focus areas of quantum computation, quantum communication, quantum simulation, and/or quantum sensing.
- The Institutes are expected to foster multidisciplinary approaches to specific scientific, technological, educational, and workforce development goals in these fields.
- Funding up to $150k, 12 months

QLCI Conceptualization Grant Awards

Title	PI	Organization
QLCI-CG: Nevada Institute for Quantum Sciences and Technology	Bernard Zygelman	University of Nevada Las Vegas
QLCI-CG: Quantum Software for Scientific and Engineering Applications	George Siopsis	University of Tennessee Knoxville
QLCI - CG: Texas Quantum Institute	Junichiro Kono	William Marsh Rice University
QLCI-CG Quantum Challenge Institute for Quantum Photonic Information Processing	Ryan Camacho	Brigham Young University
QLCI - CG: Quantum Photonic Institute	Donald Figer	Rochester Institute of Tech
QLCI-CG: Design of Novel Functional Materials for Quantum Devices	Vasili Perebeinos	SUNY at Buffalo
QLCI-CG: Institute for Hybrid Quantum Systems	Kai-Mei Fu	University of Washington
QLCI-CG: Conceptualization of The Institute for Quantum Biology on Quantum Computers	Beverly Sanders	University of Florida
QLCI-CG: Scalable Integrated Platforms for Quantum Information Processing	Marek Osinski	University of New Mexico
QLCI-CG: Atomic, Molecular, and Photonic Instruments on Chip for Quantum Sensing	Chandra Raman	Georgia Tech Research Corporation
QLCI-CG: Center for a Quantum-Engineered Distributed Computing and Communication Testbed	Eden Figueroa	SUNY at Stony Brook
QLCI-CG: Towards a Boston Area Quantum Science and Engineering Institute	Andrei Ruckenstein	Trustees of Boston University
QLCI-CG: The Open Quantum Frontier Institute	Lincoln Carr	Colorado School of Mines
QLCI-CG: Conceptualizing a Quantum Information Bioscience Institute for Quantum Sensing and Simulations in Novel Hybrid Architectures	Maria Procopio	Johns Hopkins University
QLCI-CG: Center for Quantum Sensors	Kater Murch	Washington University
QLCI-CG: Identification and Control of Fundamental Properties of Quantum Systems	Vesna Mitrovic	Brown University
QLCI-CG: Center for Interdisciplinary Research in Quantum Information Theory and Simulation	Sophia Economou	Virginia Polytechnic Institute and State University
QLCI-CG: Institute for Chiral-Quantum Materials Interfaces	Vladimiro Mujica	Arizona State University

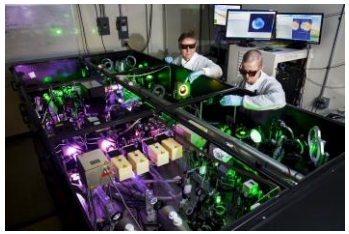
Mid-scale Research Infrastructure (Mid-scale RI) Opportunities

- Mid-scale RI is an NSF Big Idea to address the growing needs for RI to advance research.
- NSF-wide program will support projects in the MRI – MREFC gap (~$6 to $70 million range).
- RI is broadly defined, from disciplinary instrumentation to mid-scale facilities, upgrades, cyberinfrastructure, and others.

- Two solicitations released: one for projects between ~$6 M and ~$20 M (MSRI-1) and one for ~$20 - $70 M (MSRI-2).
- Awards for first group have been made; Full proposals for second are in and under review

Mid-Scale RI-1 Awards Related to MPS

Mid-scale RI-1 (M1:IP): A world-class Neutron Spin Echo Spectrometer for the Nation: UD-NIST-UMD Consortium; Award Number: 1935956;
Principal Investigator: Norman Wagner; University of Delaware

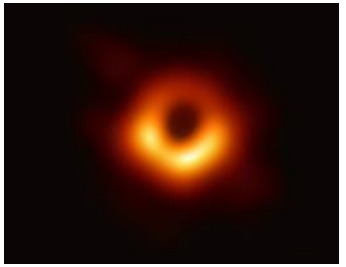


Maksimchuk, Nees @ HERCULES; Credit: Joseph Xu

Mid-scale RI-1 (M1:IP): Zettawatt-Equivalent Ultrashort Pulse Laser System (ZEUS): Award Number: 1935950;
Principal Investigator: Karl Krushelnick; U of Michigan Ann Arbor

Mid-scale RI-1 (M1:IP): NSF National EXtreme Ultrafast Science (NEXUS) Facility: Award Number: 1935885;
Principal Investigator: Lawrence Baker; Ohio State University

Mid-scale RI-1 (M1:DP): Next Generation Event Horizon Telescope Design: Award Number: 1935980; Principal Investigator: Sheperd Doeleman; Smithsonian Institution Astrophysical Observatory



EHT Black Hole

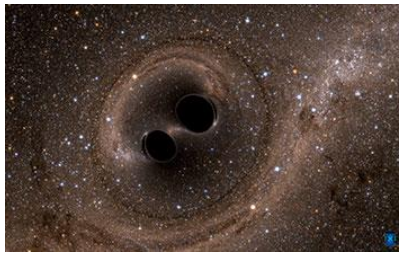
Mid-scale RI-1 (M1:DP): Consortium Proposal for CMB-S4 Design Development: Award Number: 1935892: Principal Investigator: John Carlstrom; U Chicago

PD 18-5115

Program Description: Windows on the Universe: The Era of Multi-Messenger Astrophysics

- Proposals submitted to participating programs in MPS/AST, MPS/PHY and GEO/OPP.
- Proposals funded through “Big Idea” allocation as well as existing programs.
- Criteria: <u>any area of research supported through the participating divisions that address at least one of the following:</u>
  - *Coordination:* Hardware, software, or other infrastructure to coordinate observations involving more than one messenger.
  - *Observations:* Observations of astrophysical objects or phenomena that are potentially sources of more than one messenger, including the use of existing observatories, experiments, and data archives, as well as the development and construction of new capabilities for advancing multi-messenger astrophysics.
  - *Interpretation:* Theory, simulations and other activities to understand or interpret observations of astrophysical objects that are sources of more than one messenger.

https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505593



Fiscal 2019 – WoU-MMA

$30M from WoU-MMA awarded in FY19
66 awards (full or co-funded w/ MPS/PHY/AST/OMA; GEO/PLR)
Roughly 2/3 went for support of individual investigators
The remaining 1/3 was split between Instrumentation and Facilities

Examples: (Full List at https://www.nsf.gov/awardsearch/)

PI Community (individual investigators) Ice Cube – F. Halzen (Univ. of Wisconsin) Support for 19 institutions to do the scientific analysis of data taken with the IceCube neutrino detector

Instrumentation SNEWS: a Super Nova Early Warning System - R. Lang et al. Analysis of neutrino detector data to provide a prompt alert for an impending supernova … hours before it will be visible in the sky

Facilities SCIMMA – P. Brady et al.
Scalable Cyberinfrastructure Institute for Multi-Messenger Astrophysics

HEPAP Relevant Harnessing the Data Revolution Awards

1934700: Collaborative Research: Advancing Science with Accelerated Machine Learning; Philip Harris, PI (+ collaborators); MIT; $1.8 M

1940209: Collaborative Research: Science-Aware Computational Methods for Accelerating Data-Intensive Discovery: Astroparticle Physics as a Test Case; Christopher Tunnell, PI (+ collaborators), Rice University; $1.0 M

1934752: A Framework for Data Intensive Discovery in Multimessenger Astrophysics; Patrick Brady, PI (+co-workers); U Wisconsin-Milwaukee; $2.8 M

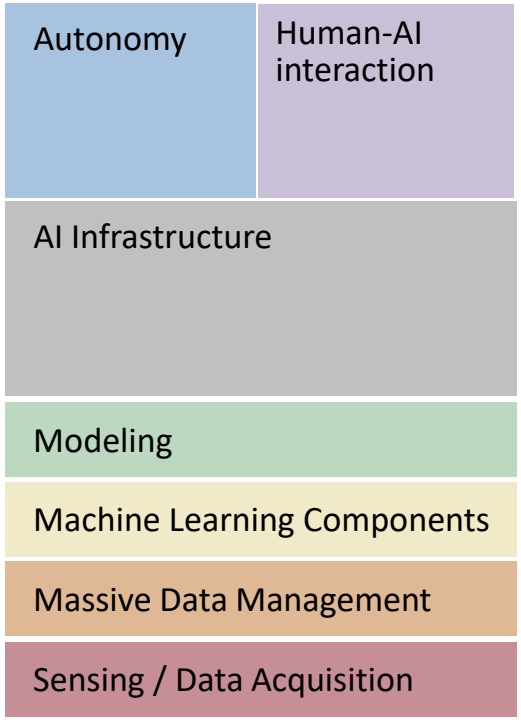
All are 2-year planning/conceptualization for FY 2021 Institutes Solicitation

AI: more than machine learning

Act:
AI-Driven Systems

Learn:
Machine Learning & Data Science

Perceive:
Data systems, sensing



New in FY 2019 and FY 2020

- **AI and Society, with the Partnership on AI**
  - $4.5M joint funding: CISE and SBE, with PAI, in FY 2019

PARTNERSHIP ON AI

amazon.com IBM facebook Microsoft DeepMind Google

PAI Founding Members

- **NSF/DARPA Program on Real-Time Machine Learning (RTML)**
  - $11M total, with CISE and ENG beginning in FY 2019

DARPA

- **NSF/Amazon Program on Fairness in AI**
  - $20M joint funding: CISE and SBE, with Amazon, in FY 2020

amazon alexa

- **DCL on FEAT for CISE: Fairness, Ethics, Accountability, and Transparency for CISE Research (NSF 19-016)**

National AI Research Institutes

- **National nexus points** for universities, federal agencies, industry and nonprofits **to advance AI research and education**
- In FY 2020:
  - *Planning grants* for future Institutes
  - Launching up to six multidisciplinary, multi-institutional research *Institutes*
- Anticipated investment: ~$200M over six years, beginning in FY 2020