Overview of the Directorate for Mathematical and Physical Sciences

NSF Regional Grants Conference

Oklahoma City, OK

March 19-20, 2007

Dana E. Lehr

Associate 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 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 Organization

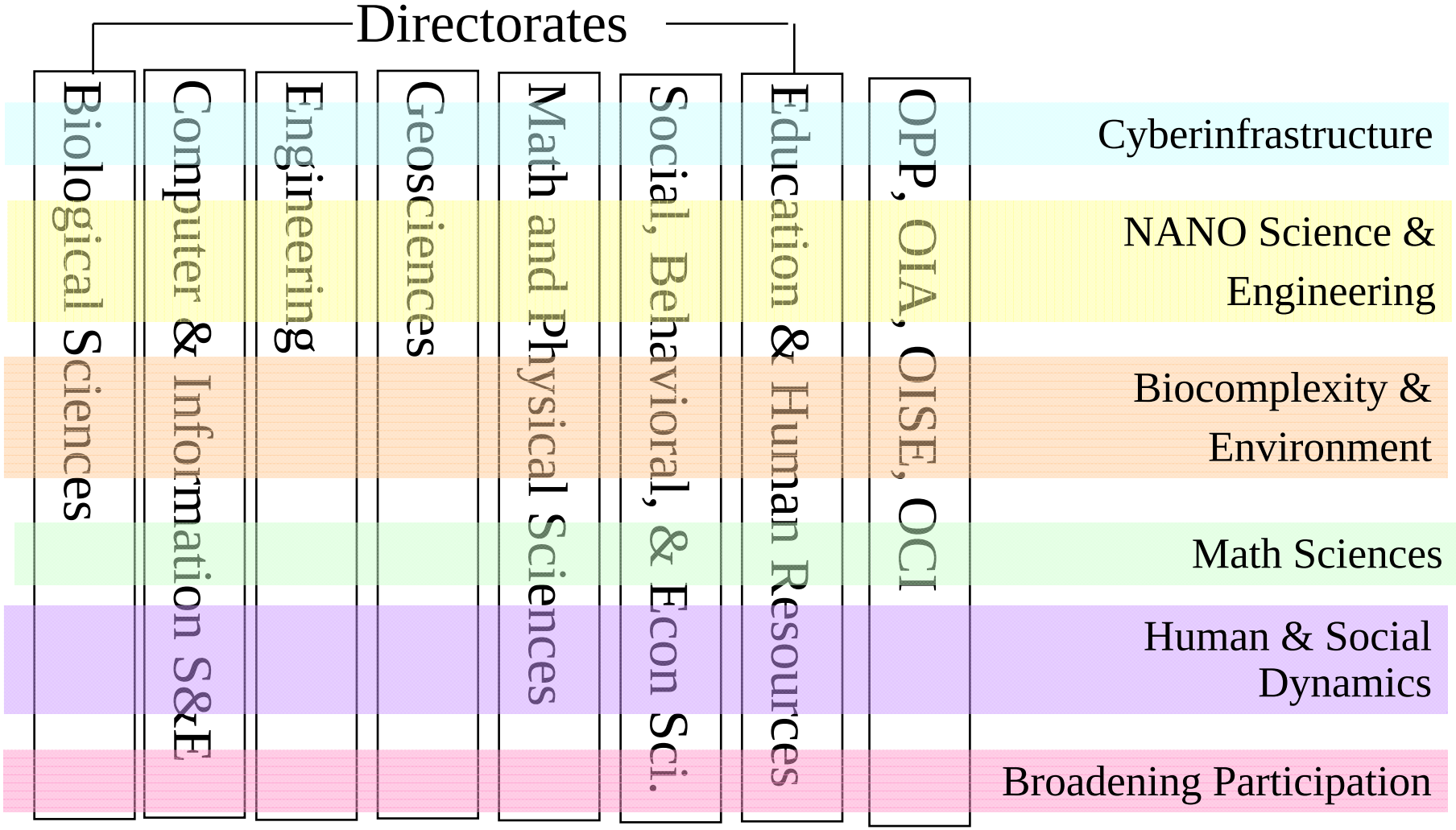
BFA, OIG, OGC, OIRM, OLPA, National Science Board

Office of the Director: Polar Programs, Integrative Activities, International,CyberInfrastructure

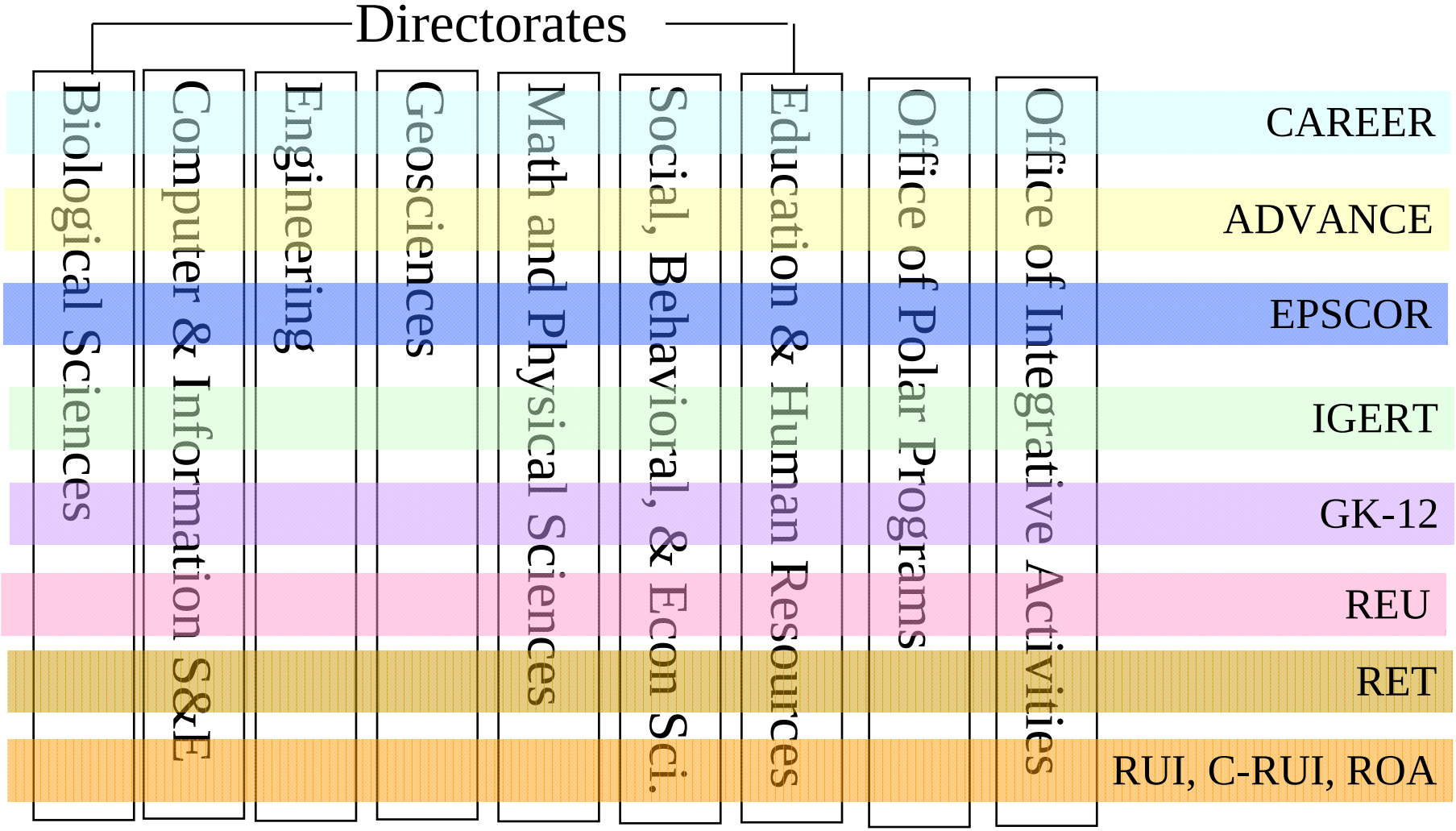
Directorates

- Education & Human Resources
- Social, Behavioral, & Econ Sci.
- Math and Physical Sciences
- Geosciences
- Engineering
- Computer & Information S&E
- Biological Sciences

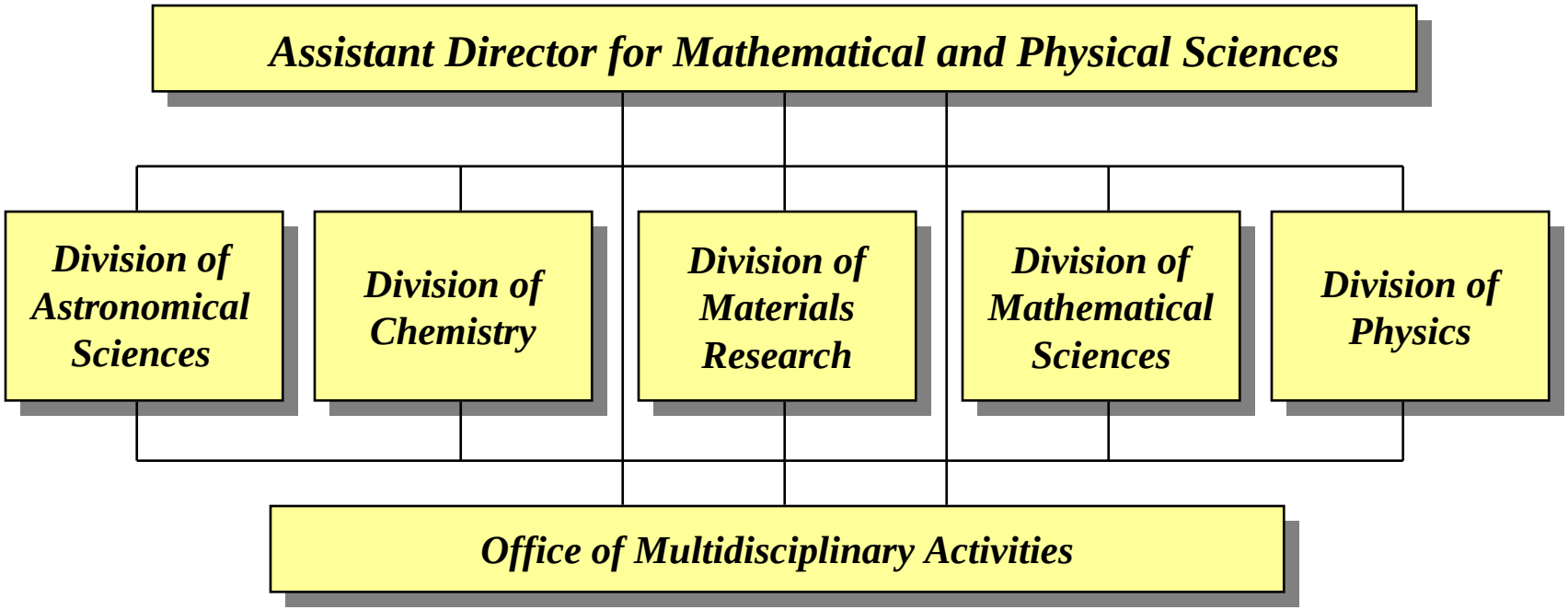
NSF Organization +



NSF Organization ++



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 Organization

BFA, OIRM, OIG, OLPA

Other Directorates

National Science Board

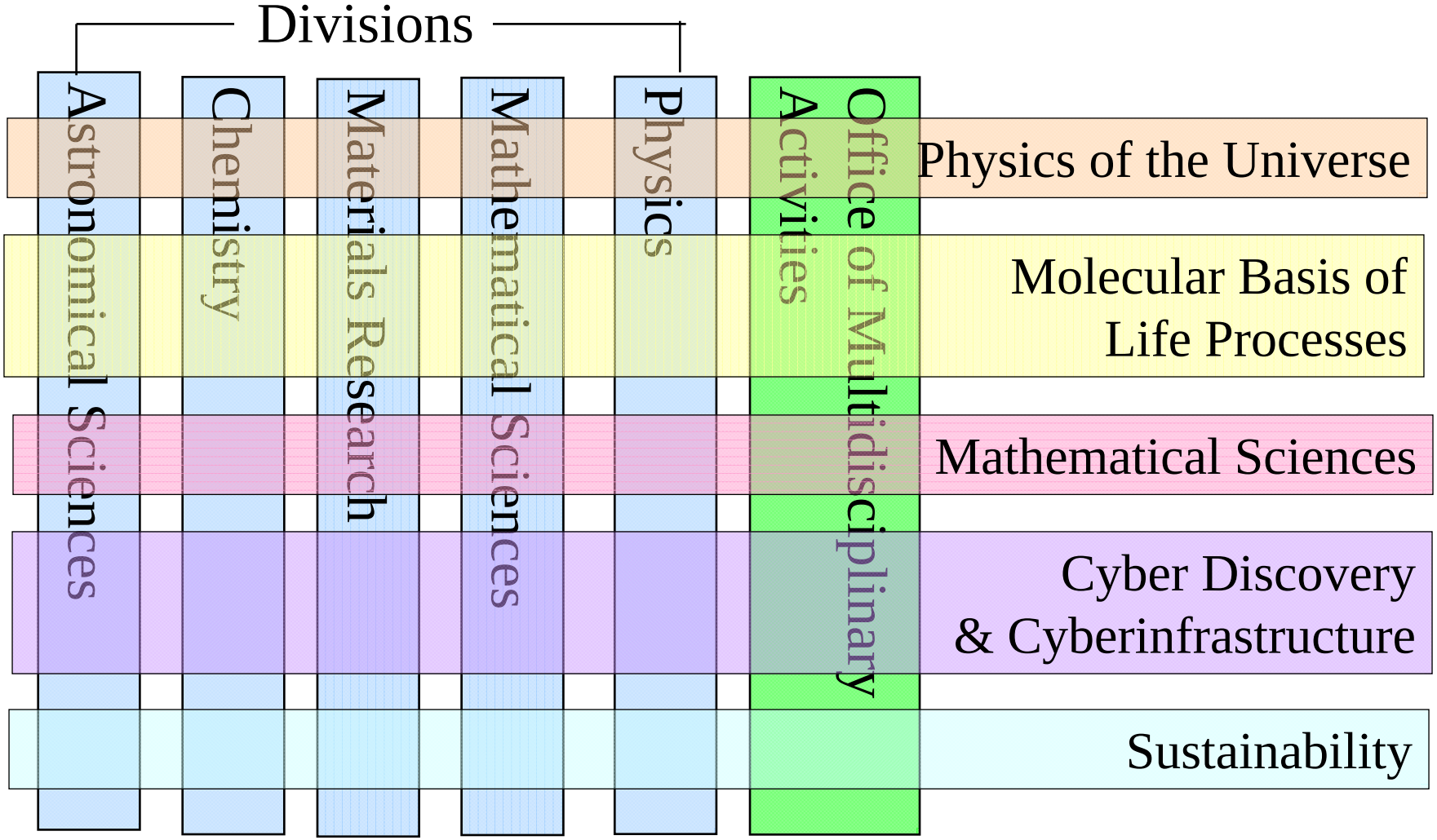
Office of the Assistant Director

Office of Multidisciplinary Activities

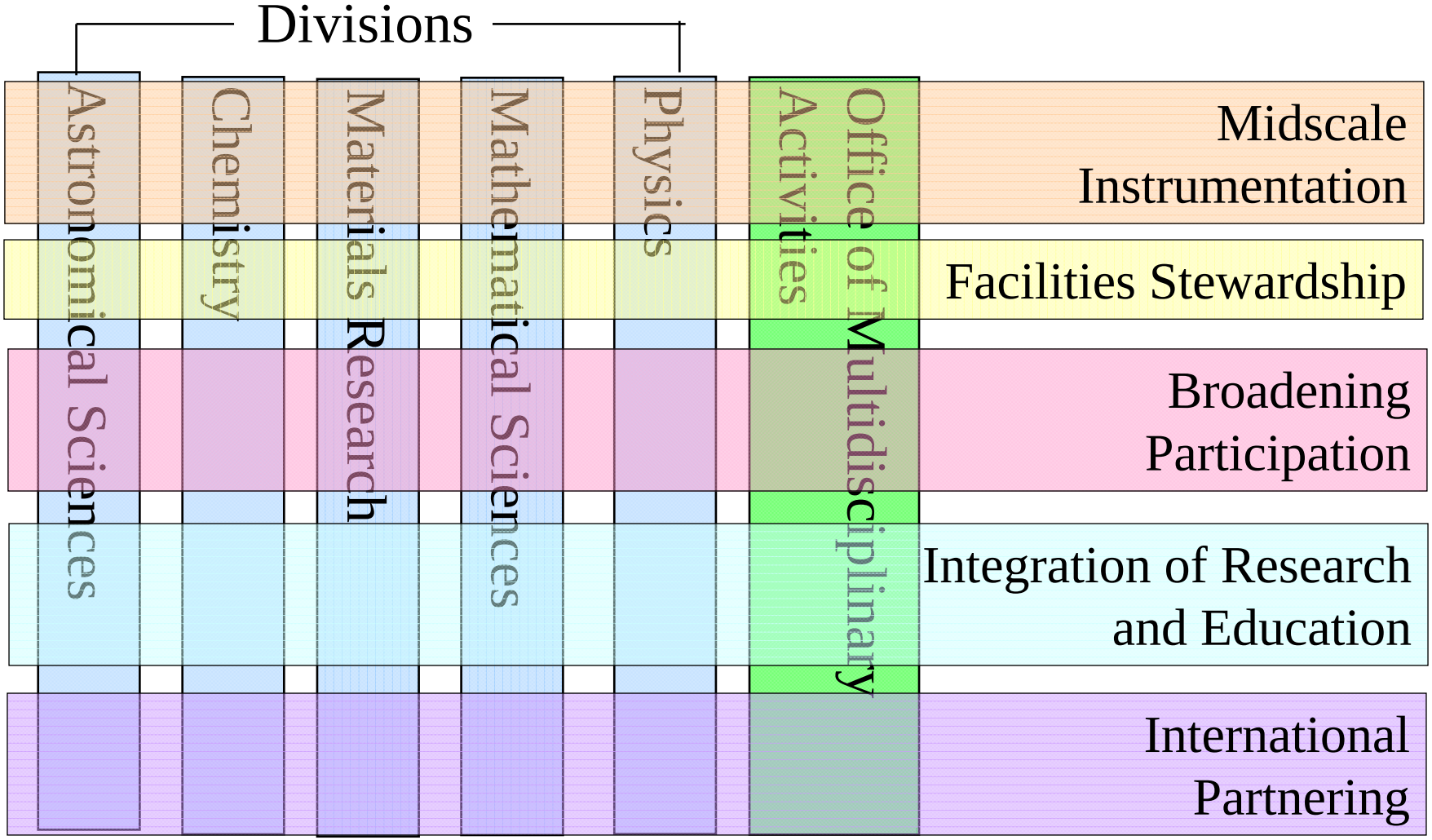
Divisions

- Physics
- Mathematical Sciences
- Materials Research
- Chemistry
- Astronomical Sciences

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, 20% of research proposals, FY06 Request: $1086M
- **Nearly half of NSF's Large Facilities**
- **Responsible for the three Core University Disciplines: Chemistry, Math, and Physics … as well as Astronomy and Materials**
- **Science scope**
  - Space: "From Quarks to the Cosmos"
  - Time: "From the Incredibly Short to Unimaginably Long"
  - Character: "From the Very Abstract to Almost Ready for the Marketplace"
- **Provides 40% of university federal funding in physical sciences**
  - More than 80% in Math and growing
  - Federal steward for ground-based astronomy

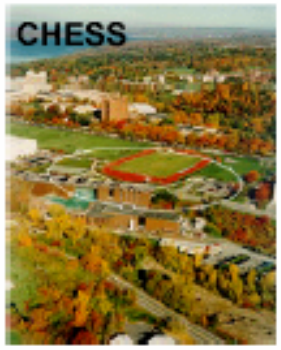
MPS Budgets by Division
FY 2006 & FY 2007

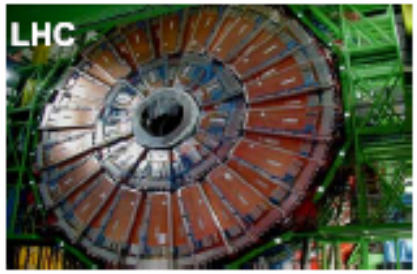
(Dollars in Millions)

	FY 2004 Actuals	FY 2005 Actuals	Change from 04 to 05	FY 2006 Current Plan	Change from 05 to 06	FY 2007 Request	Change from 06 to 07
AST	196.63	195.11	-0.8%	199.65	2.3%	215.11	7.7%
CHE	185.12	179.26	-3.2%	180.78	0.8%	191.10	5.7%
DMR	250.65	240.09	-4.2%	242.91	1.2%	257.45	6.0%
DMS	200.35	200.24	-0.1%	199.30	-0.5%	205.74	3.2%
PHY	227.77	224.86	-1.3%	233.13	3.7%	248.50	6.6%
OMA	31.07	29.80	-4.1%	29.68	-0.4%	32.40	9.2%
Total, MPS	1,091.59	1,069.36	-2.0%	1085.45	1.5%	1150.30	6.0%
R&RA	4293.34	4234.82	-1.4%	4,331.48	2.3%	4,665.95	7.7%
NSF	5652.01	5480.78	-3.0%	5,581.17	1.8%	6,020.21	7.9%

World Class Major Facilities

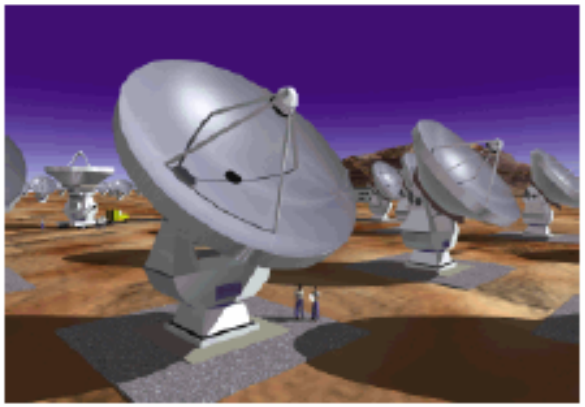
Keep University Researchers at the Frontier

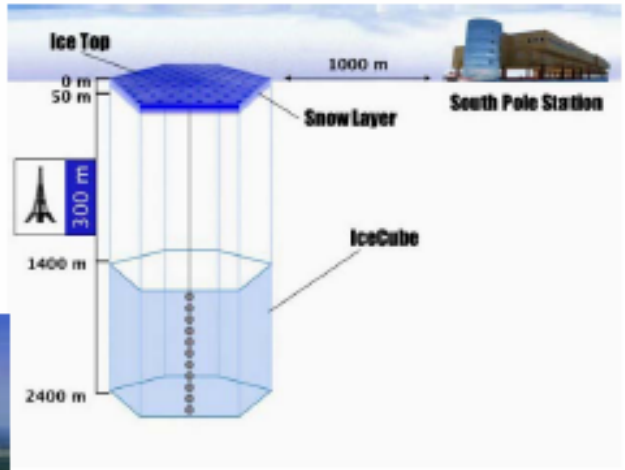




Under Construction/Approved

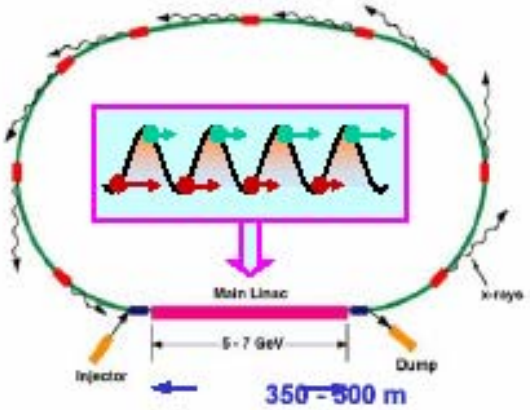
- **ALMA**
  - 50%/50% partnership with Europe
  - Start 2003; end 2011; $276M construction
- **ICECUBE (w/OPP)**
  - Start 2004; end 2010; $250M construction
  - Significant international contributions
- **Advanced LIGO**
  - Slated for 2008 start
  - Significant international contributions

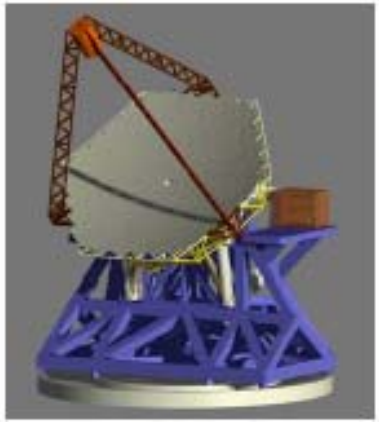




Bold Dreams: Horizon to 2020

- 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)





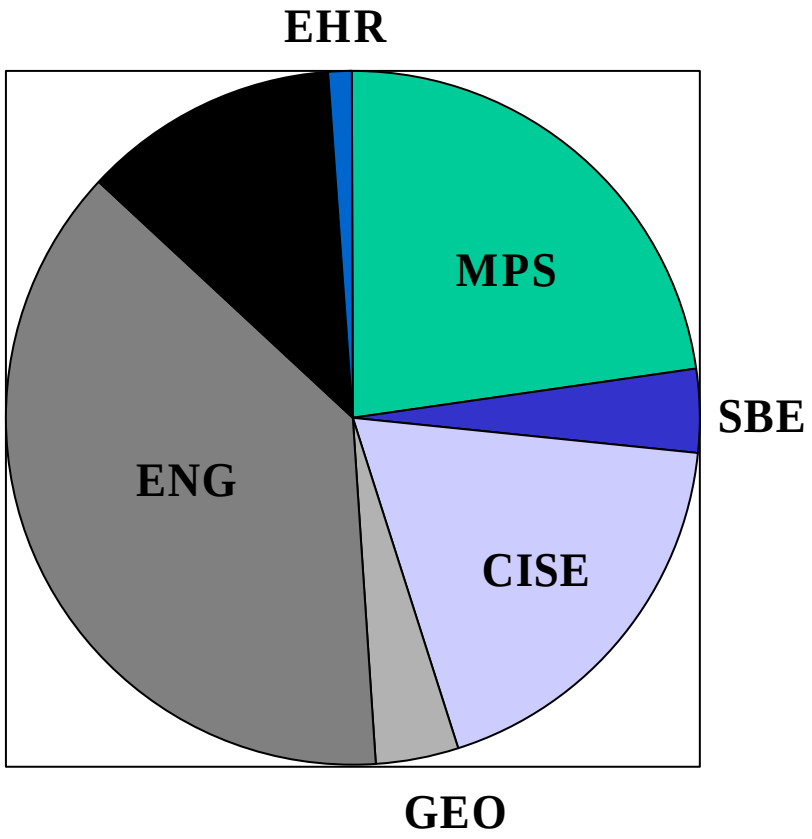
Number of People Involved in MPS Activities

	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate
Senior Researchers	6,631	6,294	7,332
Other Professionals	2,053	1,350	2,484
Post-Doctorates	2,147	1,968	1,947
Graduate Students	7,195	6,831	6,572
Undergraduate Students	2,351	2,178	2,127
K - 12 Students	310	320	320
K - 12 Teachers	449	600	650
Total Number of People	21,136	19,451	21,432

MPS spends at least $300 million annually on Graduate and Postdoctoral training!

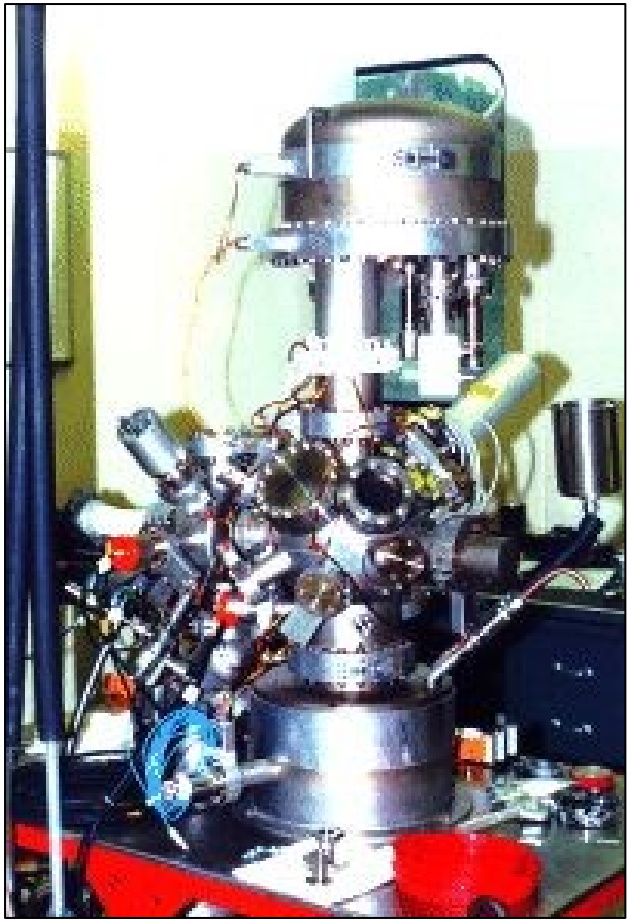
CAREER Program

- **Offers NSF's most prestigious awards for new junior faculty.**
- **Awardees selected on basis of their plans to develop highly integrative and effective research and education careers within the context of the mission of their institution.**
- **Increased participation of those traditionally underrepresented in science and engineering will be encouraged.**



Instrumentation

- **Research grants**
- **Divisional instrumentation programs**
- **Major Research Instrumentation (MRI)**



Astronomical Sciences (AST)

The Science and Its National Context

- **From the Big Bang to DNA**
  - Origin and evolution of the universe and the Challenges of "Physics of the Universe"
  - Origin and Evolution of Galaxies
  - Origin and Evolution of Planetary and Stellar Systems

- **National Astronomy Portfolio**
  - Three agencies – NSF, NASA, DOE
  - Strong private interests and history of funding
  - NSF assigned federal stewardship of ground-based astronomy
    - National facilities: NOAO, NSO, NRAO, NAIC, Gemini
    - Mission-free, unrestricted individual grants
  - NSTC Report "Physics of the Universe" sets a coordinated Federal strategy
  - Joint agency advisory committees – AAAC and CAA

AST Program Organization – FY2005

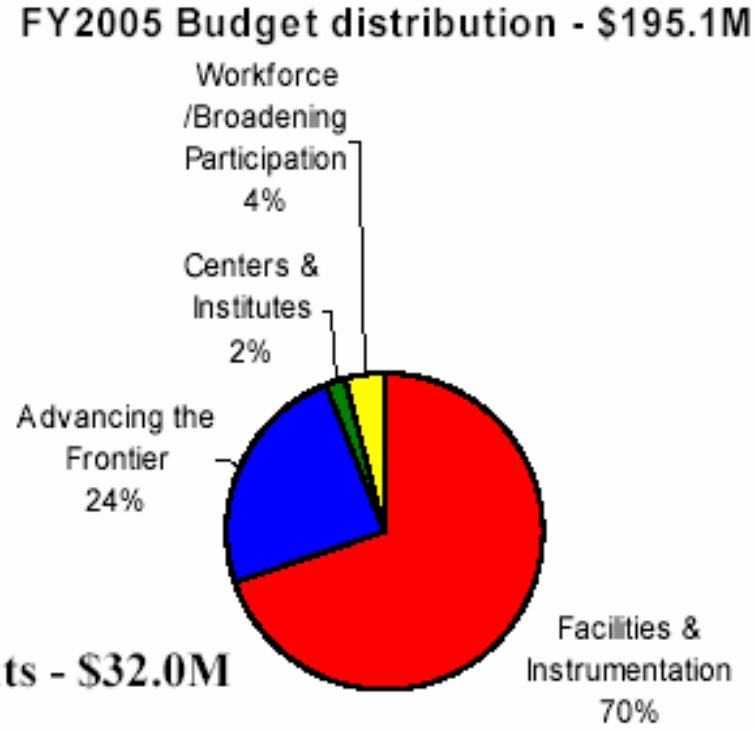
Facilities - $118.9 M

- Gemini - $15.48M (U.S. Share)
- NOAO/NSO - $34.7M
- NAIC - $10.5M
- NRAO - $47.0M
- University Radio Observatories - $11.0M
- Electromagnetic spectrum management

Grants - $76.2 M

- Astronomy & Astrophysics research grants - $32.0M
- Education & Special Programs - $6.8M
- Instrumentation - $18.4M
- Priority areas and programs outside AST (CI, POU, MSPA, etc) - $19.0M

MREFC – ALMA; D&D for ATST, LSST, GSMT, …



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

World Class Capabilities

Gemini 8-meter Telescopes

Robert C. Byrd Green Bank Telescope

CHEMISTRY (CHE)

Creating molecules and instruments that are transforming the 21st century

Molecular basis of life processes

- Learning and memory
- Chemical reaction networks and emergent behaviour

Sustainability

- Next-generation energy sources
- Green chemistry for manufacturing
- Environmental molecular science

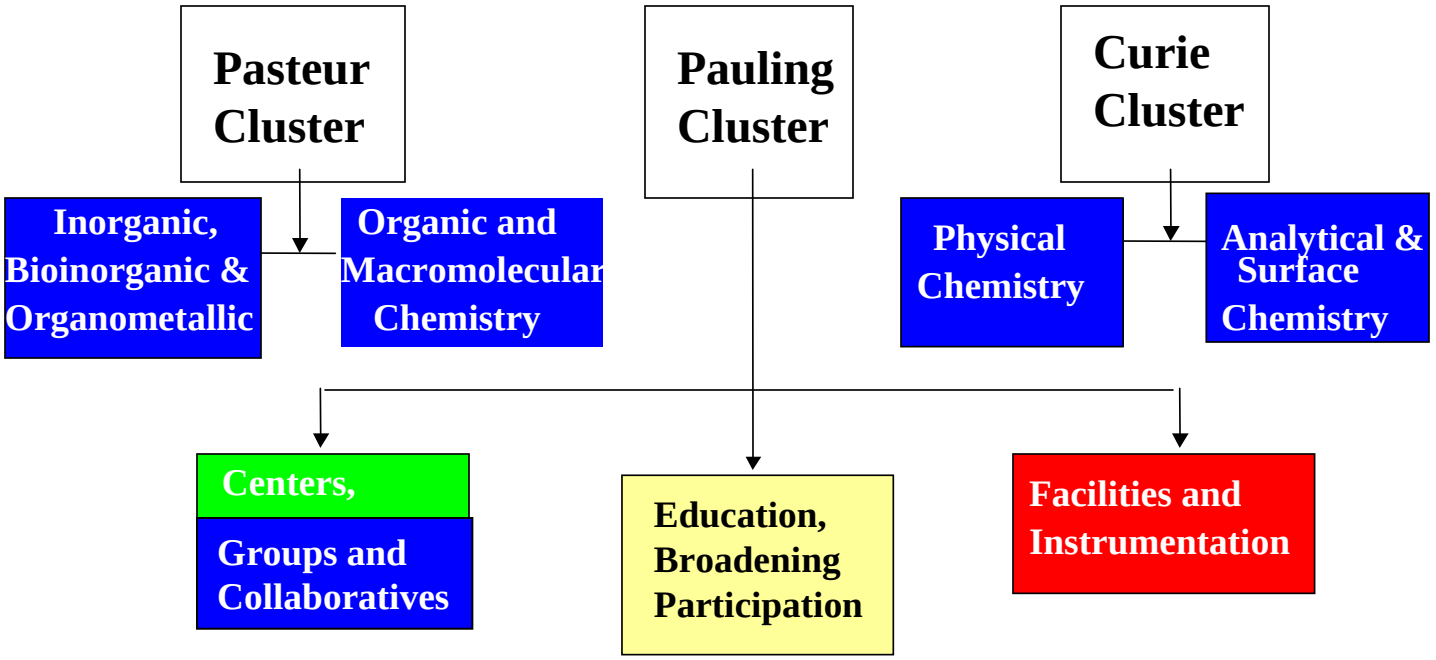
•CHE funds ~20% of university research

•NSF funds (CHE, BIO, GEO, DMR) fund ~40%

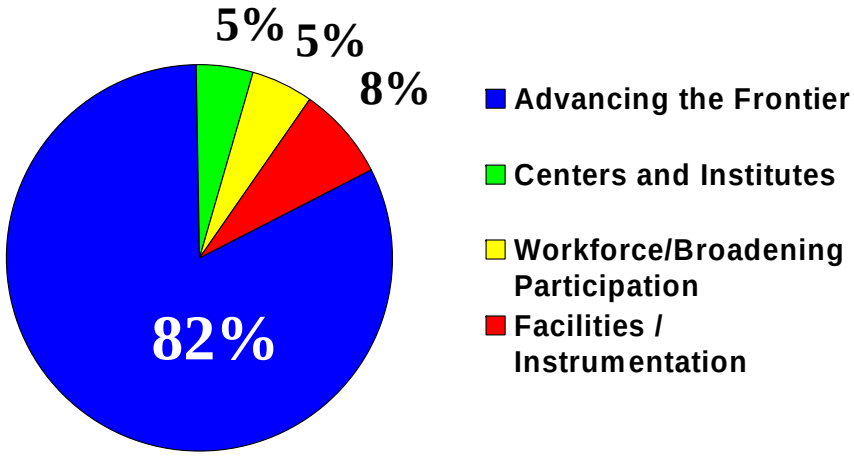
Tools for discovery and innovation

- Multi-scale chemical imaging and modeling
- Nanoscience
- Cyber-enabled chemistry

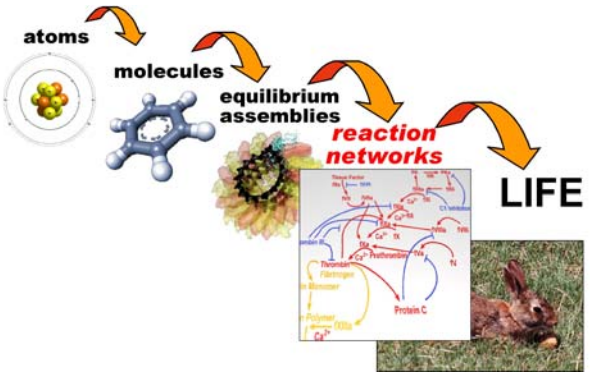
CHE Organization



FY06 Budget
$180M



CHE/MPS Emerging Science Themes



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

Examples of science drivers:

- **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**

Continuing CHE Initiatives: Broadening Participation

• Undergraduate Research Centers (URCs)

Research for 1st and 2nd year college students

– FY04 - 20 planning grants, 1 full award (Purdue)
– FY05 - 2 full awards (Ohio State, U. South Dakota)

SERVE, D. Casadonte

• National Online Poster Session for Undergraduate Research

– Pilot in summer, 2004; full-scale in summer, 2005
– Led by G. Peaslee and N. Levinger,
REU Leadership Group

• Discovery Corps Fellows

Service-oriented projects leveraging research expertise

– **Postdoctoral Fellowships:**
2-year award; within two years of the PhD
– **Senior Fellowships:**
1-year award; at least 10 years after PhD/postdoctoral training

G. Bothun, CERSP

Materials Research

Creating the materials that will transform the 21st century

The basic research which will provide the foundation for national prosperity

New tools make this possible

- **From a fundamental understanding of materials and condensed matter to projects which are only a few years to products**
- **Current hot areas within DMR**
  - **Nanoscale Science**
  - **Cyberscience/Cyberinfrastructure**
  - **Learning from biology**
  - **Global activities**
- **DMR accounts for ~50% of academic funding**
- **Connections with ENG, Chem, Phy, etc and DOE and NIH**

What is materials research?

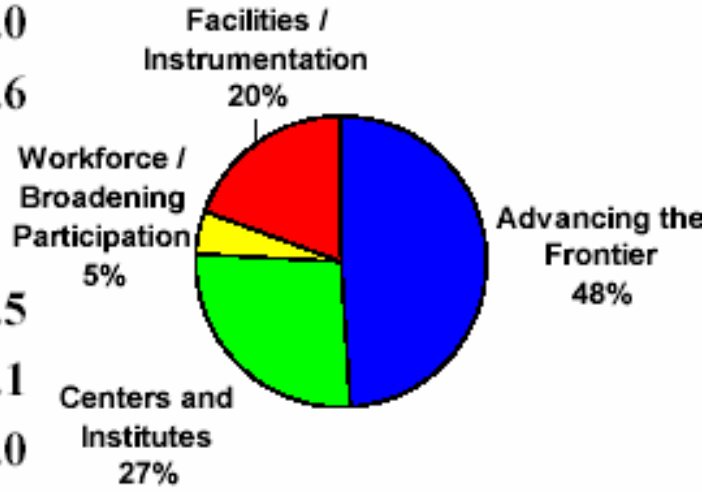
Chemistry, physics and engineering

Disciplinary Programs

Ceramics	$10.0
Condensed Matter Physics	$29.1
Electronic Materials	$17.6
Metals	$12.1
Polymers	$15.0
Solid-State Chemistry	$13.6
Biomaterials	

Cross Cutting Programs

Condensed Matter and Materials Theory	$17.5
Instrumentation (MRI $12.3)	$ 7.1
National Facilities	$40.0
Materials Science and Engineering Centers	$60.4
Office of Special Programs	$ 3.9

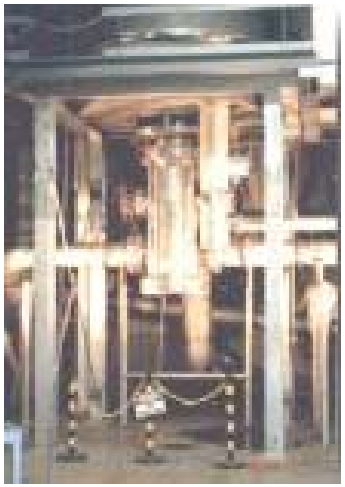


DMR Centers and Institutes

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

DMR Facilities

- National High Magnetic Field Laboratory
- Cornell High-Energy Synchrotron Source
- Synchrotron Radiation Center
- Center for High-Resolution Neutron Scattering
- National Nanofabrication Infrastructure Network



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 & structures and the relationships 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:

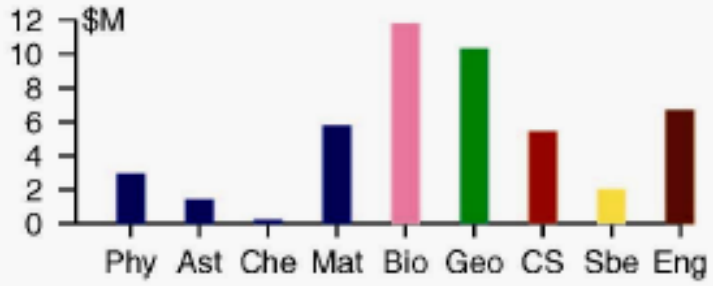
- Large data sets - analyzing their complexity and patterns
- Stochastic behavior - from deterministic to probabilistic models
- Multiscale phenomena - problems over several magnitudes of time and space
- What's the connection between superconductivity and photographic restoration?
  - The same partial differential equation! This synergy typifies mathematics.

DMS provides 80% of the federal support for academic research in mathematics.

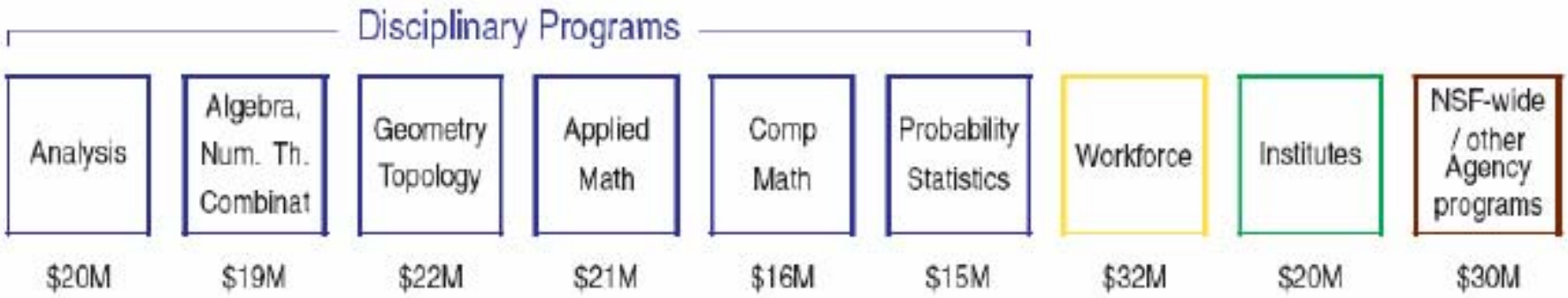
MSPA is a major factor in the division.

DMS Expenditures in Other Sciences

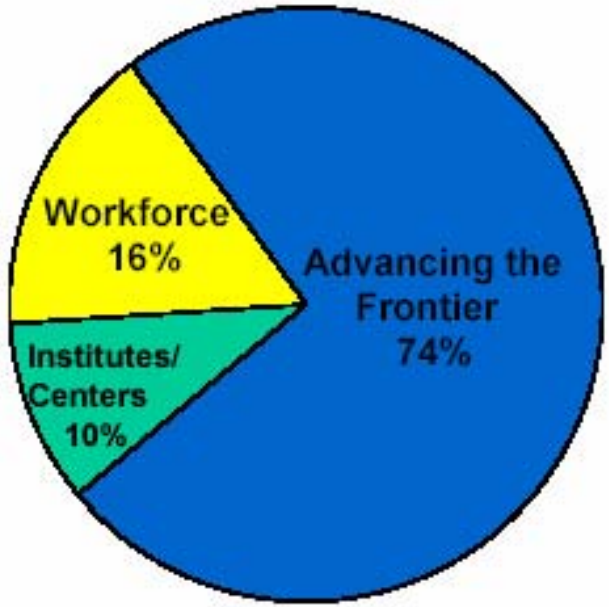
- Joint award with every NSF research division.
- Jointly reviews 700 proposals.
- Joint solicitations with NIH, DOE, DARPA.



The Division



- "Core business": single investigator and group proposals through targeted solicitations
  Covers 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
  - Postdoctoral fellowships
  - Research for Undergraduates



Mathematical Sciences Institutes

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)**
- **Research Training Groups (RTG)**
- **Mentoring through Critical Transition Points (MCTP)**

Solicitation: NSF 05-595

Physics (PHY)

Advancing the intellectual frontiers of physics 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
  - Portfolio of discovery tools
- Stewardship:
  - Primary sponsor (90%) of gravitational physics
  - Major sponsor (50%) of atomic, molecular, optical, plasma, theory
  - Important sponsor of university faculty and students in nuclear and particle physics
- Advisory committees and community connections: HEPAP, NSAC, AAAC
- Connections:
  - Intra-agency
  - Interagency
  - International

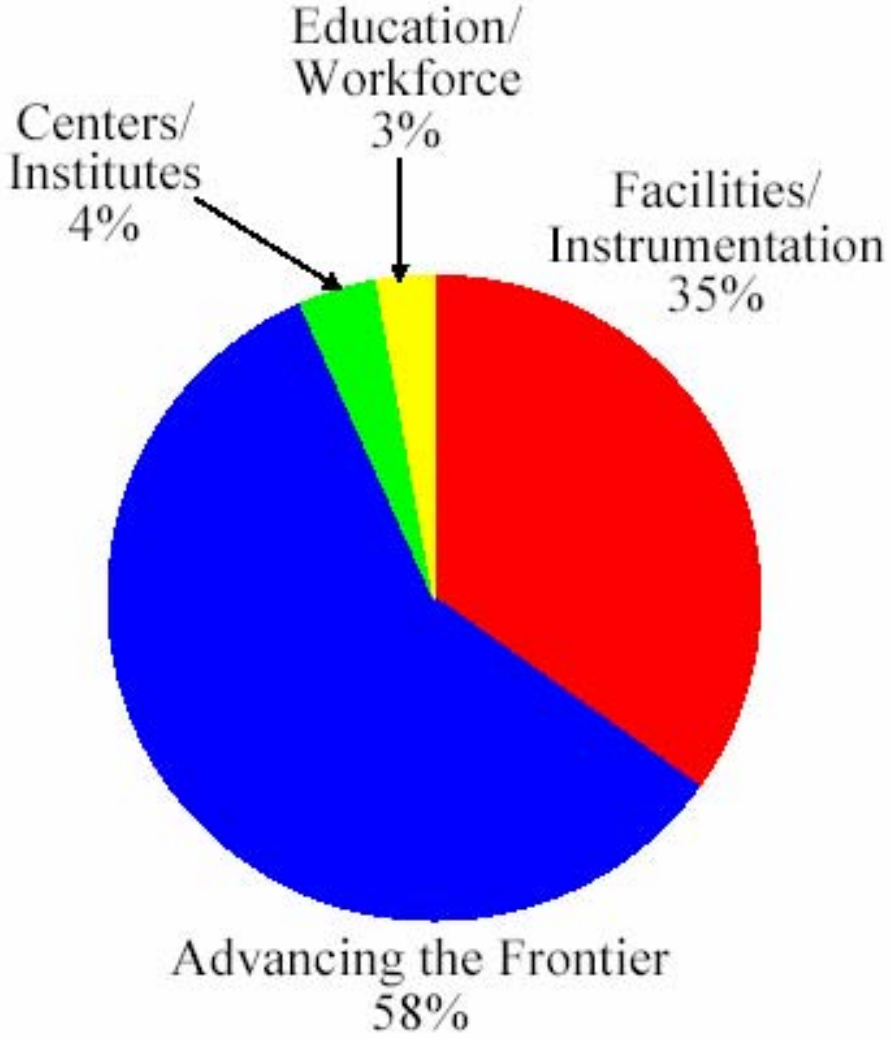
Budget Distribution

Facilities:

LHC, LIGO, IceCube, NSCL, CESR

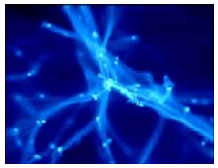
Programs:

- Atomic, Molecular, Optical, and Plasma Physics
- Biological Physics
- Elementary Particle Physics
- Gravitational Physics
- Nuclear Physics
- Particle and Nuclear Astrophysics
- Physics at the Information Frontier
- Physics Frontiers Centers
- Theoretical Physics
- Education and Interdisciplinary Programs



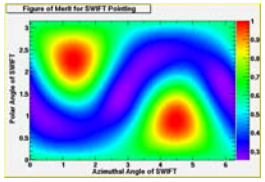
Physics Frontiers Centers

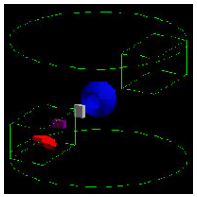
Kavli Center for Cosmological Physics – Chicago - Winstein



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

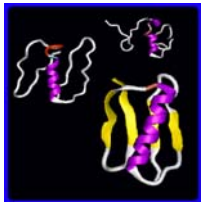
Center for Gravitational Wave Physics – Penn State – Finn





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

Center for Theoretical Biological Physics – UCSD - Onuchic

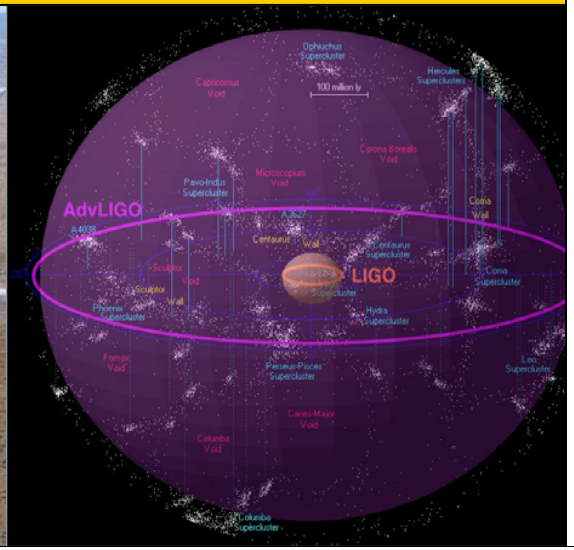


Physics Division Facilities

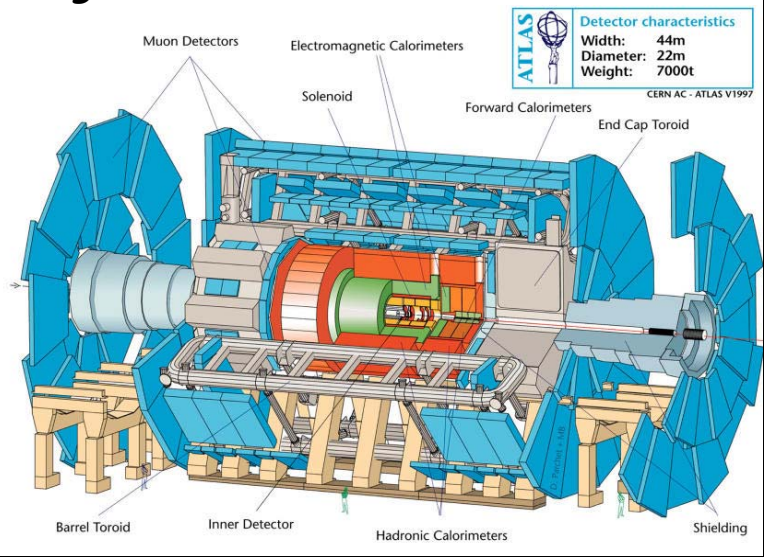
Major facilities ops 35% of budget

- LIGO (Caltech) gravity wave observatory
- NSCL (Michigan State) radioactive ion beams
- CESR e^+e^- Collider (Cornell) *phaseout path*
- U.S. LHC [ATLAS, CMS] (CERN) *1st beam 2007, physics 2008*
- Others in construction or planning stages: IceCube, Adv.LIGO, ERL, DUSEL

Laser Interferometer Gravitational-wave Observatory



Large Hadron Collider ATLAS Detector



Office of Multidisciplinary Activities (OMA)

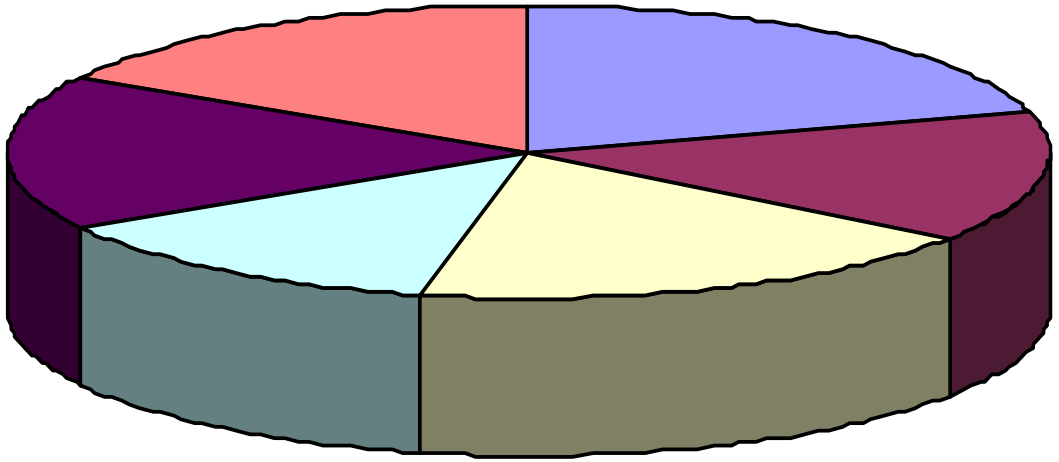
- Catalyze and Support Emerging, Cross-Cutting Areas
- Champion Broadened Participation in MPS
- Enable and Facilitate through
  - Partnerships
  - Innovative models for education
  - Broadly enabling infrastructure
  - New research modalities
  - Integration of research and education

** OMA Does not accept or review proposals **

OMA Co-Investment with MPS Divisions – FY06

MPS $4.8 M

AST $6.1 M



PHY $5.1M

CHE $4.3 M

DMS $3.8 M

DMR $5.4 M

Broadening Participation

The Greatest Threat to MPS Science

The Face of American Science

Is Not the Face of America

Broadening Participation

MPS Strategy

- Robust MPS presence in Foundation-wide activities
- Research based; embedded throughout MPS
- Build capacity through partnerships

LA-STEM

PREM

LIGO

Hampton

We Need You!

- Reviewers and panelists
- Workshop participants and organizers
- Rotators

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http://www.nsf.gov/home/mps/

See also “MPS Directory and Staff” on MPS home page