Overview of the Directorate for Mathematical and Physical Sciences

NSF Regional Grants Conference

Omaha, NE

October 20-21, 2008

Nigel Sharp, nsharp@nsf.gov

Program Director

Division of Astronomical Sciences

NSF Vision and Goals

- Vision
  - » Advancing discovery, innovation and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering.
- Goals
  - » Discovery
  - » Learning
  - » Research Infrastructure
  - » Stewardship

NSF Strategic Plan

- Objectives
  - To Inspire and Transform
  - To Grow and Develop
- Core Values
  - Visionary; Dedicated to Excellence; Broadly Inclusive; Accountable
- Investment Considerations
  - Alignment; Budget; Integration of Research with Education; Leveraging Collaborations; Potential for Impact and Transformation; Urgency and Readiness

MPS Goals

- Goal I: Advancing the Frontier
  - » Strategy 1: Strengthen Individual Investigator research
  - » Strategy 2: Take advantage of unique scientific opportunities
  - » Strategy 3: Address scientific infrastructure needs and impact
- Goal II: Service to the Nation
  - » Strategy 1: Strengthen support for early career investigators, for new interdisciplinary efforts, and for high-risk areas of research
  - » Strategy 2: Strive toward a diverse and capable scientific workforce
  - » Strategy 3: Communicate the societal importance of the mathematical and physical sciences to the public
- Goal III: Global Engagement
  - » Strategy: Increase International Connections

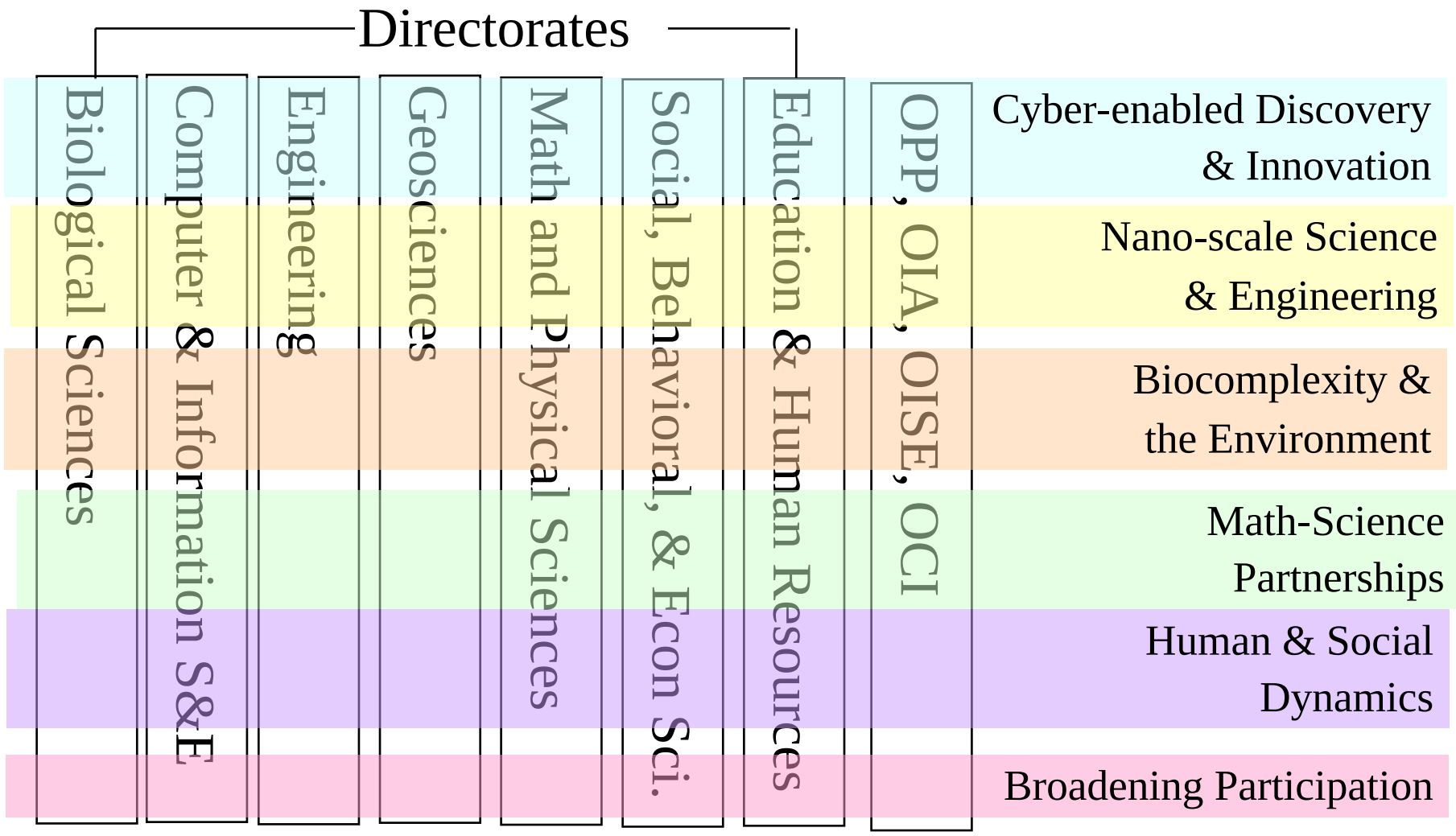
MPS as Investment Broker

- Makes decisions on what is in a piece of the investment portfolio
- Takes into account the context in which that piece sits
- Helps generate opportunities for investment
- Helps community explore opportunities

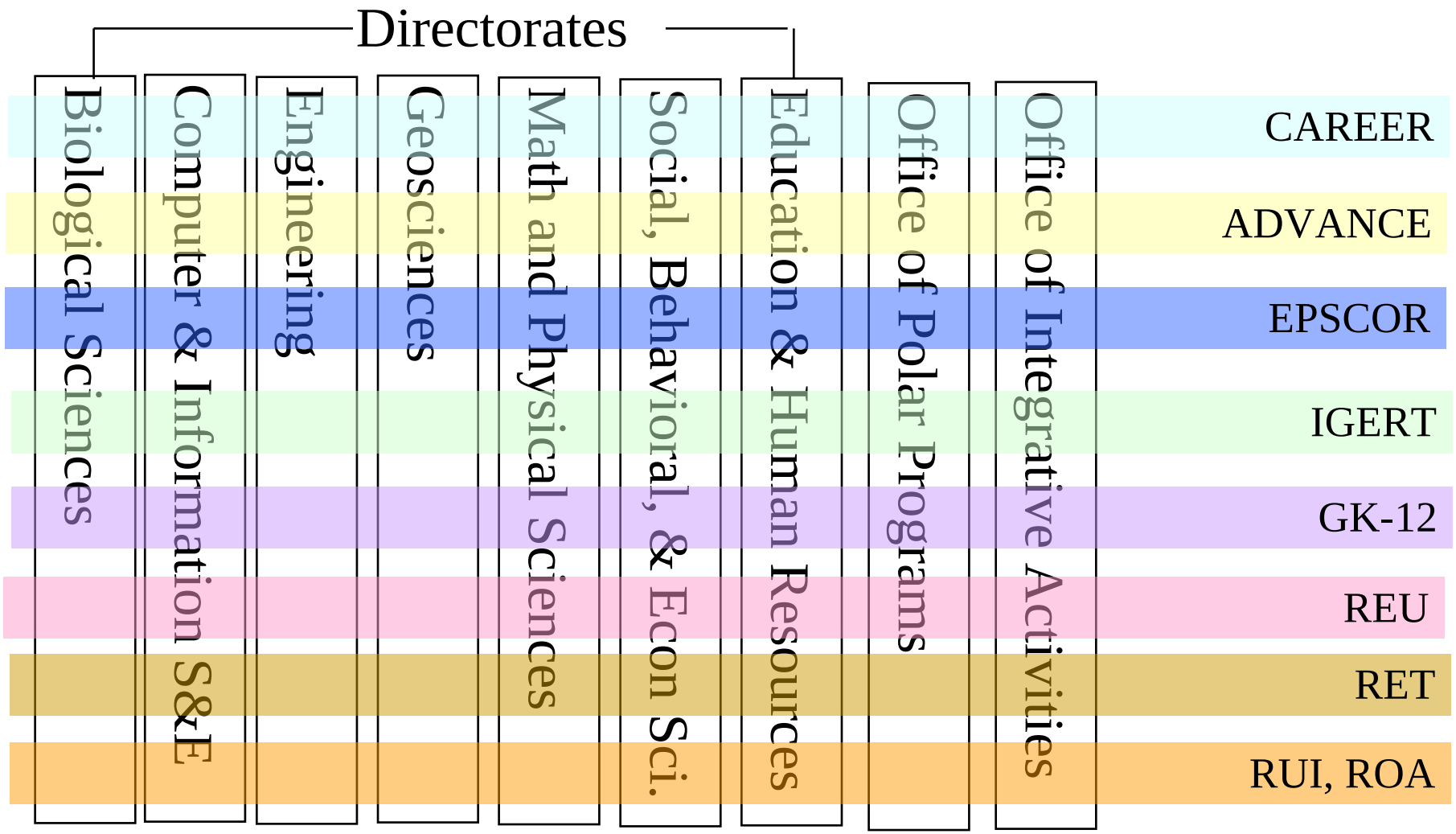
The Partnering Strategy

- Among
  - » People
  - » Disciplines
  - » Institutions
  - » Institution types
  - » Sectors
  - » Nations
- Building synergy for research and education

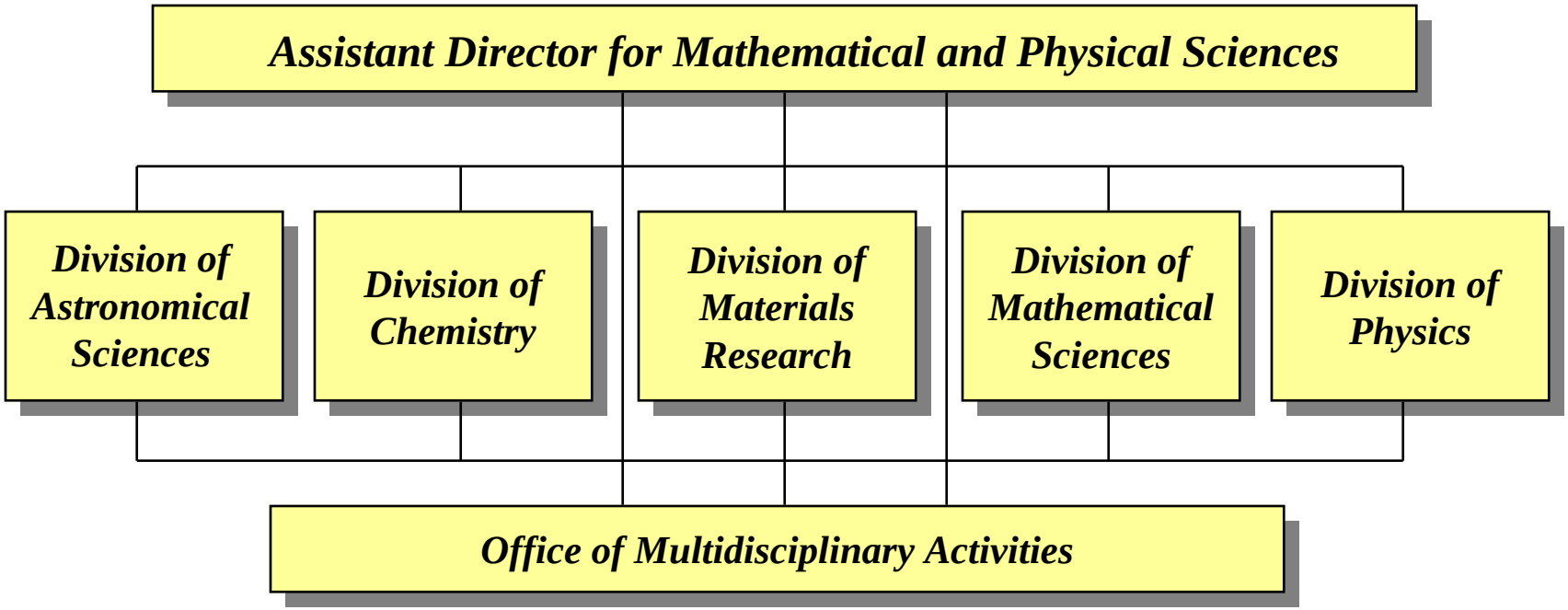
NSF-wide programs



NSF-wide programs +



Directorate for Mathematical and Physical Sciences



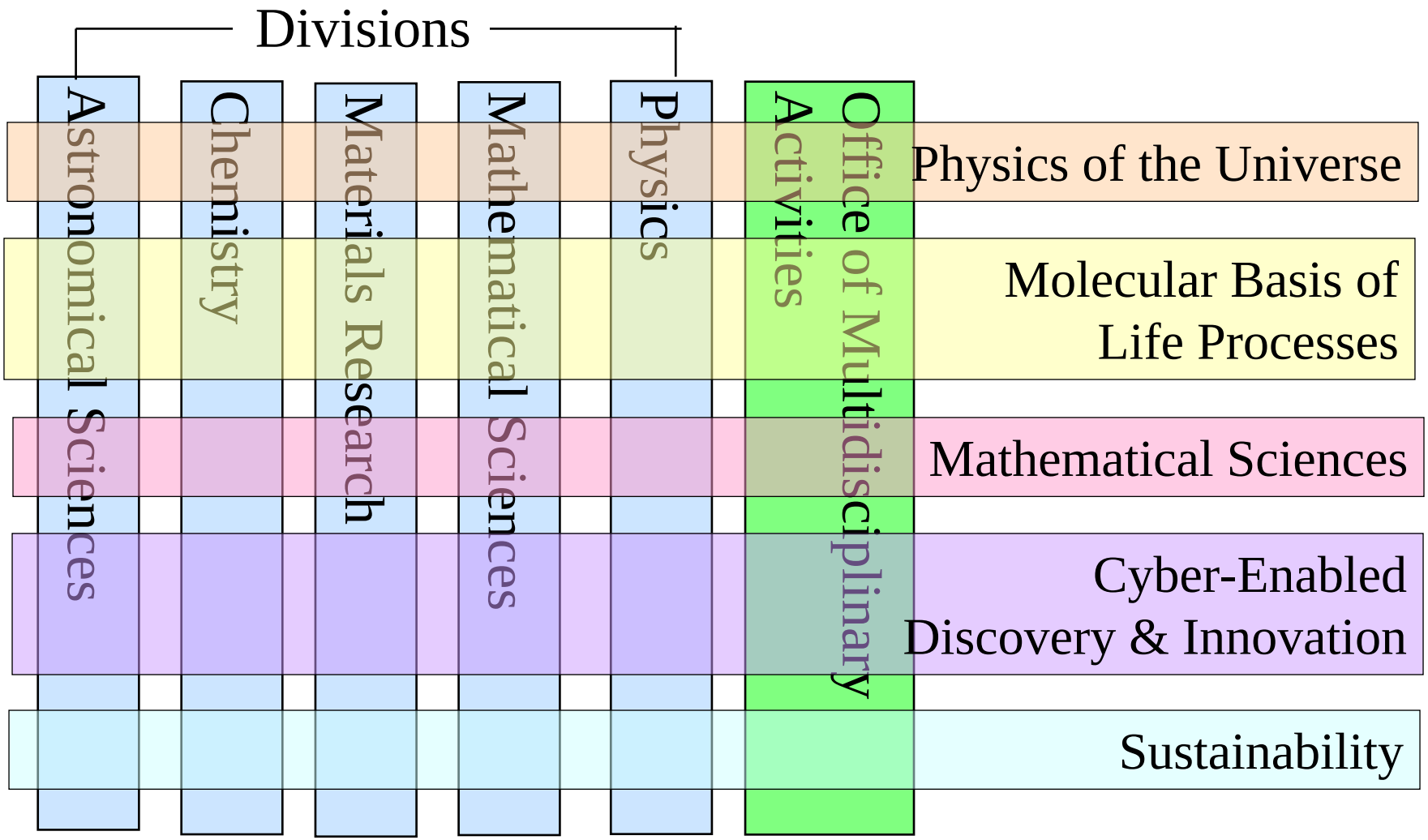
MPS Mission Statement

- To make discoveries about the Universe and the laws that govern it; to create new knowledge, materials, and instruments which promote progress across science and engineering; to prepare the next generation of scientists through research, and to share the excitement of exploring the unknown with the nation.

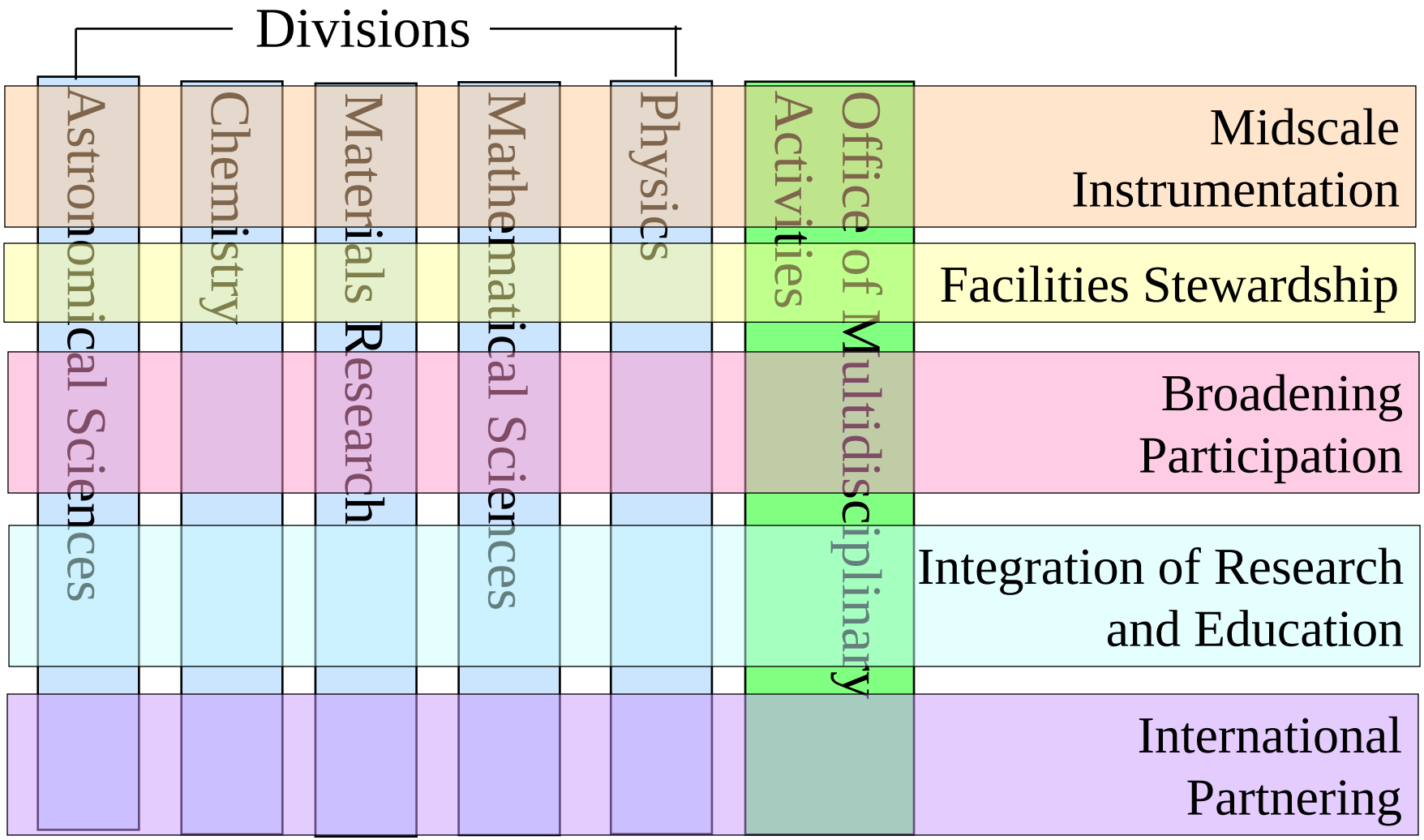
Scientific Themes

- 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 Crosscutting Activities



MPS Crosscutting Activities



Other Goal-Related Considerations

- Customer Service
  - » Time to prepare proposals; time to decision
- Risk, innovation
- Diversity
  - » Gender, racial and ethnic, geographic
- New investigators
- Award size and duration
- Merit review process
- Construction and operation of facilities

MPS at a Glance

- Largest directorate
  - ~25% of R&RA, ~18% of proposals, FY08 budget $1184m
- Nearly half of NSF's large facilities
- Responsible for the three "core" university disciplines - Physics, Chemistry and Mathematics - as well as 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 …

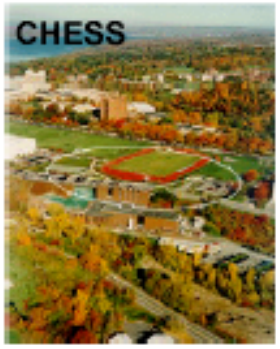
MPS Budgets by Division

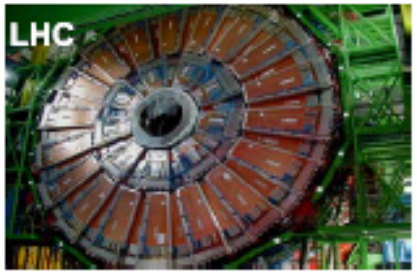
Mathematical and Physical Sciences Funding
(Dollars in Millions)

	FY 2004 Actual	FY 2005 Actual	FY 2006 Actual	FY 2007 Actual	FY 2008 Actual
Astronomical Sciences	$196.63	$195.11	$202.10	$215.39	$218.62
Chemistry	185.12	179.26	187.79	191.22	201.42
Materials Research	250.65	240.09	252.04	257.27	271.01
Mathematical Sciences	200.35	200.24	197.35	205.74	209.26
Physics	227.77	224.86	234.31	248.47	252.28
Multidisciplinary Activities	31.07	29.80	29.53	32.64	31.36
Total, MPS	$1,091.59	$1,069.36	$1,103.12	$1,150.73	$1,183.95

World Class Major Facilities

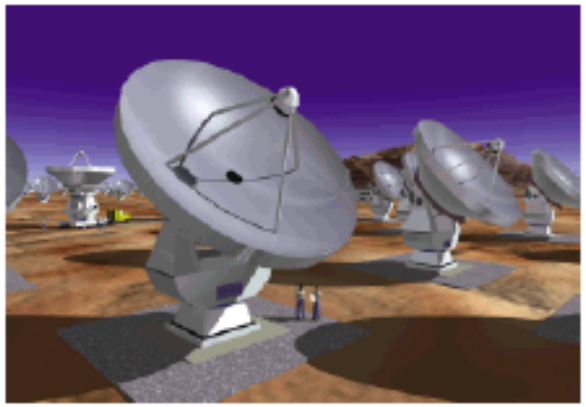
Keep University Researchers at the Frontier

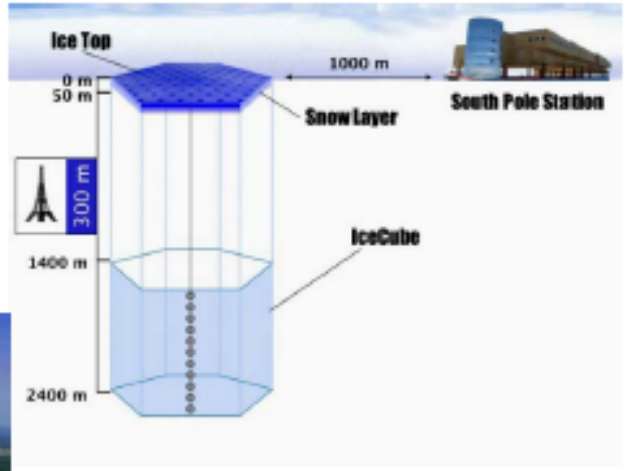




Under Construction/Approved

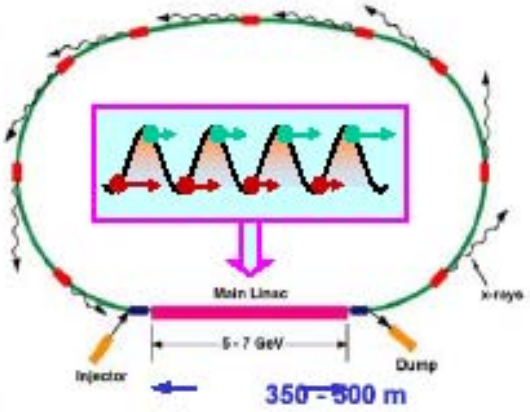
- **ALMA**
  - 50%/50% partnership with Europe
  - Start 2003; end 2011; $276M construction
- **ICECUBE (w/OPP)**
  - Start 2004; end 2010; $250M construction
  - Significant international contributions
- **Advanced LIGO**
  - Slated for 2008 start
  - Significant international contributions

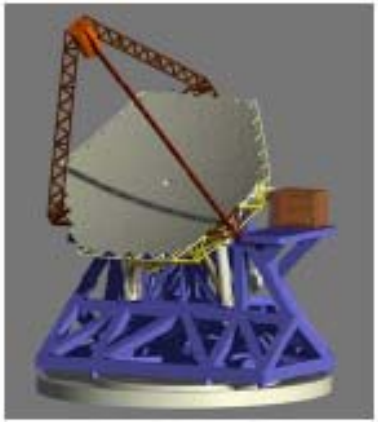




Bold Dreams: Horizon to 2020

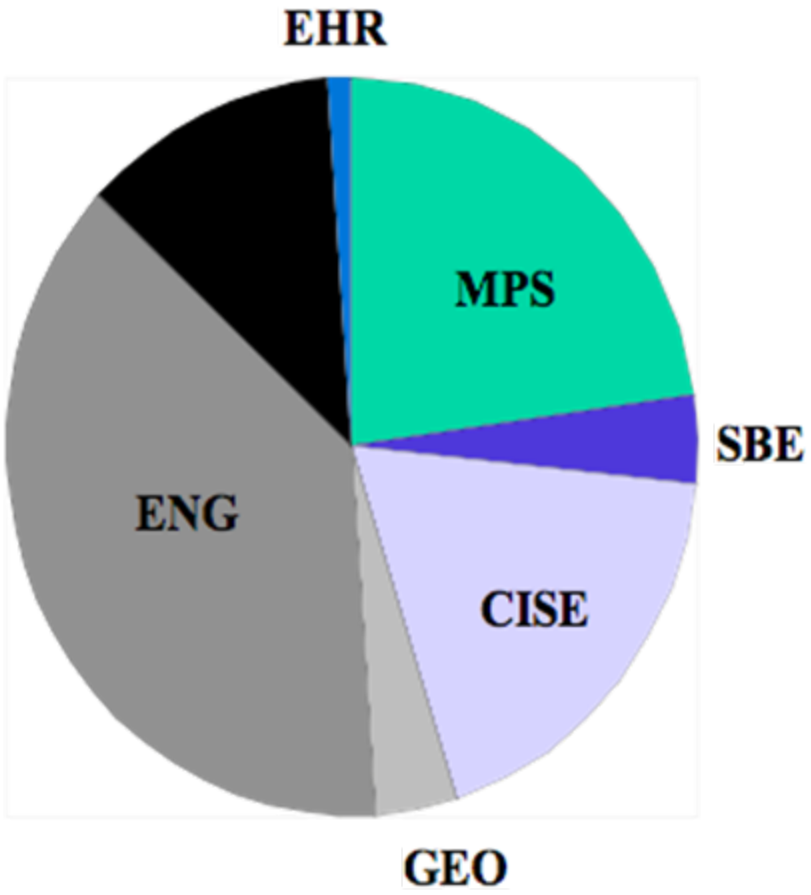
- Advanced Technology Solar Telescope (ATST)
- Deep Underground Science and Engineering Laboratory (DUSEL)
- Energy Recovery LINAC (ERL)
- Giant Segmented Mirror Telescope (GSMT)
- Large Synoptic Survey Telescope (LSST)
- Extended VLA (EVLA)
- Square Kilometer Array (SKA)





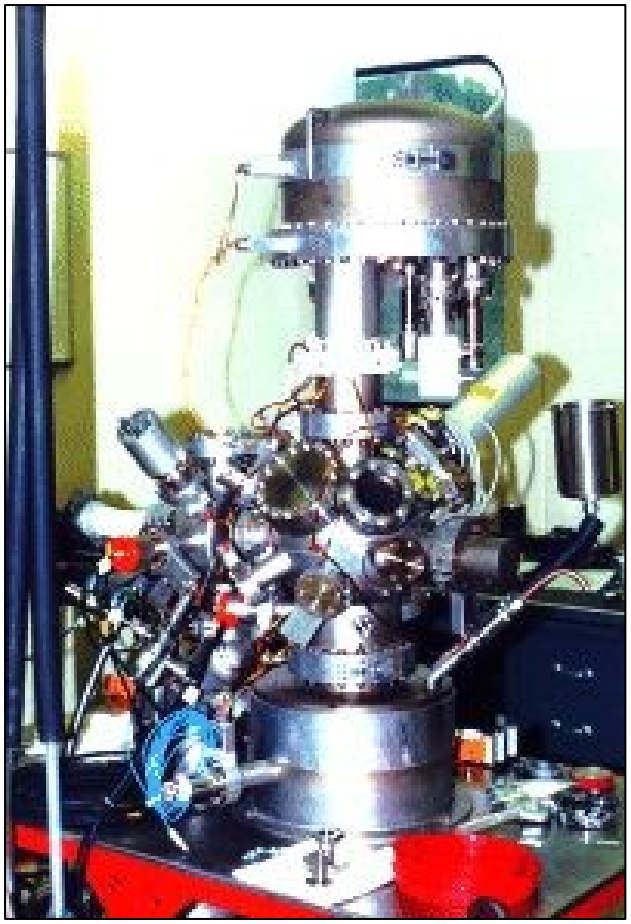
CAREER Program

- **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)**



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**
  - **NSTC “Physics of the Universe” set a coordinated federal strategy**
  - **Joint advisory mechanism: AAAC, CAA, NRC “decadal” surveys”**

Now some examples from each of the MPS Divisions.

Note that these are not exhaustive, comprehensive lists, but a selection of ideas, topics, areas of emphasis, facilities, and so on, to give you some idea of the flavor of MPS support.

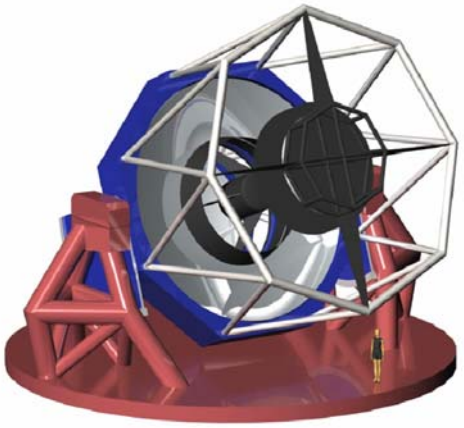
AST Centers and Facilities

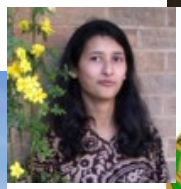
- **Optical/IR Facilities**
  - **Gemini Observatories**
  - **National Optical Astronomy Observatory**
  - **National Solar Observatory**
- **Radio Facilities**
  - **National Radio Astronomy Observatory**
    - Very Large Array, New Mexico
    - Robert C. Byrd Green Bank Telescope, West Virginia
    - Very Long Baseline Array (U.S. & Possessions)
    - Atacama Large Millimeter Array (Chile)
  - **National Astronomy and Ionosphere Center**
    - Arecibo Radio Telescope, Puerto Rico

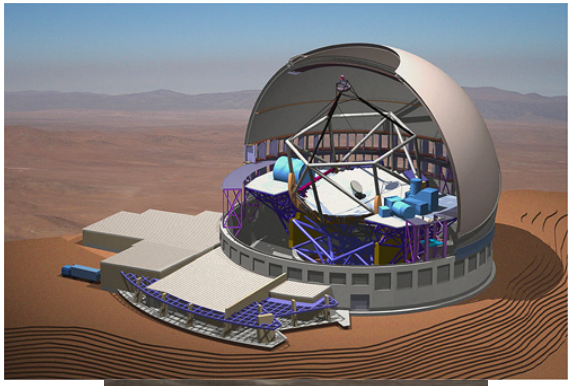
AST: world class capabilities

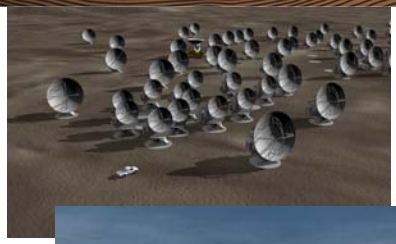
Gemini 8-meter Telescopes

Robert C. Byrd Green Bank Telescope

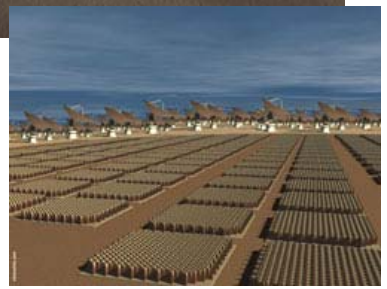








Meeting the challenges requires a global effort, developing the best minds, giving them the best tools, and supporting their research.



Division of Chemistry (CHE)

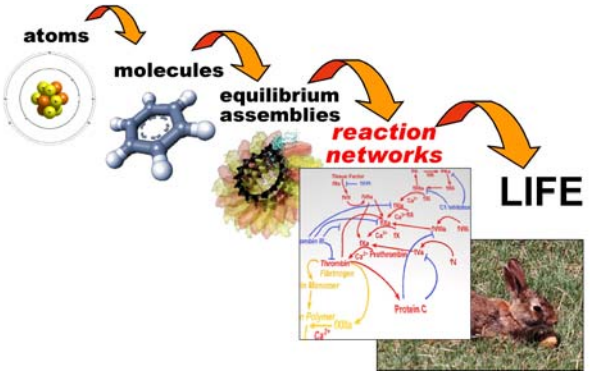
Creating molecules and instruments that are transforming the 21st century

- **Mission:**
  - **To support innovative research in chemical sciences, integrated with education, through strategic investment in a globally engaged workforce reflecting the diversity of America**
- **Topic areas**
  - **Inorganic, bioinorganic, and organometallic chemistry**
  - **Organic and macromolecular chemistry**
  - **Physical chemistry**
  - **Analytical and surface chemistry**
  - **Integrative chemistry activities**

Division of Chemistry (CHE)

- **Critical areas**
  - **Energy: Which multiple electron processes will store and deliver more energy than gasoline? Which light driven reactions will make solar energy a major contributor to the renewable energy mix?**
  - **Element and molecule recycling: Can metalloenzymes present in organisms be modeled to produce catalysts to recycle organic material in an energy efficient manner?**
  - **Designed emergent behavior: Can we construct complex chemical assemblies like molecules and nanoparticles by design? Chemical synthesis from molecules to life?**
  - **Imaging the Ultrasmall: Can we further develop Ultrafast Electron Diffraction, Probeless Laser-based Spectroscopy, Mass Spectrometry Imaging, Radiationless Magnetic Resonance, etc., etc.**
- **Centers for Chemical Innovation**
  - **Enhancing the US competitive edge by narrowing the innovation gap**
  - **Agile, virtual centers of excellence promoting high risk/high gain transformative research, connections with industry, and the active and creative engagement of the public**

Division of Chemistry (CHE)



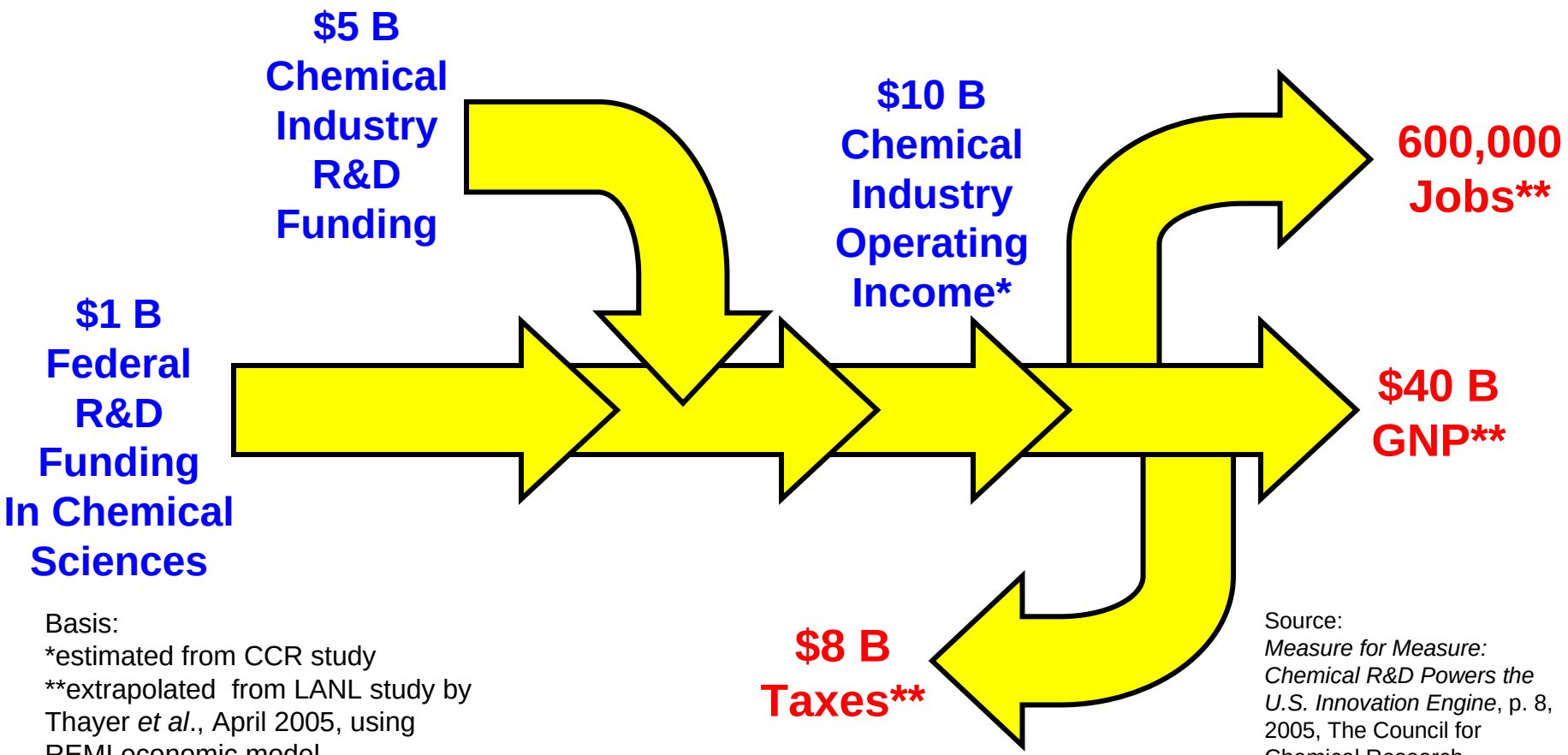
Molecular Basis of Life Processes (MBLP) –MPS Emphasis Area Coordination by CHE

- **First formation of biologically relevant molecules, and organization into self-replicating cells**
- **Emergence of life processes from reaction networks**
- **Collective organizing principles at the mesoscopic scale**
- **Basis of memory and learning**
- **TMS for predictive understanding of the living world**
- **New and enhanced molecular-level measurement tools**
- **Harnessing of biological machinery for new functions**

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)

- **From a fundamental understanding of materials and condensed matter to projects which are only a few years from commercial exploitation**
- **What is materials research?**
  - **Chemistry, physics, and engineering**
  - **Ceramics, condensed matter physics, electronic materials, metals, polymers, solid state chemistry, biomaterials**
- **Key areas**
  - **Environmental, energy, and economic sustainability**
  - **Matter by design**
  - **The quantum realm**
  - **Physical-chemical-biological interfaces**

DMR Centers and Institutes

- Science and Technology Centers
- Nanoscale Science and Engineering Centers
- Materials Research Science and Engineering Centers (MRSECs)
- International Materials Institutes
- Partnerships for Research and Education in Materials

Class of 2008 MRSECs

Institution	PI	Topics
Brandeis University	Meyer	Physics and Chemistry of Biomaterials in Confined Geometries
U Chicago	Nagel	Soft and hard condensed matter physics
Colorado School of Mines	Taylor	Renewable energy: photovoltaics and full cell membrane
U Colorado Boulder	Clark	Soft materials: liquid crystals
Georgia Tech	Hess	Graphene - new electronic materials
Harvard University	Weitz	Biomaterials; soft materials; microfluidics
U Minnesota/Twin Cities	Lodge	Polymers; electronic and magnetic materials; nanoparticles
MIT	Rubner	Polymer; battery materials; optical fiber materials
U Nebraska - Lincoln	Tsymbal	Quantum and spin phenomena in nanomagnetic structures
New York University	Ward	Colloidal assemblies – geometry and chemistry
Ohio State Univ	Padture	Spintronic and multiferroic materials
Penn State University	Mallouk	Nanomotors;multiferroics; condensed matter physics; photonics
Princeton University	Register	Polymers; electronics and photonics; condensed matter physics
U Mass - Amherst	Russell	Polymers; nanomaterials

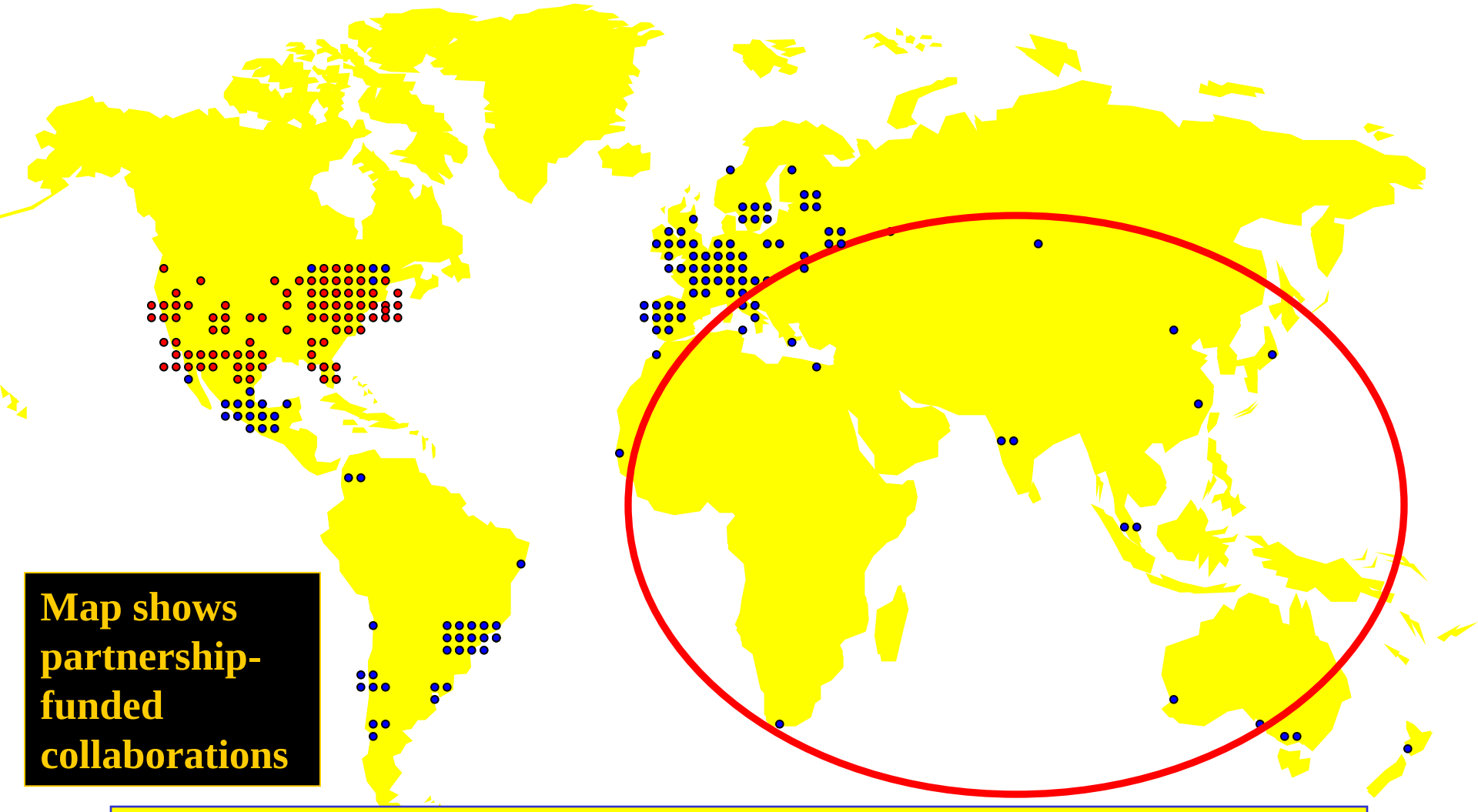
New MRSECs in red

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**

The Materials World Network - 2007

Since 2001 ~950 NSF proposals, 182 awards, $67M



Map shows partnership-funded collaborations

The International Materials Institutes are developing collaborations within Asia and Africa…

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. Math. IS everywhere

Division of Mathematical Sciences (DMS)

- **Temperature of Mathematical Sciences?**
  - *Hot! Hot! Hot!*
- **Collaboration across enormous intellectual scales (internal and external)**
  - ***PDE/Topology; Topology/Data; Data/Harmonic Analysis; Harmonic Analysis /Number Theory; Number Theory/PDE***
  - ***Bio/Med/Life Sciences; Geo/Climate/Water; Statistics Everywhere; Large Data/Defense/National Security***
  - ***Randomness, computation, dynamics, shape, number***

Mathematical Sciences Research Institutes

New call: NSF 08-565, February 27, 2009 (large-scale group efforts)

Mathematical Sciences Research Institute (MSRI) – Berkeley, CA

Institute for Mathematics and Its Applications (IMA) – U of Minnesota

Institute for Pure and Applied Mathematics (IPAM) – UCLA

Statistical and Applied Mathematical Sciences Institute (SAMSI) – Duke U, NC State U, U North Carolina, NISS

Mathematical Biosciences Institute (MBI) – Ohio State U

Partial support provided for:

American Institute of Mathematics (AIM)

Institute for Advanced Study (IAS)

Enhancing the Mathematical Sciences Workforce in the 21st Century

EMSW21 has three components for increasing the number of U.S. students trained for and pursuing careers in the mathematical sciences:

- **VIGRE (departmentally-based); fading, go to**
- **Research Training Groups (RTG)**
- **Mentoring through Critical Transition Points (MCTP)**

Solicitation: NSF 05-595

Physics (PHY)

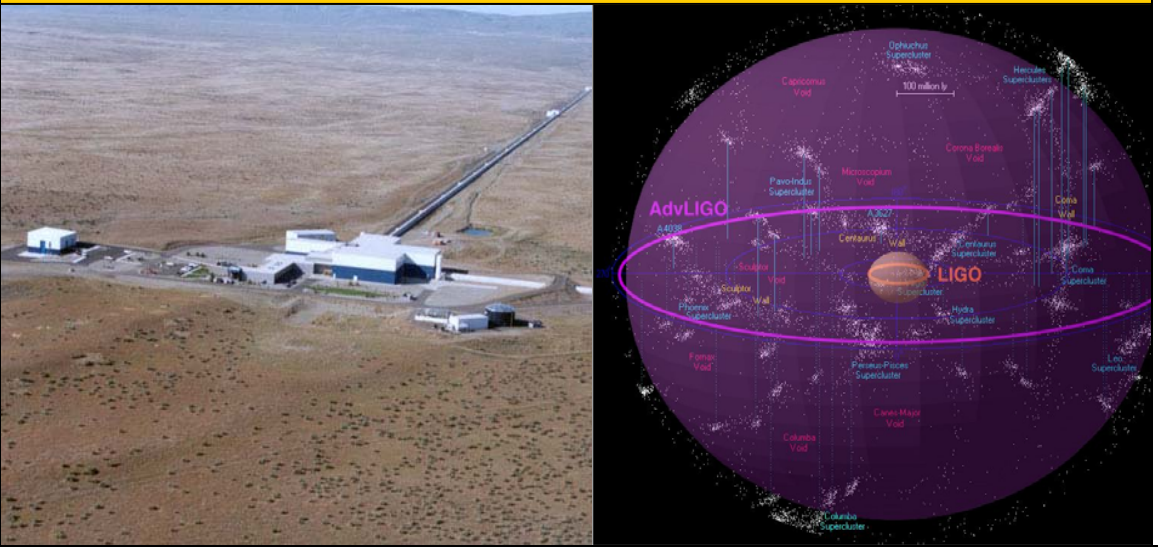
- From the discovery of new fundamental particles to understanding the biological cell and the cosmos
- Notable features
  - Physics of the Universe
  - Renaissance in Atomic, Molecular and Optical Physics (AMOP)
  - Joint NSF/DoE partnership in fundamental plasma physics
  - Biological physics
- Stewardship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

Physics Division Facilities

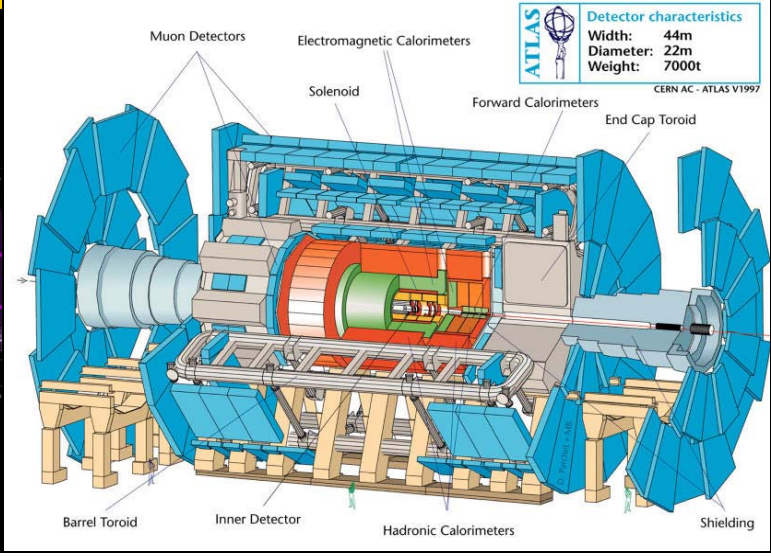
Major facilities ops
35% of budget

- LIGO (Caltech) gravity wave observatory
- NSCL (Michigan State) radioactive ion beams
- CESR e^+e^- Collider (Cornell) *phasing out*
- U.S. LHC [ATLAS, CMS] (CERN) *first beam seen*
- Others in construction or planning stages: IceCube, Adv.LIGO, ERL, DUSEL

Laser Interferometer Gravitational-wave Observatory



Large Hadron Collider ATLAS Detector



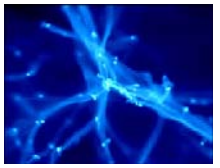
DUSEL

Deep **U**nderground **S**cience and **E**ngineering **L**aboratory

at Homestake, SD

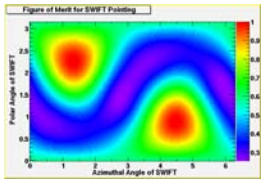
Physics Frontier Centers

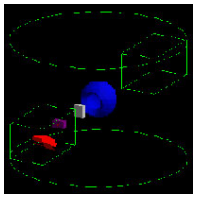
Kavli Center for Cosmological Physics – Chicago - Winstein



FOCUS: Frontiers in Optical Coherent and Ultrafast Science
Michigan/Texas - Bucksbaum

Center for Gravitational Wave Physics – Penn State – Finn





Center for the Study of the Origin and Structure of Matter
Hampton - Baker

Center for Theoretical Biological Physics – UCSD - Onuchic

Office of Multidisciplinary Activities (OMA)

- **Catalyze and support emerging, cross-cutting areas**
- **Enable and facilitate through:**
  - **Partnerships**
  - **Innovative models for education**
  - **Broadly enabling infrastructure**
  - **New research modalities**
  - **Integration of research and education**
- **Champions broadened participation throughout MPS**

- ***OMA neither receives nor reviews proposals***

Broadening participation

Perhaps the greatest threat to MPS science

The Face of American Science

Is Not the Face of America

EDGE – Enhancing Diversity in Graduate Education

Workshop on Excellence Empowered by a Diverse Academic Workforce: Achieving Racial & Ethnic Equity in Chemistry

We Need You!

- Reviewers and panelists
- Workshop participants and organizers
- Rotators

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 also "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