Overview of the Directorate for Mathematical and Physical Sciences

NSF Regional Grants Conference

The University of Utah/Utah State University

Salt Lake City, UT, October 25-26, 2010

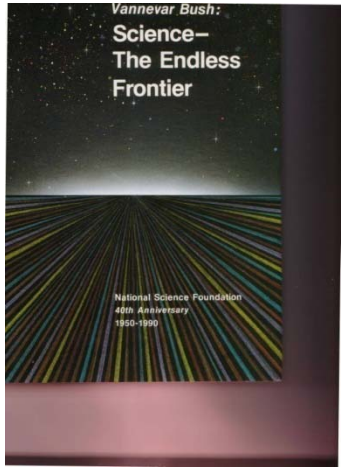
Nigel Sharp, nsharp@nsf.gov

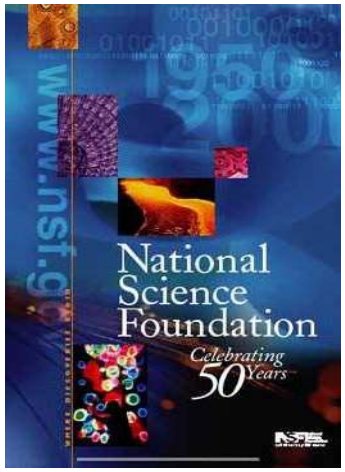
Program Director

Division of Astronomical Sciences

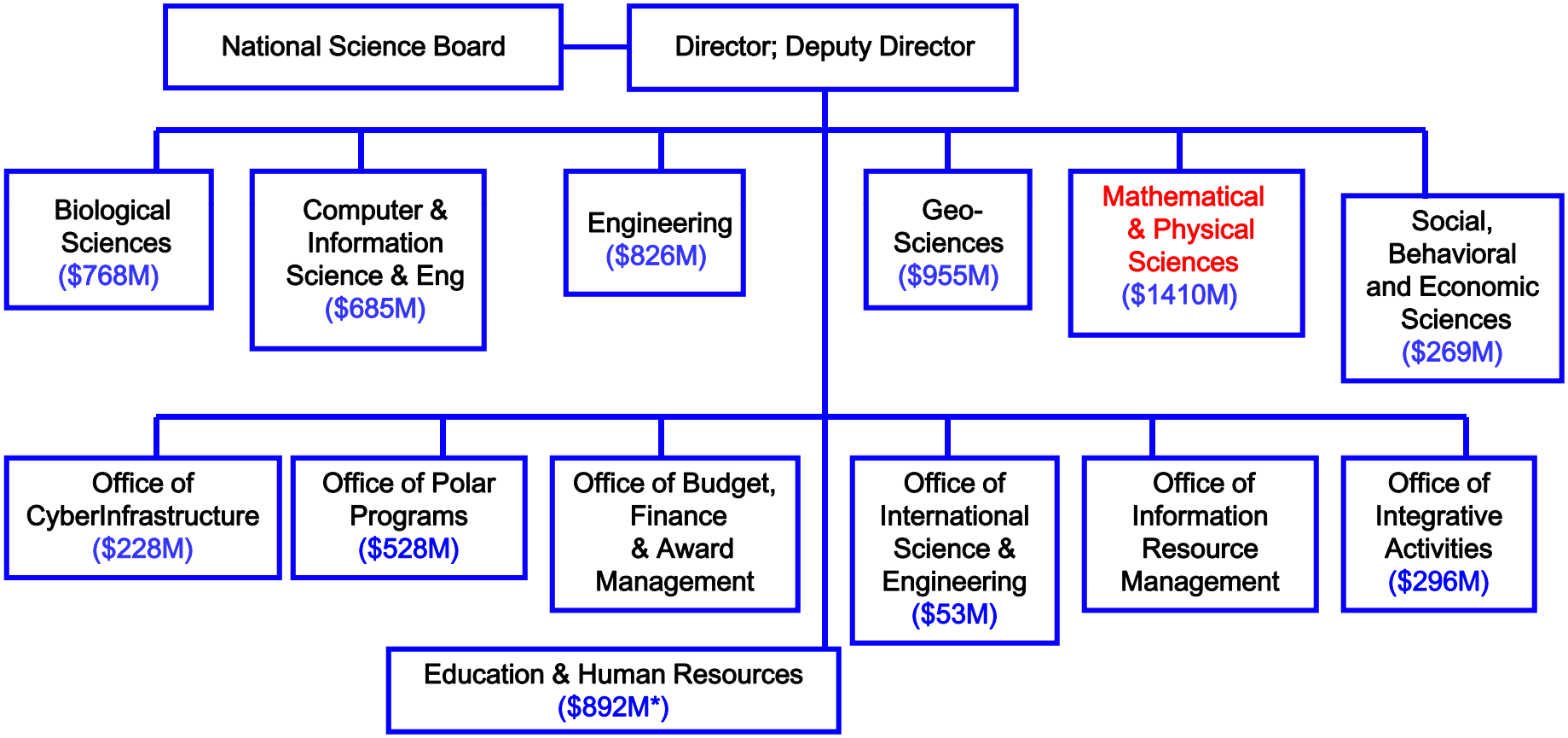
NSF in a Nutshell

- **VISION: To enable America's future through discovery, learning and innovation**
- **MISSION: To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense.**
- **Basic research and education using two grant mechanisms**
  - **Unsolicited, curiosity driven**
  - **Solicited, more focused**
- **Peer reviews: *intellectual merit* & *broader impact***
- **No laboratories of its own, but supports large facilities**
- **Discipline-based structure, covering all fields of Science, Technology, Engineering, and Mathematics (STEM)**
- **Cross-disciplinary mechanisms**





NSF in a Nutshell



Budgets are taken from the FY 2011 Request

NSF-wide scientific investments

Cyber-enabled Discovery & Innovation

National Nanotechnology Initiative

NSF Centers

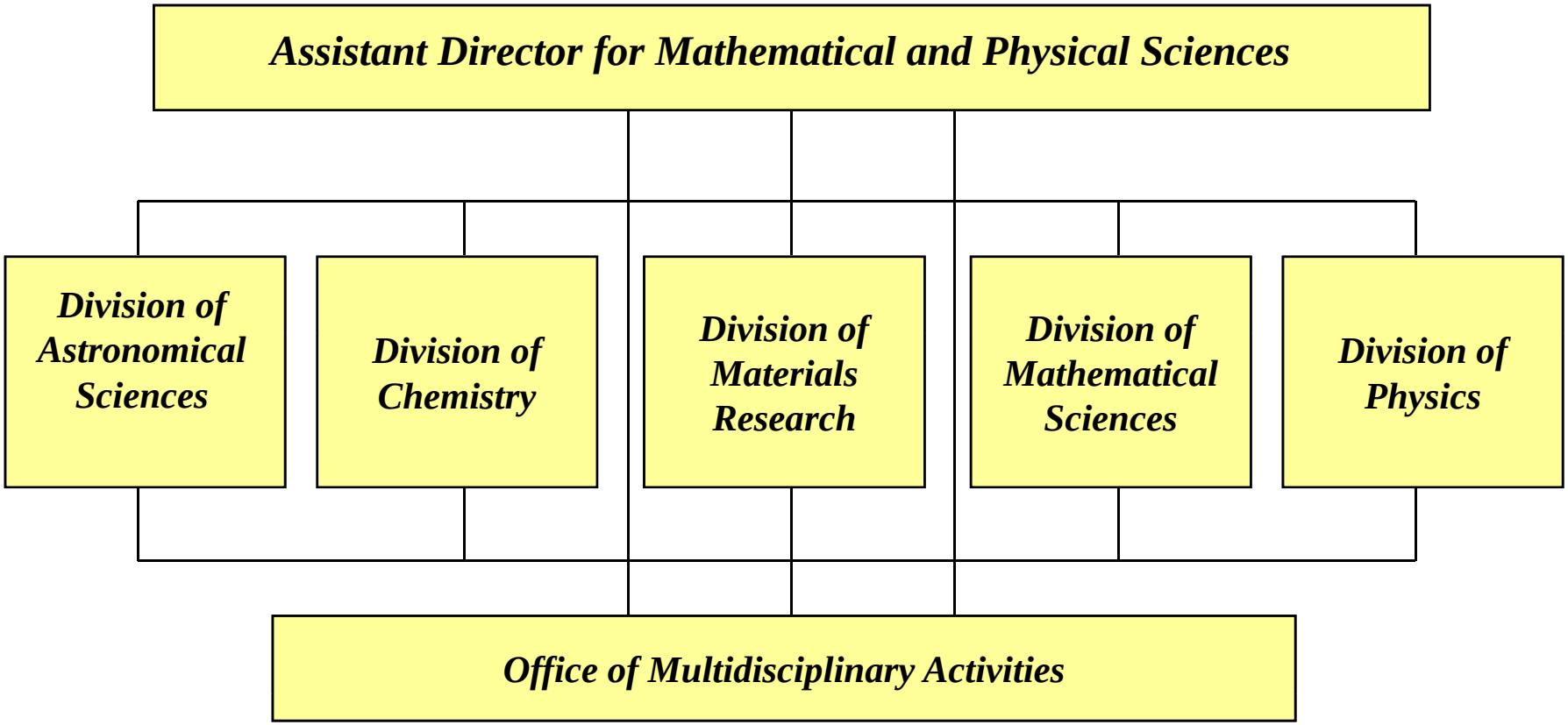
Biocomplexity and the Environment

Networking & Information Technology R&D

Science and Engineering Beyond Moore's Law

Broadening Participation

Directorate for Mathematical and Physical Sciences



MPS in a (different) Nutshell

- Largest directorate
  - » ~25% of R&RA, ~18% of proposals, FY11 request $1410m
- Nearly half of NSF's large facilities
- Responsible for the three "core" university disciplines - Physics, Chemistry, Mathematics – plus Astronomy and Materials Research
- Over 40% of university federal funding in the physical sciences
  - » More than 80% in mathematics, and (was) growing
  - » Federal steward for ground-based astronomy
- Science scope - extension on every scale
  - » Femtoseconds and attoseconds to petaseconds and exaseconds
  - » From the Planck size to the Cosmic size
  - » From nanoKelvin to GigaKelvin
  - » From fundamental research to marketable technologies
  - » Every mental horizon from n-dimensions to infinity and beyond …

MPS Scientific Themes

- Charting the evolution of the Universe from the Big Bang to habitable planets and beyond
- Understanding the fundamental nature of space, time, matter, and energy
- Creating the molecules and materials that will transform the 21st century
- Developing tools for discovery and innovation throughout science and engineering
- Understanding how microscopic processes enable and shape the complex behavior of the living world
- Discovering mathematical structures and promoting new connections between mathematics and the sciences
- Conducting basic research that provides the foundation for our national health, prosperity, and security

MPS Scientific Opportunities

- Physical sciences at the nanoscale
- Science beyond “Moore’s Law”
- Physics of the Universe
- Complex systems (multi-scale, emergent phenomena)
- Fundamental mathematical and statistical science
- Sustainability (energy, environment, climate)
- Interface between the physical and life sciences
- Computational Science & Cyber-enabled Discovery and Innovation (CDI)
- CHE-DMR-DMS Solar Energy Initiative (SOLAR)

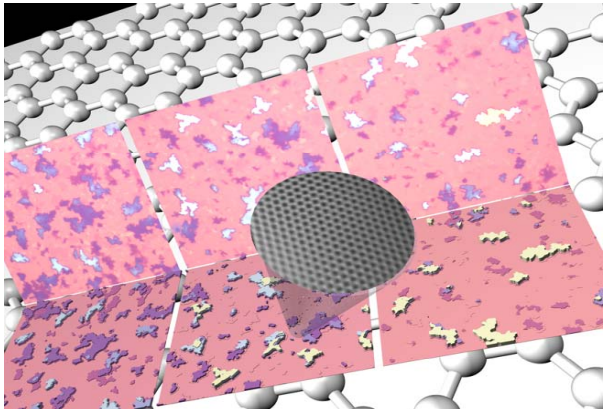
National Nanotechnology Initiative

- Nanomaterials and nanodevices
  - Computing
  - Communications
  - Energy (e.g., solar)
- Nanomanufacturing
- Environment, health, and safety

Science and Engineering beyond Moore's Law (SEBML)

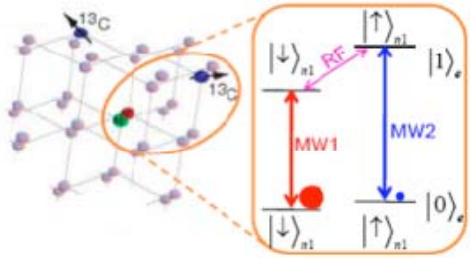
SEBML request: + 50% (to$70.2M)

Goal: To position the U.S. at the forefront of communications and computation capability beyond the physical and conceptual limitations of current technologies.



Materials for ultra-fast computing: MPS-supported research on graphene materials could lead to microchips that operate at much higher speeds than is possible with today's standard silicon chips.

Quantum Information Science is a promising area of SEBML. Quantum information is fragile and susceptible to loss. Recent progress in electron spin quantum memory improved robustness by controlling interactions with nuclear spins in diamond.



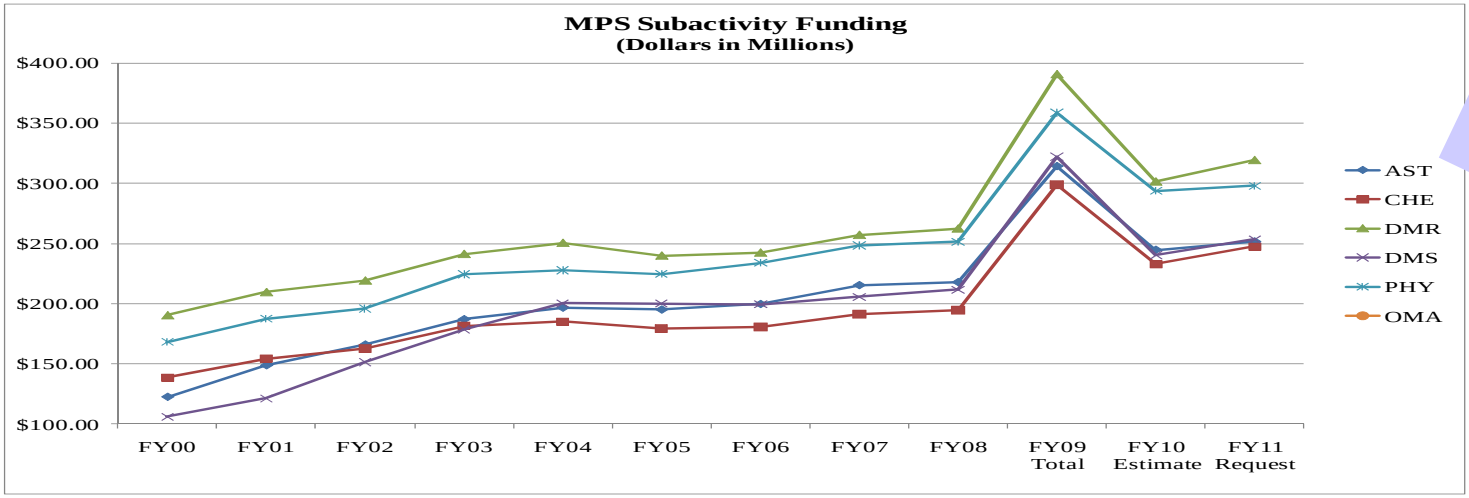
Jiang et al., Science **326**, 267 (2009)

MPS Budgets by Division

Discovery +6.7%

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Plan	FY 2011 Request	Change Over FY 2010 Plan Amount	Change Over FY 2010 Plan Percent
Astronomical Sciences	$228.67	$85.80	$245.69	$251.77	$6.08	2.5%
Chemistry	$211.67	$87.36	$233.73	$247.56	$13.83	5.9%
Materials Research	$282.52	$108.17	$302.67	$319.37	$16.70	5.5%
Mathematical Sciences	$224.84	$97.34	$241.38	$253.46	$12.08	5.0%
Physics	$262.47	$96.30	$290.04	$298.19	$8.15	2.8%
OMA	$33.70	-	$38.33	$39.56	$1.23	3.2%
Total, MPS	**$1,243.87**	**$474.97**	**$1,351.84**	**$1,409.91**	**$58.07**	**4.3%**



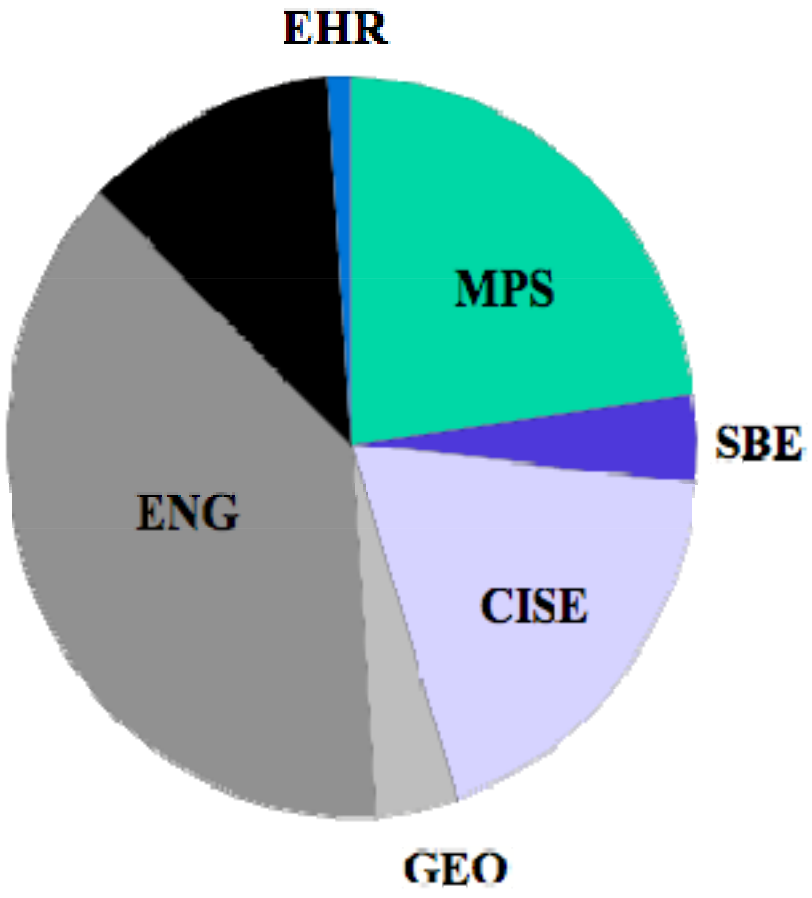
Average annualized increase 5%

NSF-wide programs

CAREER	ADVANCE
EPSCOR	IGERT
REU	RET
RUI, ROA	GK-12

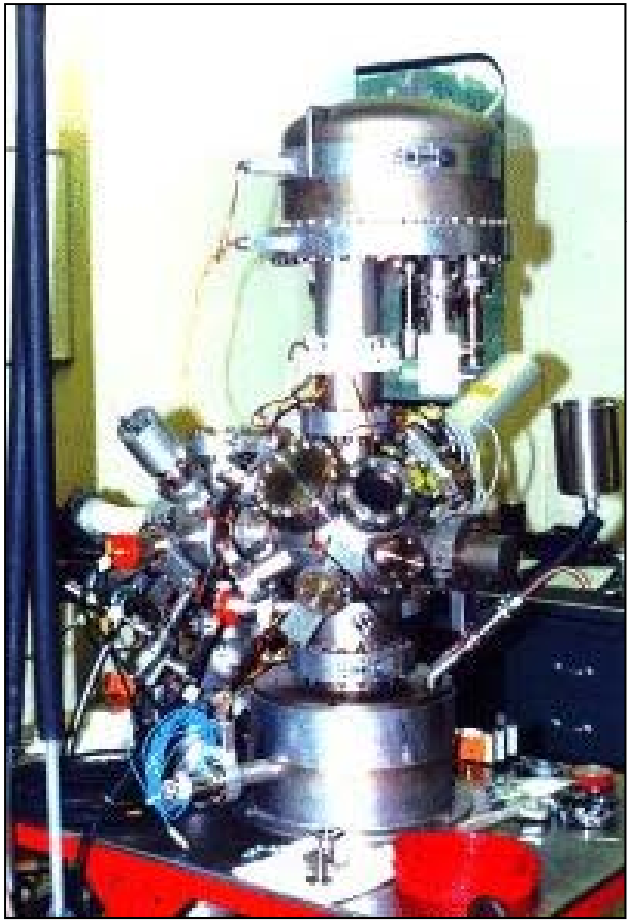
CAREER program

- NSF's most prestigious awards for new junior faculty.
- Awardees are selected based on their plan to develop a highly integrative and effective research and education career within the context of the mission of their institution.
- Increased participation of those traditionally under-represented in science and engineering is encouraged.



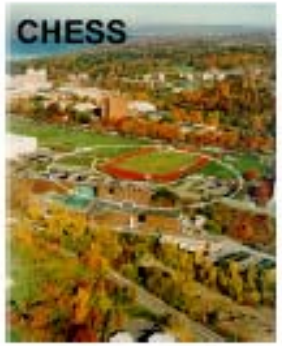
Instrumentation

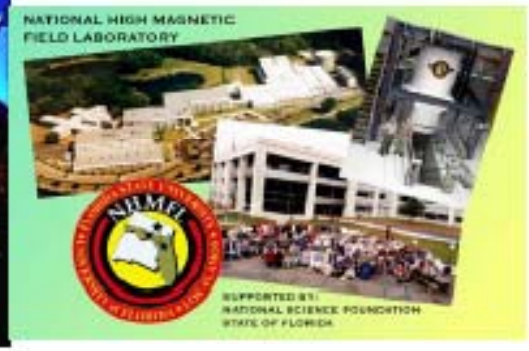
- Both acquisition and development
- Research grants
- Divisional instrumentation programs
- Major Research Instrumentation (MRI)



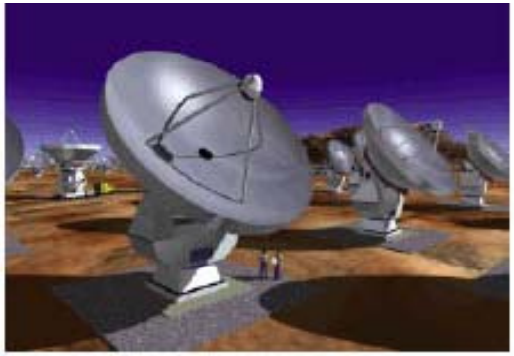
World Class Major Facilities

Keep University Researchers at the Frontier

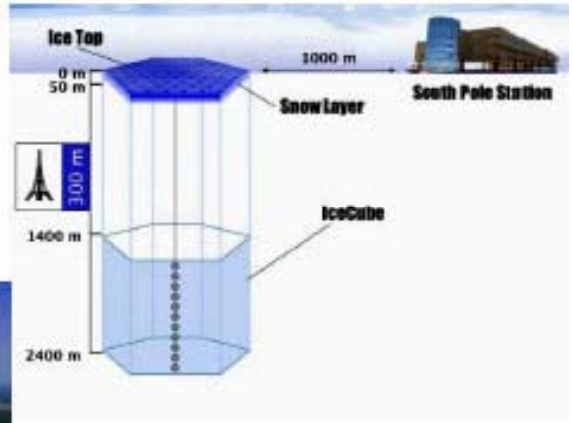




Coming Soon



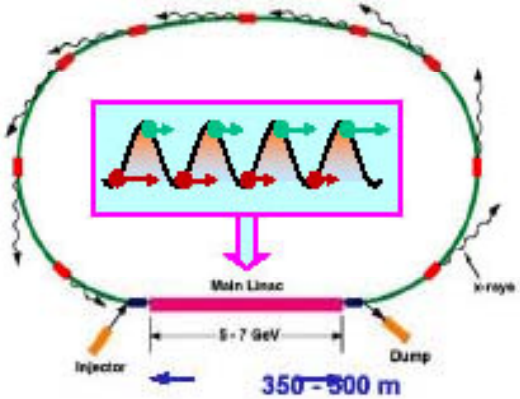
- Atacama Large Millimeter/ submillimeter Array (ALMA)
  - » NSF, Europe, Japan, Taiwan - radio telescope in high Chilean Andes
- Extended Very Large Array (EVLA)
  - » New Mexico array improved by two orders of magnitude



- IceCube
  - » MPS/OPP, international - cubic kilometer of ice instrumented to detect neutrinos
- Advanced LIGO
  - » Louisiana/Washington gravitational wave detectors

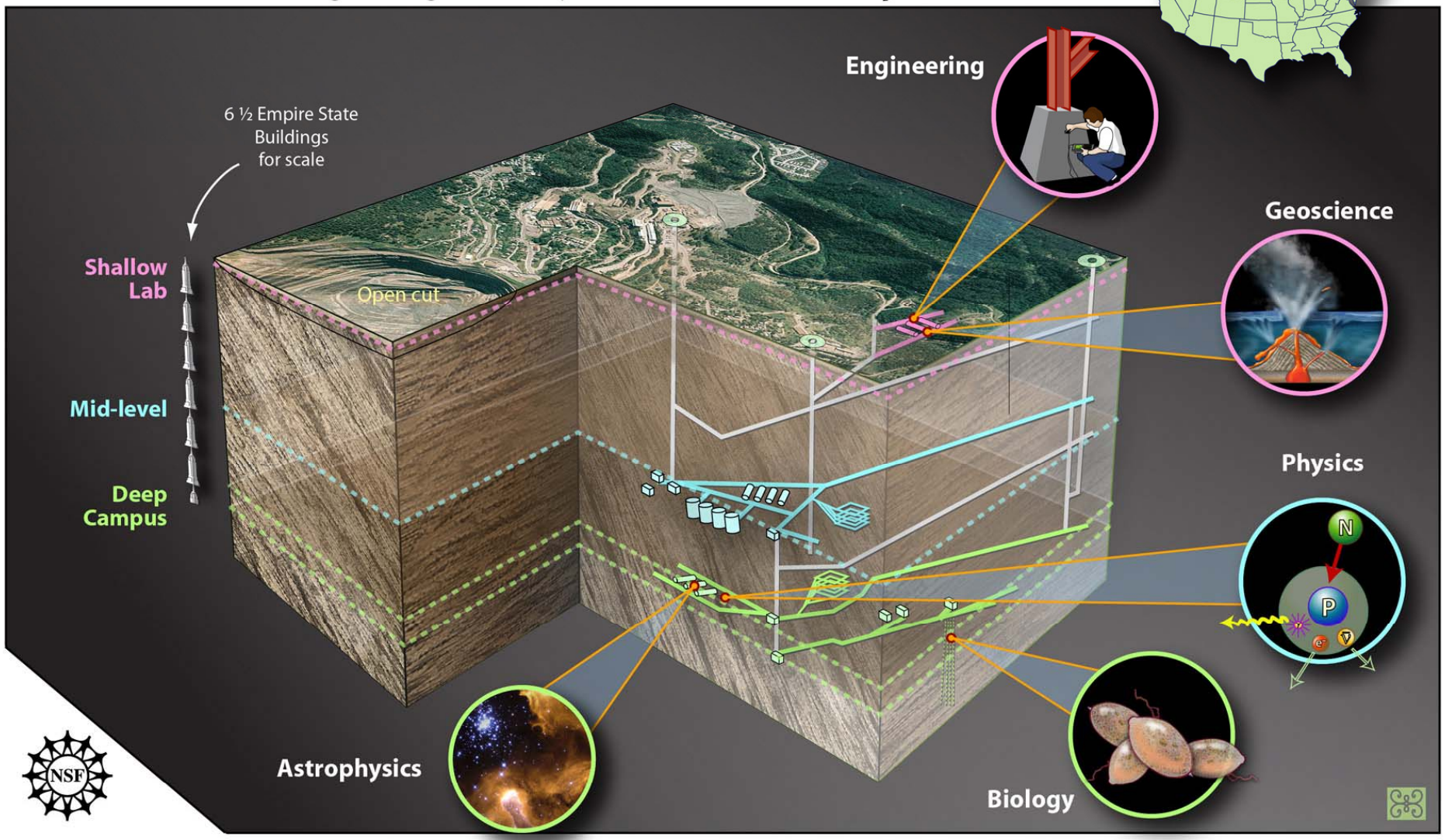
Major New Capabilities

- Large Synoptic Survey Telescope (LSST)
- Energy Recovery LINAC (ERL)
- Giant Segmented Mirror Telescope (GSMT)
- Square Kilometer Array (SKA)

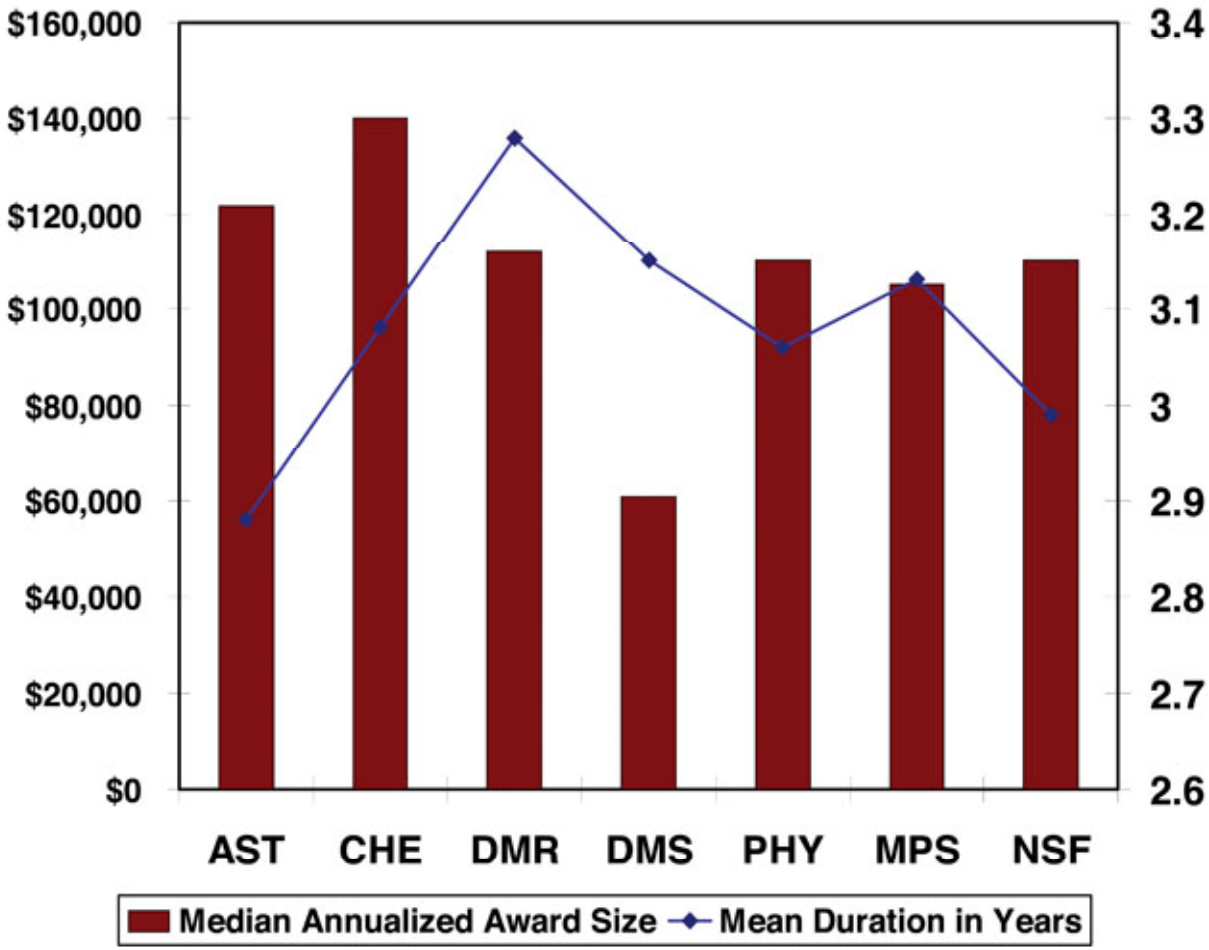


- Advanced Technology Solar Telescope (ATST)
- Deep Underground Science and Engineering Laboratory (DUSEL)

DUSEL Deep Underground Science and Engineering Laboratory at Homestake, SD



Median annual award size and duration

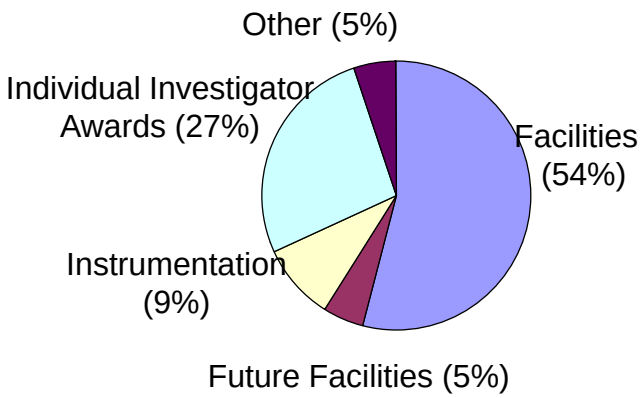


Slightly out of date – add 5%

The MPS Divisions

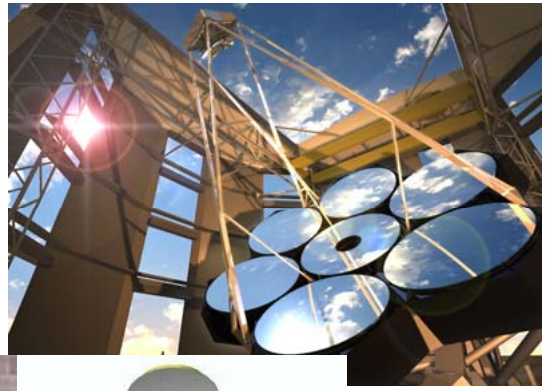
Division of Astronomical Sciences (AST)

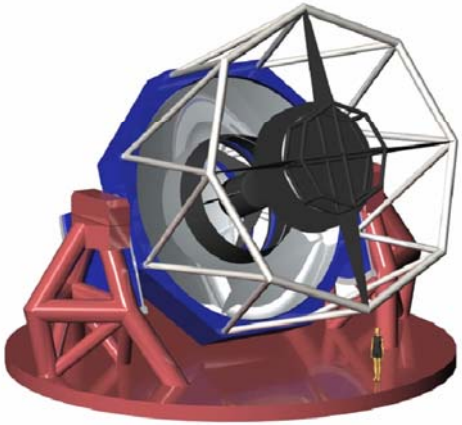
- From the Big Bang to DNA
  - » Origin and evolution of the Universe
  - » “Physics of the Universe” program
  - » Origin and evolution of galaxies
  - » Origin and evolution of planetary and stellar systems

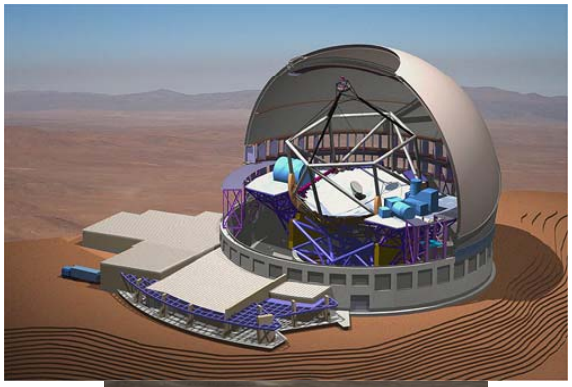


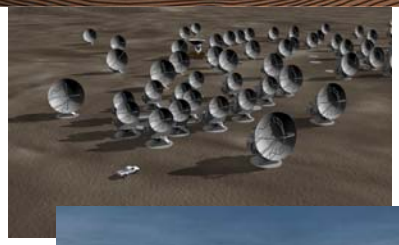
- National astronomy portfolio
  - » Three agencies - NSF, NASA, and DoE
  - » Strong tradition of private funding
  - » NSF assigned federal stewardship of ground-based astronomy
  - » Includes open-access facilities and mission-free unrestricted grants
  - » Joint advisory mechanism: AAAC, CAA, NRC “decadal” surveys

Strong Education and Special Programs, including a major investment in post-docs

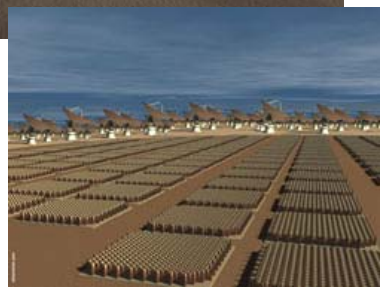








Meeting the challenges requires a global effort, developing the best minds, giving them the best tools, and supporting their research.



Division of Chemistry (CHE)

Creating molecules and instruments that are transforming the 21st century

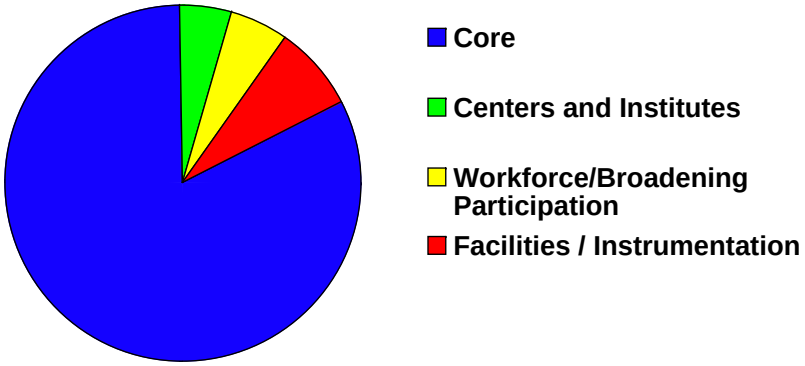
- Chemical Synthesis
- Chemical Structure, Dynamics, and Mechanisms
- Theory, Models, and Computational Methods
- Chemical Measurement and Imaging

Integrative Chemistry Activities

- Centers
- Education and Broadening Participation
- Facilities and Instrumentation

- Environmental Chemical Sciences
- Chemistry of Life Processes
- Chemical Catalysis
- Macromolecular, Supramolecular, and Nanochemistry

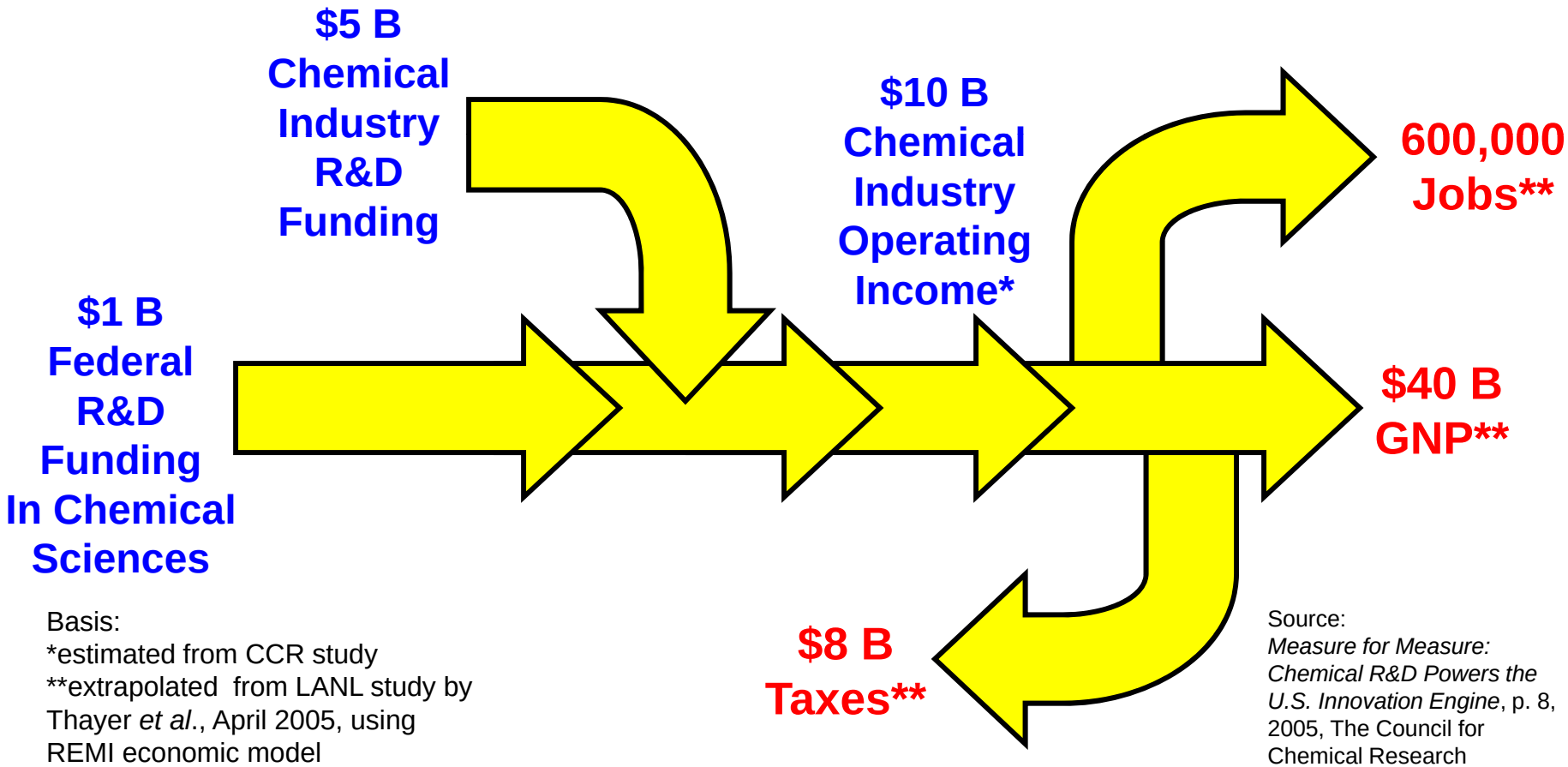
- Major CAREER and REU support
- Centers program growing
- Collaborations with NIH and DOE
- Critical areas of research:
  Energy, Element and Molecule Recycling, Designed Emergent Behavior, Imaging the Ultrasmall
- Centers for Chemical Innovation



ACI, American COMPETES and Chemical Sciences

Macroeconomic Implications

http://www.ccrhq.org/Measure_for_Measure_Presentation_04-26-062.ppt



Basis:
*estimated from CCR study
**extrapolated from LANL study by Thayer *et al*., April 2005, using REMI economic model

Source:
Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine, p. 8, 2005, The Council for Chemical Research

Division of Materials Research (DMR)

Creating the materials that will transform the 21st century

- From a fundamental understanding of materials and condensed matter to projects which are only a few years from commercial exploitation

- Metals, Ceramics, Electronic Materials
- Condensed Matter Physics, Condensed Matter and Materials Theory
- Solid-State Chemistry, Polymers, Biomaterials
- Materials Research Science and Engineering Centers (MRSECs)
- National Facilities and Instrumentation
- Office of Special Programs

Key Research Areas:

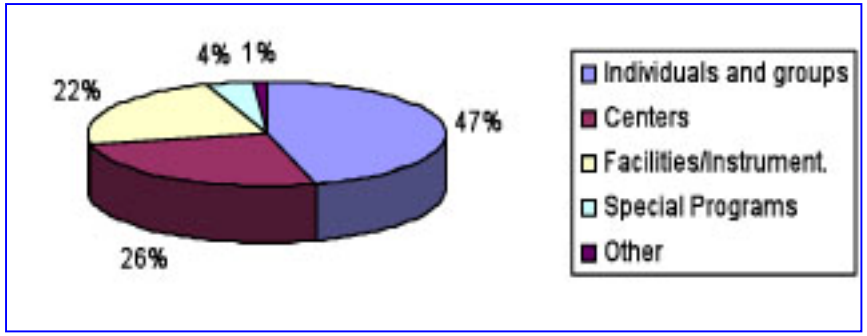
» Environmental, energy, and economic sustainability

» Matter by design

» The quantum realm

» Physical-chemical-biological interfaces

DMR supports a wide breadth of science, from fundamental research to the development of technological applications.

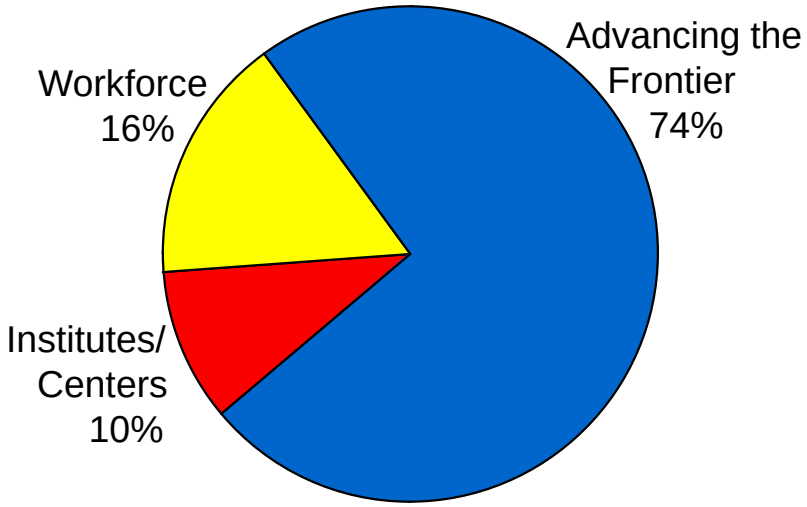


Materials World Network

- Funds the US researchers in an International Collaboration
- Foreign researchers are funded by their respective agencies
- Countries and Agencies involved:
  - » Algeria, Argentina, Australia, Austria, Brazil, Canada, Chile, China, Colombia, Croatia, Czech Republic, Egypt, Ethiopia, European Commission, European Science Foundation, Finland, France, Germany, Ghana, Greece, Hungary, India, Ireland, Israel, Italy, Jamaica, Japan, Luxembourg, Mexico, Morocco, Namibia, Nigeria, Norway, Poland, Portugal, Russian Federation, Rwanda, Senegal, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Taiwan, Trinidad & Tobago, Tunisia, Turkey, Uganda, United Kingdom, Ukraine, and Zimbabwe

Division of Mathematical Sciences (DMS)

- Mathematicians investigate patterns and structures and the relations between them
  - » *"God wrote the Universe in the language of mathematics" Galileo*
  - » *"Mathematics is the door and key to the sciences" Francis Bacon*
- Science drivers
  - » Large data sets - analyzing complexity and patterns
  - » Stochastic behavior - determinism and probability
  - » Multiscale phenomena - over many orders of magnitude in space and time
  - » Q: what connects superconductivity and image restoration? A: the same PDE. Mathematics IS everywhere.



Division of Mathematical Sciences (DMS)

Analysis

Geometry Topology

Computational Math

Workforce

Institutes

Algebra

Number Theory Combinatorics

Applied Math

Probability Statistics

"Core business": Single investigator and Group proposals through targeted solicitations, covering the entire mathematical spectrum

Institutes: 5 NSF-initiated, support for 3 others
Visitors to long term programs, workshops

Workforce: Responding to a major challenge. EMSW21 training grants;

In addition to fundamental research, DMS plays an enabling role in all other sciences and has many successful partnerships with other parts of NSF and with other agencies.

Division of Physics (PHY)

- From the discovery of new fundamental particles to understanding the biological cell and the cosmos
- Notable features
  - » Physics of the Universe
  - » Renaissance in Atomic, Molecular and Optical Physics (AMOP)
  - » Joint NSF/DoE partnership in Fundamental Plasma Physics
  - » Physics of Living Systems
  - » Physics at the Information Frontier
- Stewardship
  - » The primary sponsor of gravitational physics
  - » University faculty and students in nuclear and particle physics
  - » Facilities: LIGO/Advanced LIGO, LHC, DUSEL, NSCL, IceCube, …

Division of Physics (PHY)

Programs:

Atomic, Molecular, & Optical Physics;

Plasma Physics; Biological Physics;

Elementary Particle Physics;

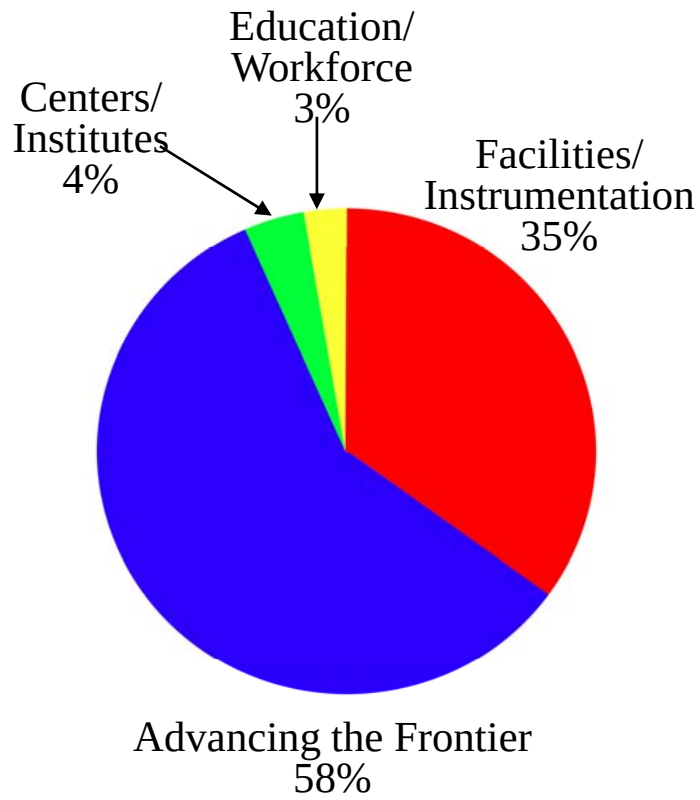
Gravitational Physics; Nuclear Physics;

Particle and Nuclear Astrophysics;

Physics at the Information Frontier;

Physics Frontier Centers;

Theoretical Physics; Education and Interdisciplinary Programs



PHY collaborates closely with DOE and international partners to support science at large facilities. NSF's physics portfolio is more diverse than physics portfolios at any other federal agency.

Office of MultiDisciplinary Activities (OMA)

- Catalyzes cross-cutting research in areas of strategic emphasis in MPS, as well as areas that may emerge as strategic
- Facilitates partnerships with other agencies, industries, state and local governments, and international organizations
- Supports innovative experiments in education and broadening participation

- *OMA neither receives nor reviews proposals*
  - » Rather, OMA co-invests with MPS Divisions

Reasons For Funding A Competitive Proposal

- Scientific Impact
- PI Career Point
- Program Portfolio Balance
- Special Programmatic Considerations (CAREER/RUI/EPSCoR, for example)
- **Diversity Issues**
- **Educational Impact**
- **Impact on Institution/State**

Secrets for Success !

- New and original ideas
- Sound, succinct, detailed focused plan
- Preliminary data and/or feasibility calculations
- Relevant experience
- Clarity concerning future direction
- Well-articulated broader impacts

Get Involved

- Volunteer to be a reviewer and panelist
- Participate in NSF-funded events, workshops, etc.
- Send your best ideas to NSF: consistent with program focus and goals
- Get to know your Program Directors
- Keep us informed of your accomplishments
- Work to support collaborative, interdisciplinary research
- Call our attention to things that need improvement
- Suggest transition strategies from basic research to prototyping and production
- Plan to serve as a program officer (“rotator”) or division director

Look us up

For information on a particular division or program, go to the MPS home page on the Web and “drill down”

That’s http://www.nsf.gov/dir/index.jsp?org=MPS

See “View MPS Staff Directory” on that same home page

And talk to us! Contact, contact, contact. Ask your friendly neighborhood Program Officer

And if all else fails, ask me: nsharp@nsf.gov