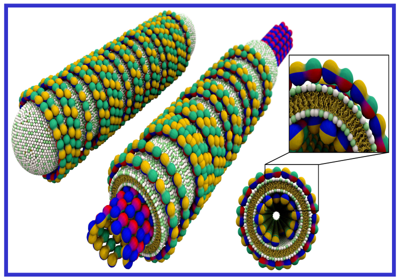
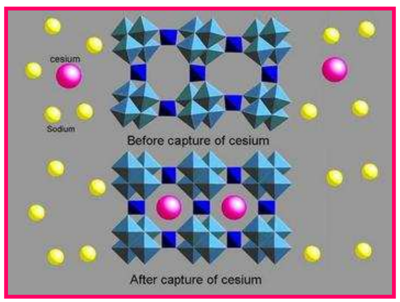
Condensed Matter and Materials Research
New Developments and Opportunities

http://www.nsf.gov/materials





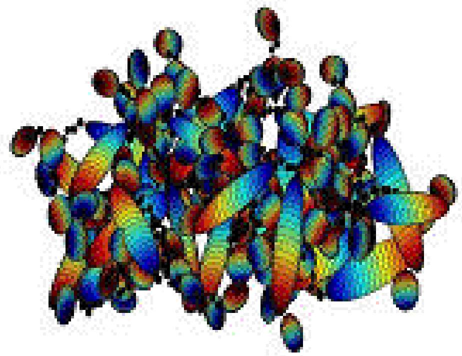
Ulrich Strom

Executive Officer

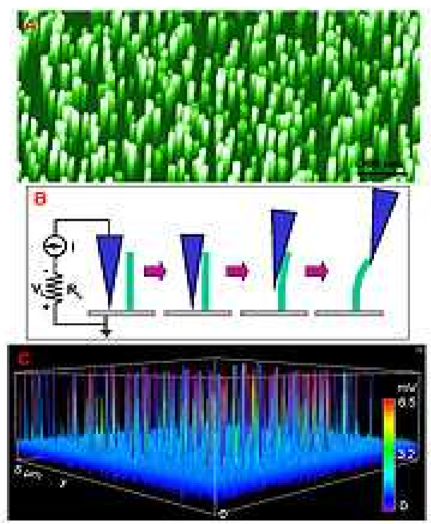
Division of Materials Research

We seek a fundamental understanding of materials and condensed matter

Can we create new materials for science and technology?



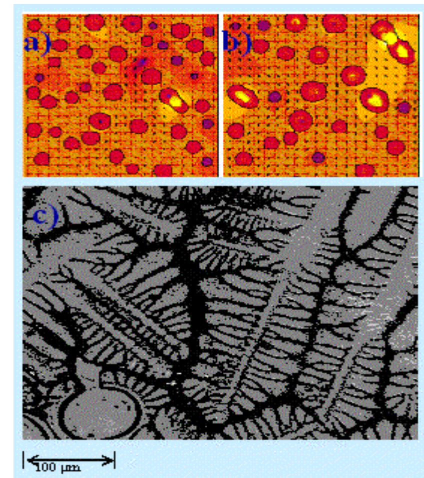
Can we understand and apply the physics of condensed matter?



How can we understand and exploit the nano-world?

"TRANSFORMATIVE MATERIALS"

Can we understand and control processing/structure/properties relationships in engineering materials?



How can we explore and develop the frontier between materials and biology?

Division of Materials Research

Focus for Diverse Communities and Funding Modes

NSF support for materials research is not limited to DMR

- *Programs for Individual Investigators and Groups*
  - **Condensed Matter and Materials Theory, Condensed Matter Physics**
  - **Solid State Chemistry, Polymers, Biomaterials**
  - **Metals, Ceramics, Electronic/Optical Materials**
- *Cross-cutting Programs*
  - **Centers, Institutes & Partnerships**
  - **User Facilities and Instrumentation**
  - **Office of Special Programs (International Collaboration; Education)**
- *Distributed Mechanisms*
  - **Focused Research Groups**
  - **NSF-wide programs – *REU/RET, CAREER, GOALI, MRI, etc***
  - ***DMR is a major partner in NSF-NANO***
- *Connections*
  - **Other areas of NSF, federal agencies, international, industry**

Division of Materials Research (DMR)

OFFICE of the DIVISION DIRECTOR


Zakya Kafafi
Division Director


Ulrich Strom
Executive Officer (Acting)


Lorretta J. Hopkins
Senior Staff Associate


Neila Odom-Jefferson
Operations Specialist


Denise Hundley
Division Secretary

ADMINISTRATIVE UNIT


Carol Savory-Heflin
Program Support Manager


Denese Logan
Program Analyst


Bill Daniels
Program Specialist


Deborah E. Dory


Renée Ivey


Shirley Millican


Bernie Trumble

Senior Program Assistants

Program Directors

Condensed Matter & Materials Theory (CMMT)


Daryl W. Hess


Michael A. Lee
Kent State U.


Mark R. Pederson
NRL

Condensed Matter Physics (CMP)


Wendy Fuller-Mora


Roy Goodrich


Oscar O. Bernal


Udo Pernisz
Dow Corning

Solid-State & Materials Chemistry (SSMC)


Dave L. Nelson


Akbar Montaser
George Washington U.

Polymers (POL)

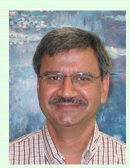

Andrew J. Lovinger


Freddy Khoury

Biomaterials (BMAT)


David A. Brant


Joseph A. Akkara


Satyendra Kumar
Kent State U.

Ceramics (CER)


Lynnette D. Madsen

Electronic Materials (EM)


LaVerne D. Hess


Z. Charles Ying

Metals (MET)


Harsh D. Chopra
SUNY


Bruce A. MacDonald

Materials Research Science & Engineering Centers (MRSECs)


Maija M. Kukla


Thomas P. Rieker


Rama Bansil
Boston U.

Office of Special Programs (OSP)


Carmen I. Huber


Uma Venkateswaran

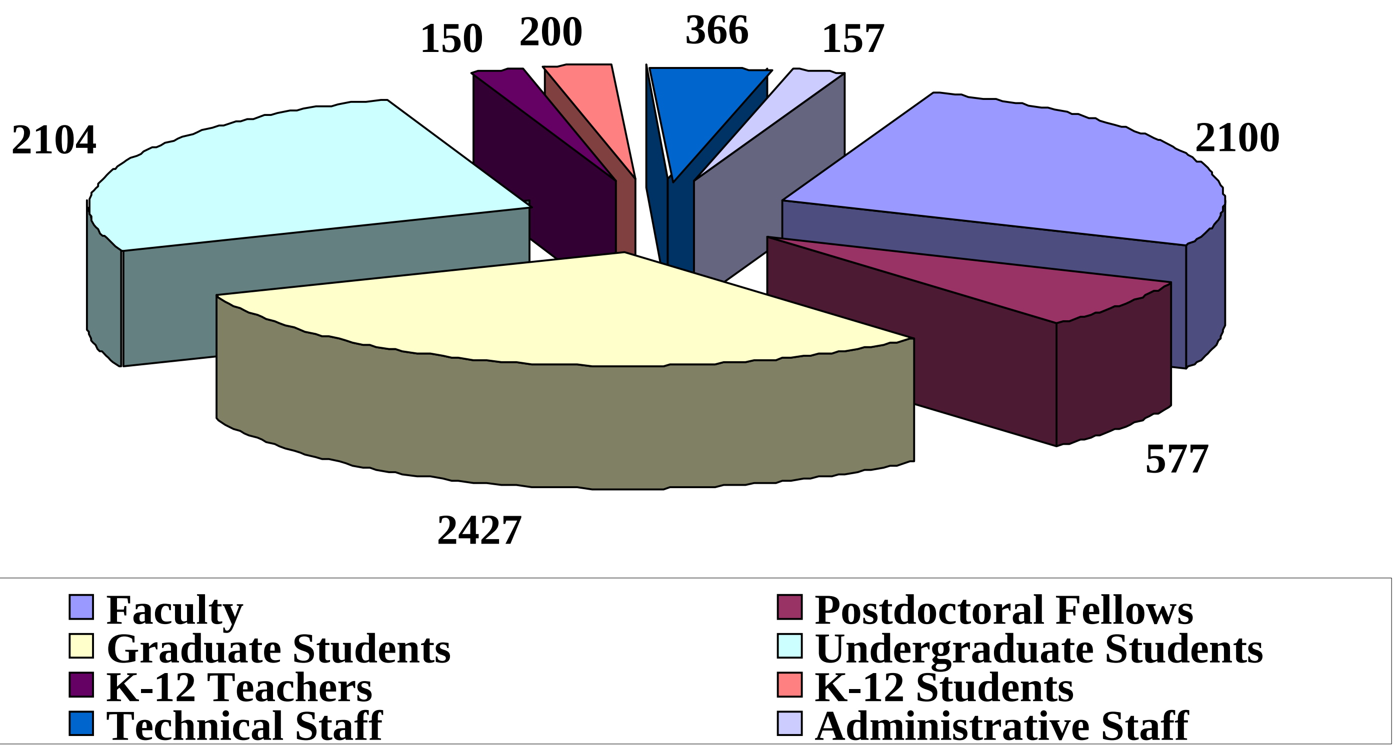
Instrumentation for Materials Research (IMR)


Charles Bouldin

National Facilities (NAF)


Guebre X. Tessema

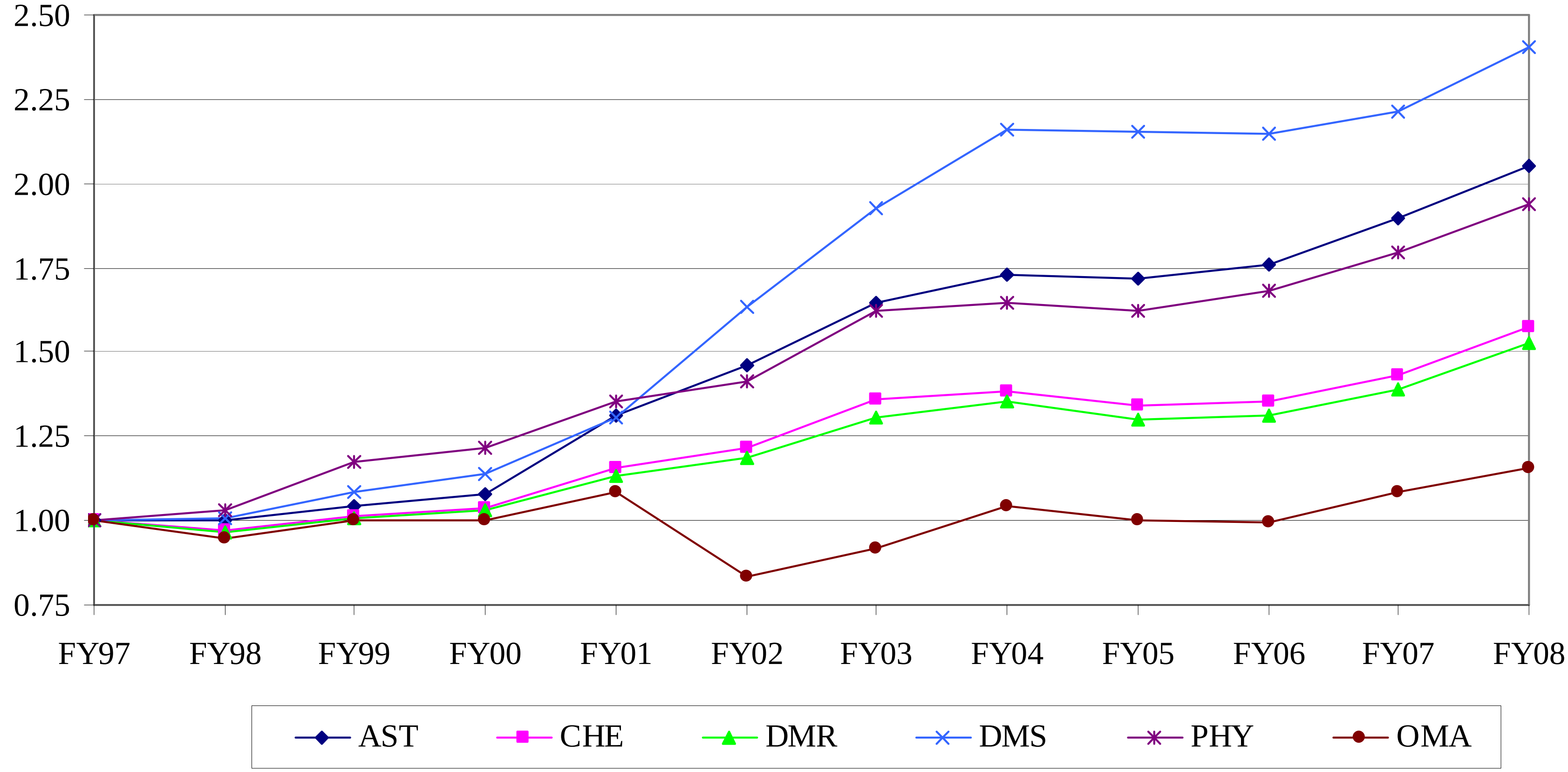
Distribution of People Funded by DMR in Materials Research & Education



> 5,000 people used DMR-supported facilities in FY07

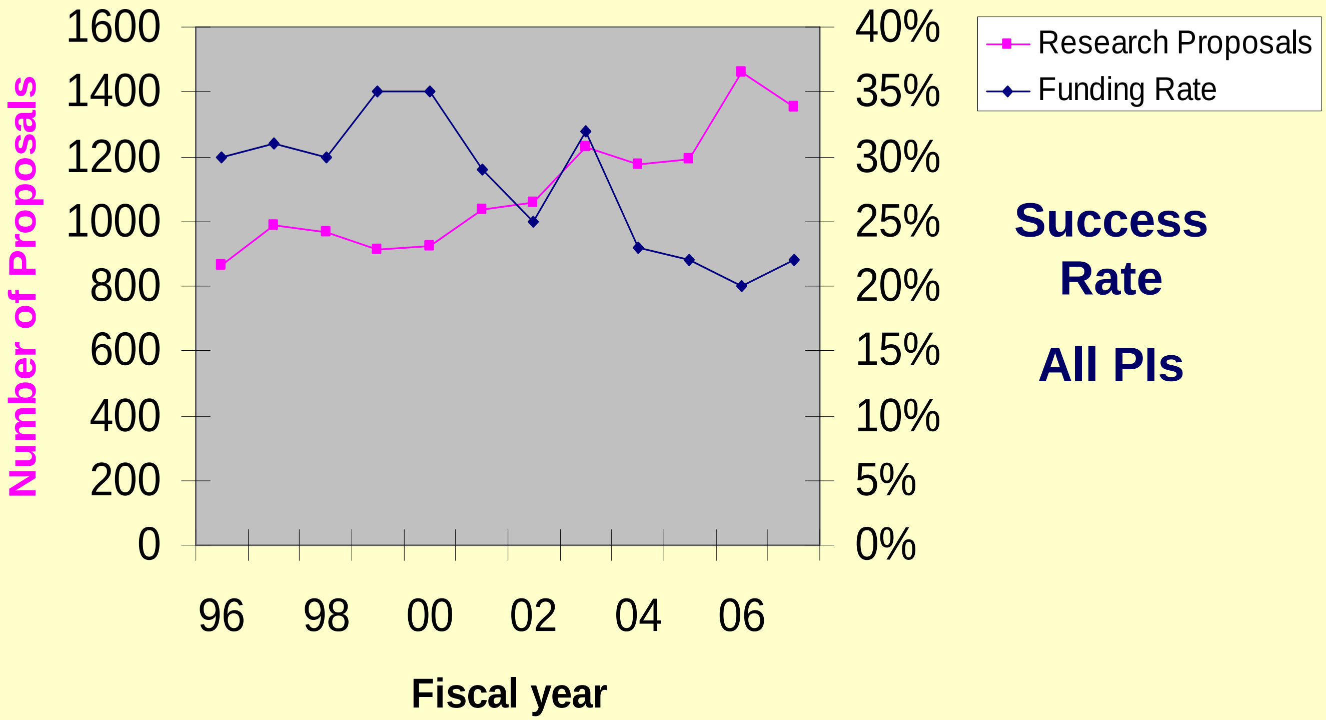
Directorate for Mathematical & Physical Sciences Funding History, FY 1997 - FY 2008*

Budgets normalized to FY 1997



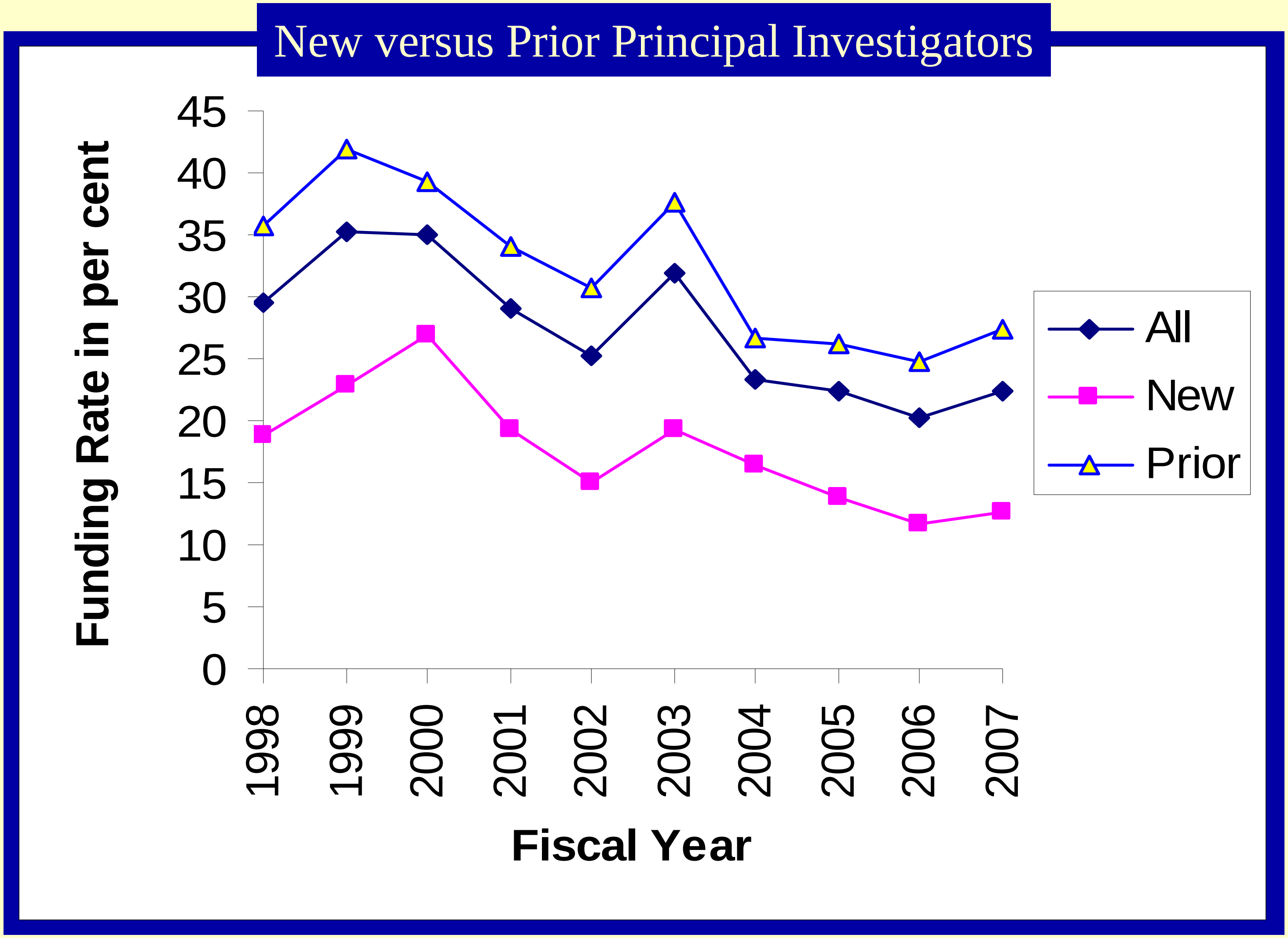
* FY 2008 budget as requested

DMR Proposals & Success Rates (Research Grants 1996 - 2007)



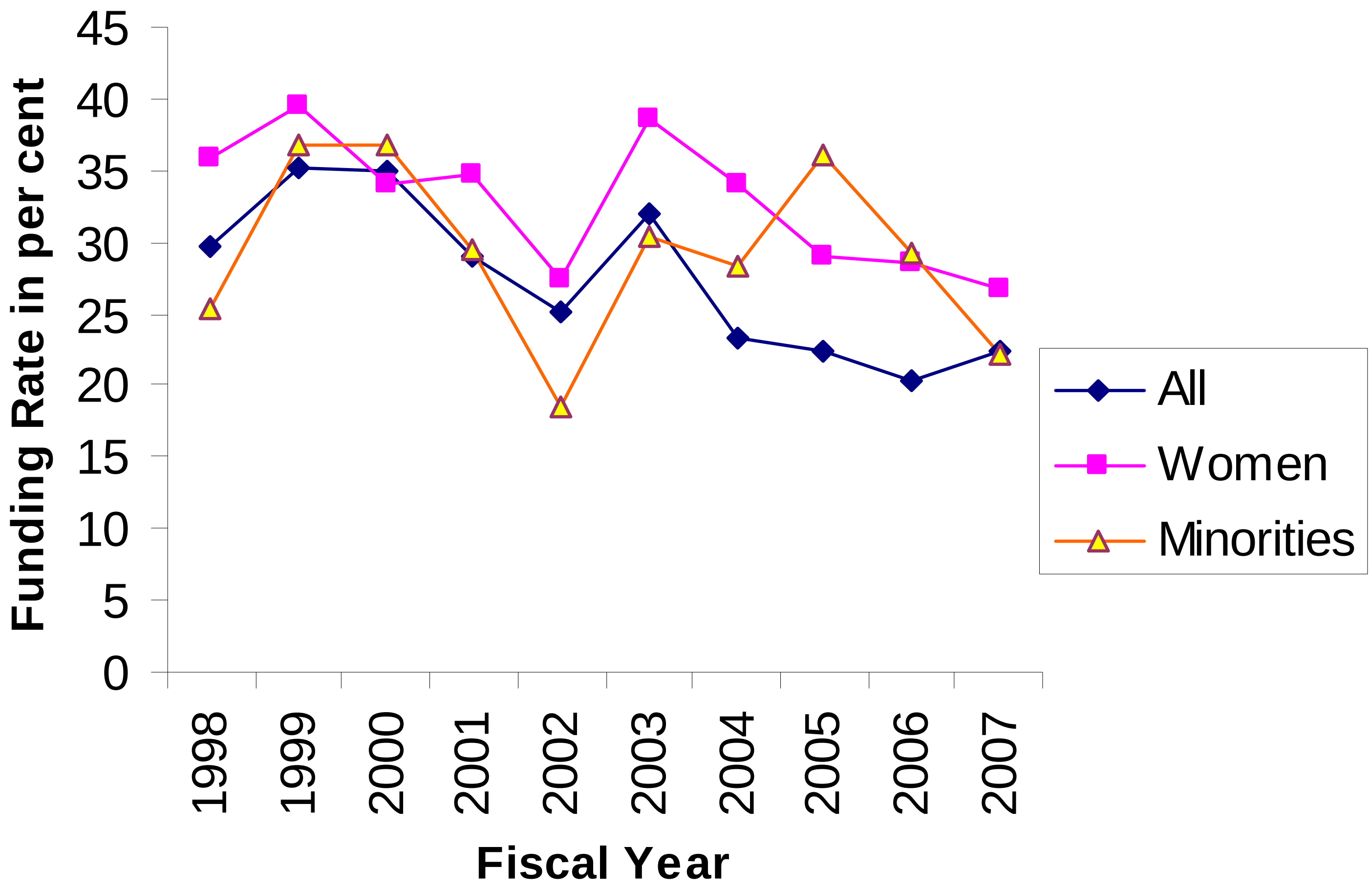
- Many strong proposals declined essentially for lack of funds
- Grant sizes not keeping pace with ‘scientific’ inflation
- Success rates vary but NSF-wide average is no better

DMR Funding Rate for Research Proposals

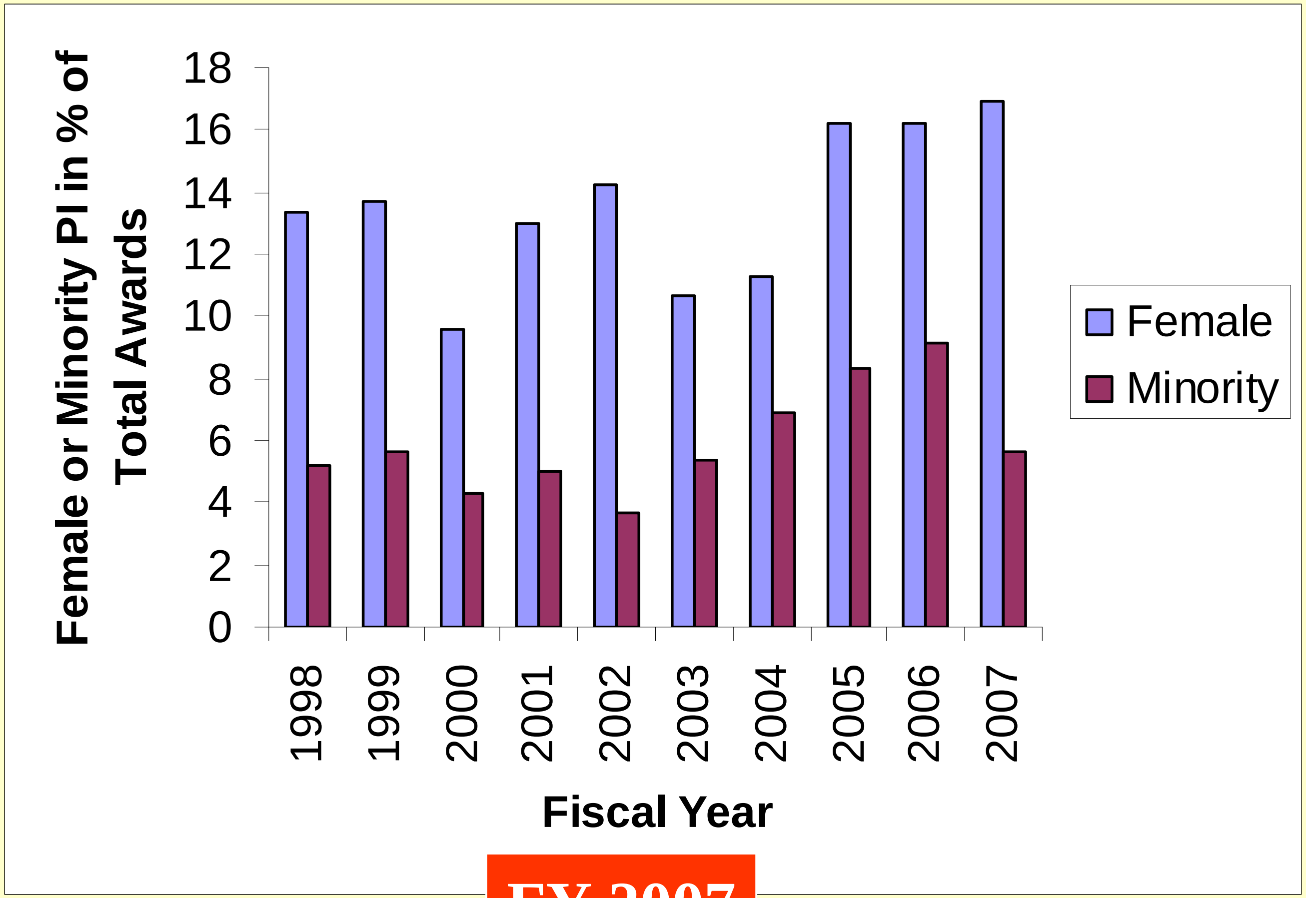


DMR Funding Rate for Research Proposals

Women or Minority Principal Investigators



DMR Awards Demographics in FY 1998 – FY 2007



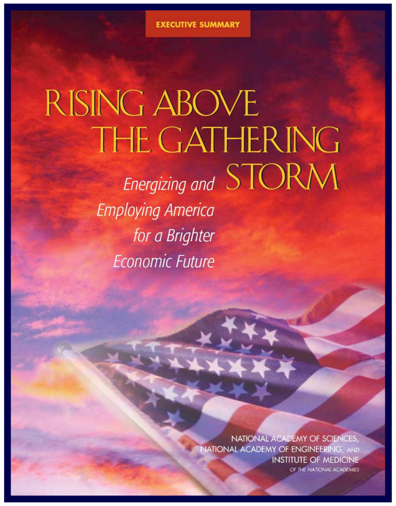
FY 2007

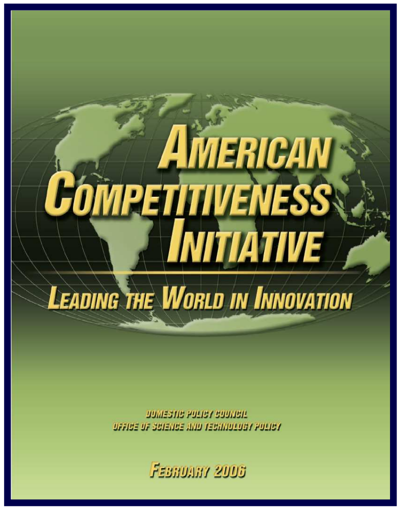
Total number : 1,352 proposals / 301 awards

Women PIs : 191 proposals / 51 awards

Minority PIs : 77 proposals / 17 awards

Call for Reinvestment in Science, Technology, Engineering, and Mathematics (STEM)





- Increase US talent pool
- Strengthen basic research
- Develop, recruit & retain best/brightest
- Ensure innovation in America

- From fundamental discoveries to marketable technologies
- Focus on Physical Sciences & Engineering
- Facilities and instrumentation
- World class science and engineering workforce

Doubles NSF/DOE/NIST Budget over 10 years!

FY 2009 Budget Request by Division

The Good News

Mathematical and Physical Sciences Funding

(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimated	FY 2009 Request	Change over FY 2008 Estimated Amount	Change over FY 2008 Estimated Percent
Astronomical Sciences	$215.39	$217.86	$250.01	$32.15	14.8%
Chemistry	191.22	194.22	244.67	50.45	26.0%
Materials Research	257.27	260.22	324.59	64.37	24.7%
Mathematical Sciences	205.74	211.79	245.70	33.91	16.0%
Physics	248.47	250.52	297.70	47.18	18.8%
Multidisciplinary Activities	32.64	32.70	40.00	7.30	22.3%
Total, MPS	$1,150.73	$1,167.31	$1,402.67	$235.36	20.2%

Totals may not add due to rounding.

NSF:
$6.854 B,
+13.0%

MPS by Division

(Dollars in Millions)

FY 2005 - FY 2008

Back To Reality

	FY 2005 Actuals	FY 2006 Actuals	FY 2007 Actuals	Change from 06 to 07	FY 2008 Request	Change from 07 to 08	FY 2008 Estimate	Change from 07to 08
AST	195.11	$199.75	$215.39	7.8%	$232.97	8.2%	$217.86	1.1%
CHE	179.26	180.70	191.22	5.8%	210.54	10.1%	194.22	1.6%
DMR	240.09	242.59	257.26	6.0%	282.59	9.8%	260.22	1.2%
DMS	200.24	199.52	205.74	3.1%	223.47	8.6%	211.79	2.9%
PHY	224.86	234.15	248.47	6.1%	269.06	8.3%	250.52	0.8%
OMA	29.80	29.90	32.64	9.2%	34.37	5.3%	32.70	0.2%
MPS	1,069.36	1,086.61	1,150.72	5.9%	1,253.00	8.9%	$1,167.31	1.4%

NOTE: DMR FY 2004 Actuals = $250.65M

Impact of FY2008 Budget on DMR Programs

- DMR will be **unable** to *increase* research and education support

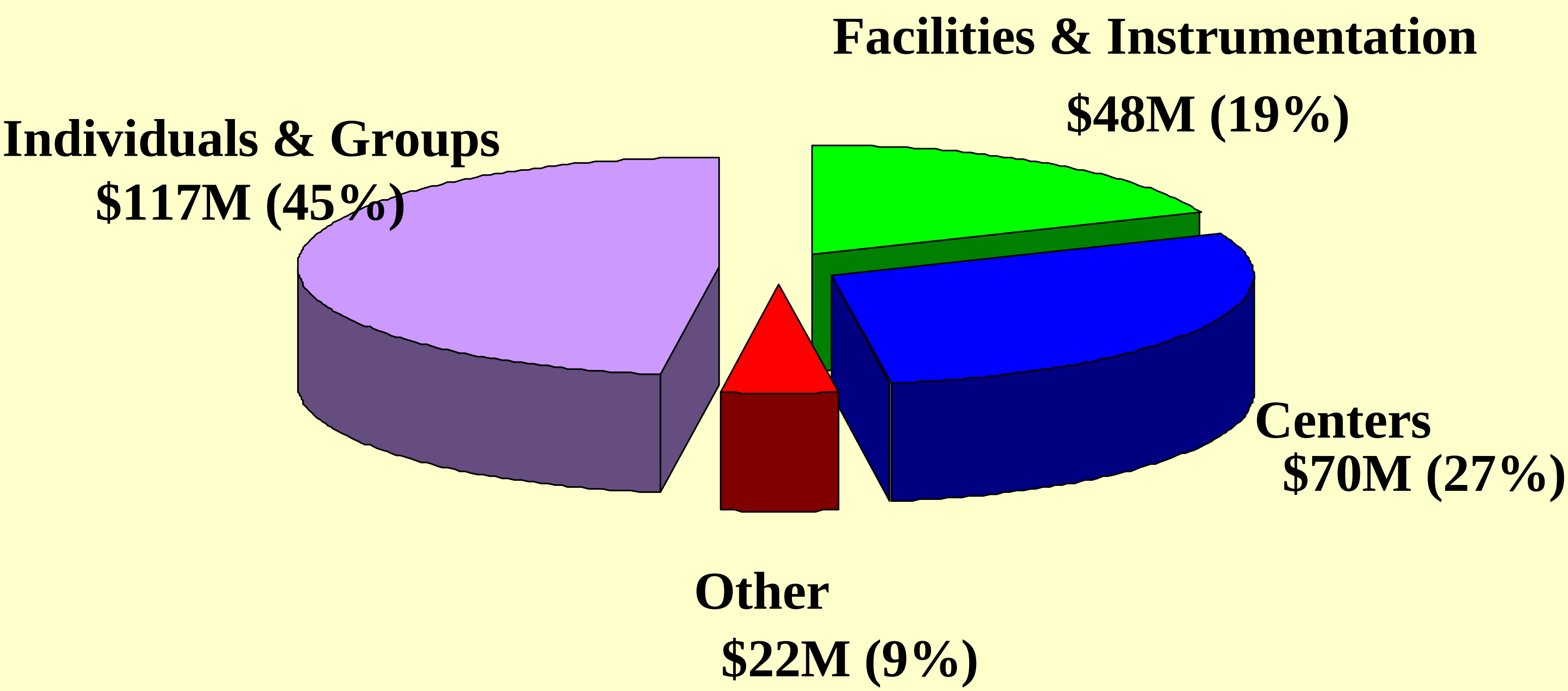
- Success rates for individual investigators will remain at historically low levels

- DMR will be **unable** to *increase* support for centers

- DMR will be **unable** to *enhance* research, user programs, instrument upgrades or education activities at the National High Magnetic Field Laboratory

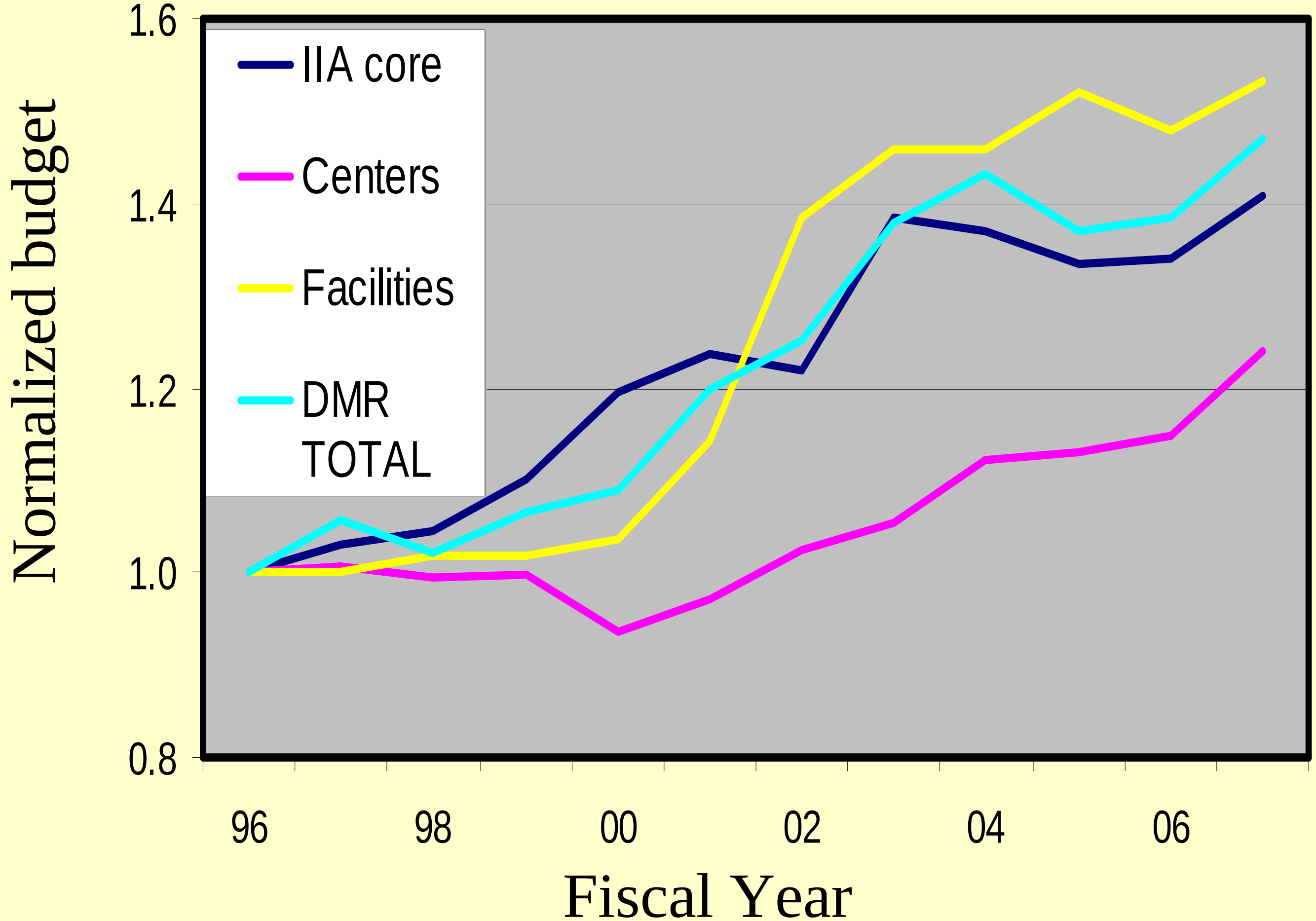
BUT, modest new investments will be made in awards relating to instrumentation acquisition & development and in the recently established biomaterials program.

DMR Budget
$257 M in FY2007

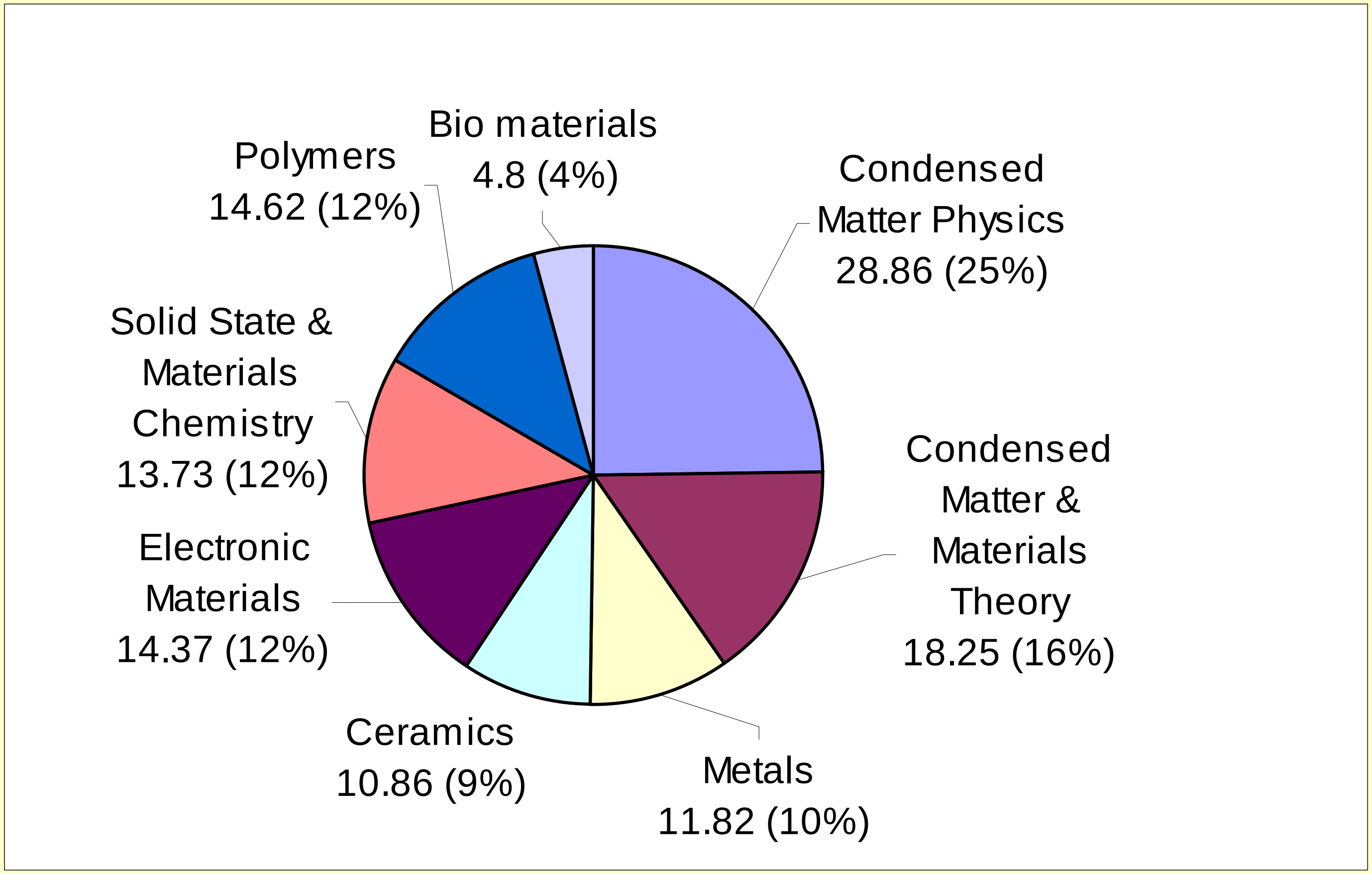


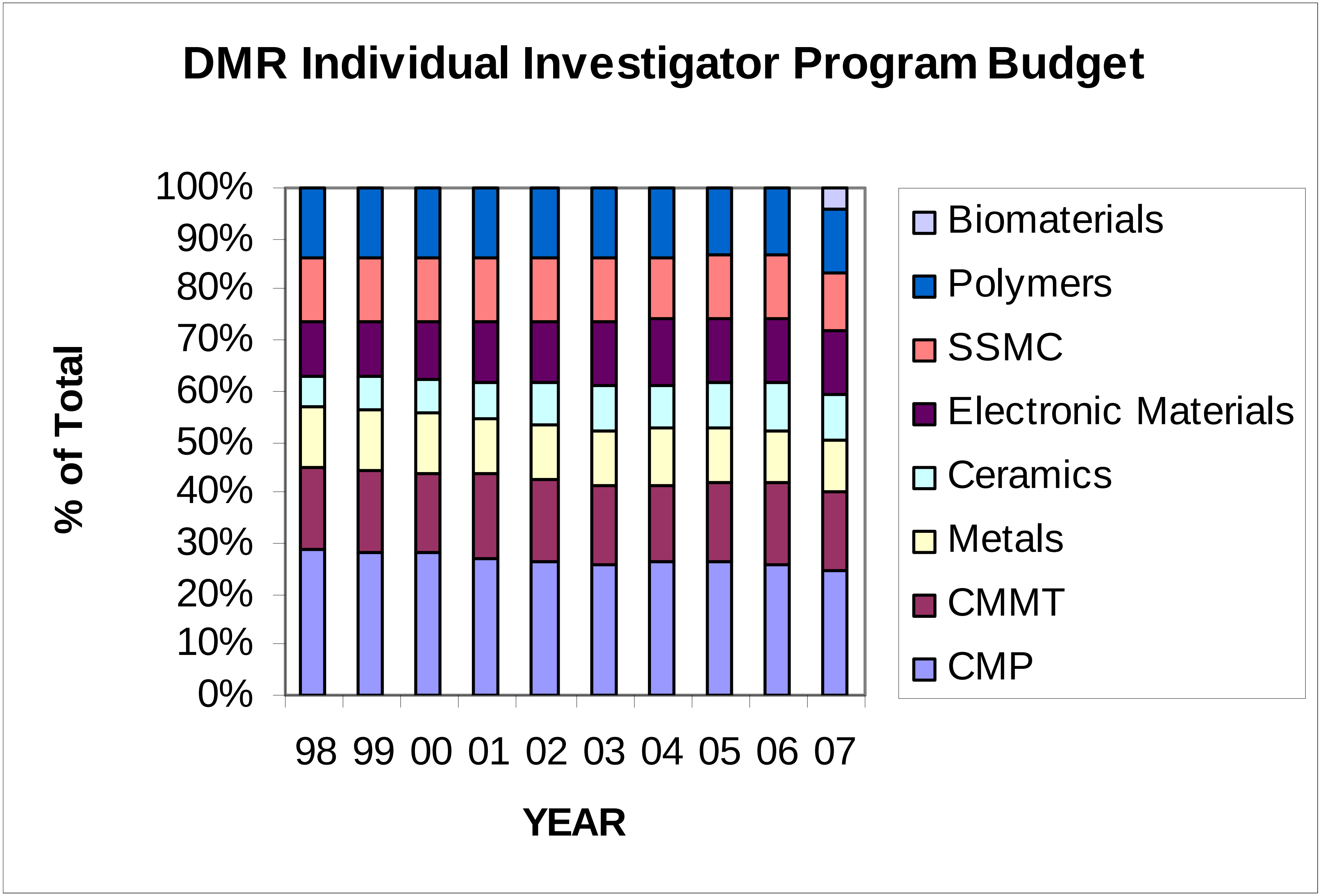
DMR Funding History, 1996-2007

$257.26 in FY07

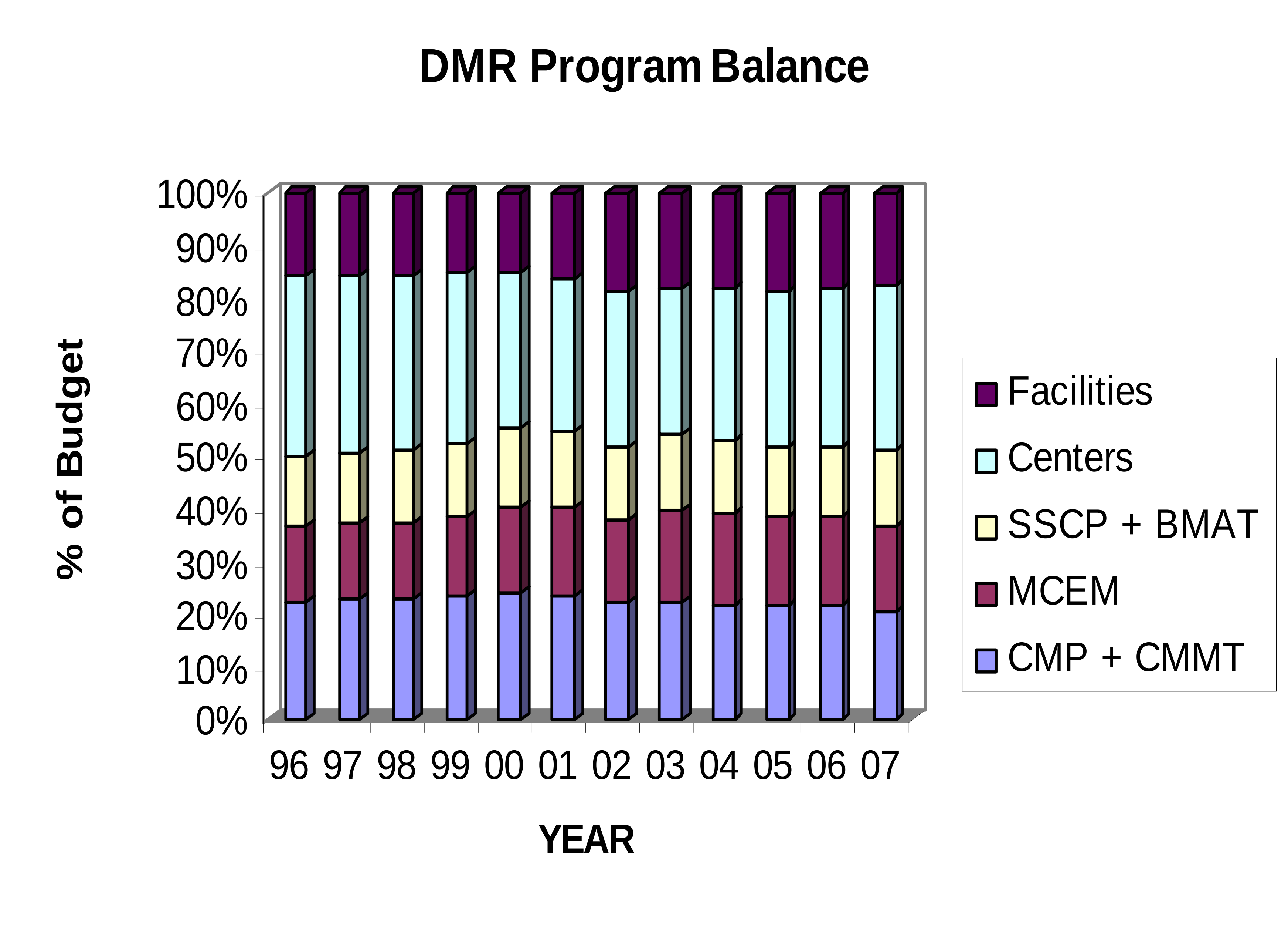


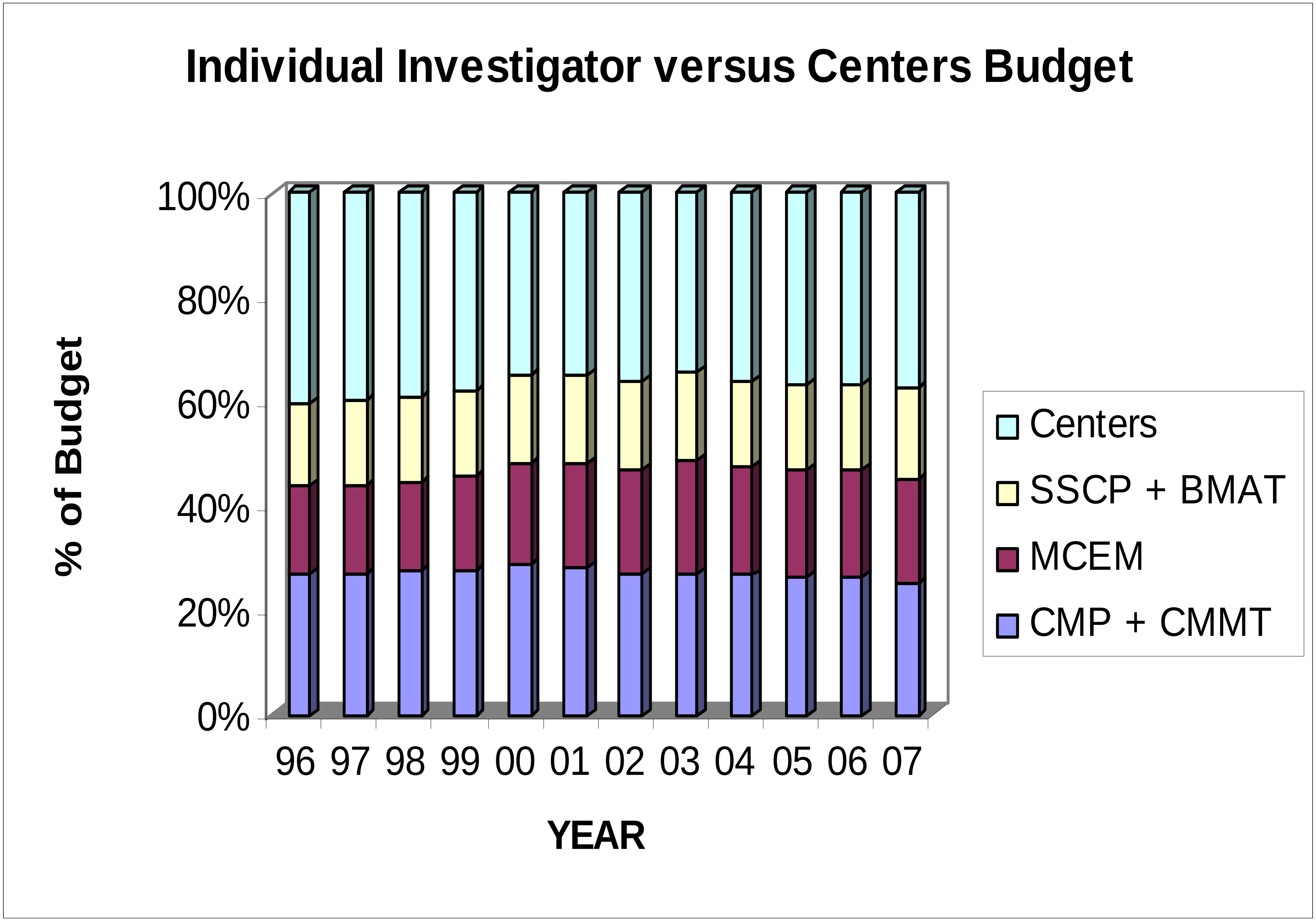
Funding ($M) Distribution for Individual Investigator Programs in FY 2007





DMR Individual Investigator Program Budget
% of Total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
98 99 00 01 02 03 04 05 06 07
YEAR
Biomaterials
Polymers
SSMC
Electronic Materials
Ceramics
Metals
CMMT
CMP


DMR Program Balance
% of Budget
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
96 97 98 99 00 01 02 03 04 05 06 07
YEAR
Facilities
Centers
SSCP + BMAT
MCEM
CMP + CMMT



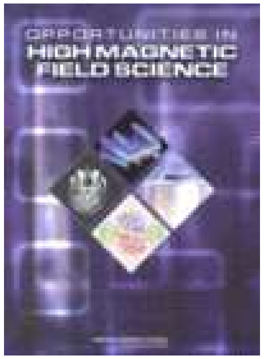
Individual Investigator versus Centers Budget
% of Budget
100%
80%
60%
40%
20%
0%
96
97
98
99
00
01
02
03
04
05
06
07
YEAR
Centers
SSCP + BMAT
MCEM
CMP + CMMT

DMR Strategic Goals

- Advance discovery & encourage innovation through transformational, multidisciplinary & global Materials Research
- Promote excellence in K-12, undergraduate, graduate, postdoctoral and public Materials Education
- Develop a strong Materials Research infrastructure via new tools, interdisciplinary centers and multi-user facilities
- Support a capable, diversified and responsive DMR staff for achieving excellence in Materials Research & Education

NAS Studies & NSF Workshops

National Academy of Sciences (NAS)



- Opportunities in High Magnetic Field Science (2005)
- Midsize Facilities (2006)
- Condensed-Matter and Materials Physics (2007)
- Materials Research, Science & Engineering Centers (2007)

National Science Foundation (NSF)

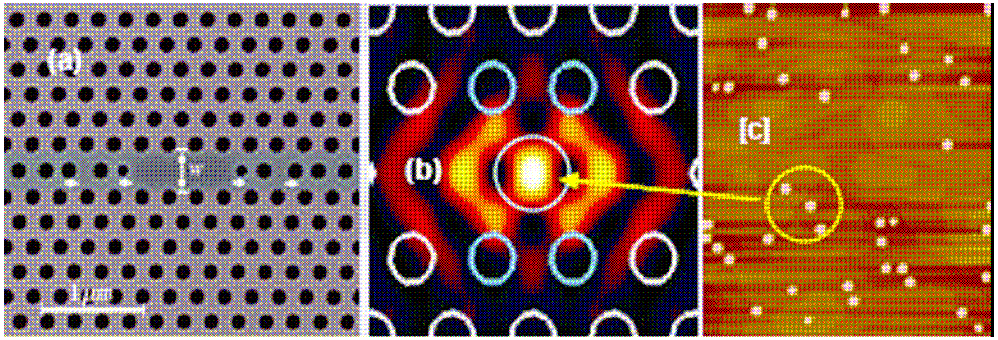
- Cyberinfrastructure & Cyberdiscovery in Materials Science (2006)
- Future Directions in Solid-State Chemistry (2008)
- Interdisciplinary, Globally Leading, Polymer Science & Engineering (2008)

Physics 2010 – Six Scientific Challenges

1. **How do complex phenomena emerge from simple ingredients?**
2. **How will the energy demands of future generations be met?**
3. **What is the physics of life?**
4. **What happens far from equilibrium and why?**
5. **What new discoveries await us in the nanoworld?**
6. **How will the information technology revolution be extended?**

Also,

- **How do we extend the frontiers of measurement & prediction?**
- **How can we inspire and teach others?**



Quantum-dot photonic crystal cavity
Evelyn Hu et al., UCSB

Current & future growth areas for CMP & MP

Courtesy of CMP program directors

- New quantum states of matter
- Interface with AMO Physics
- Quantum-classical interface, including nano
- Interface of ‘soft’ and ‘hard’
- Phenomena and structures for quantum information, including spintronics
- Emergent behavior & complexity
- Strongly correlated electron systems
- Real time data analysis during experiments

CMMT - Some Intellectual Challenges

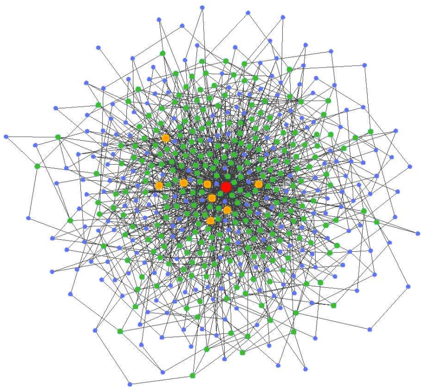
Courtesy of CMMT program directors

"Challenges of many interacting particles"

- Discover new classes of matter, emergent properties and phenomena, and ways to control them
- From the fundamentals, predict the structure and properties of matter and materials
- Non-equilibrium statistical mechanics: from fracture to life
- Discover the fundamental principles that underlie seemingly diverse phenomena and properties of matter and materials, reaching across disciplines

DMR Intellectual Focus Areas

- Cyber-enabled discovery and innovation
- Fundamental research addressing "Science Beyond Moore's Law"
- Nanoscale materials and phenomena
- Research at the interface between the physical and biological sciences
- Emergence; systems beyond equilibrium
- Materials for sustainability
- "Blue-Sky" materials (e.g. meta-materials, materials linking physical & living systems, etc)
- Seeing beyond the frontiers *and expect the unexpected!*



Scale-free networks

Philippe Cluzel, U Chicago

Education is integrated with Research throughout

Cyber-enabled Discovery
Computational Materials

- **The inverse problem**
  - **“The Holy Grail for materials research” - Materials by Design**

- **The forward problem**
  - **Quantitative Understanding of the Origin of Materials Properties and Phenomena**

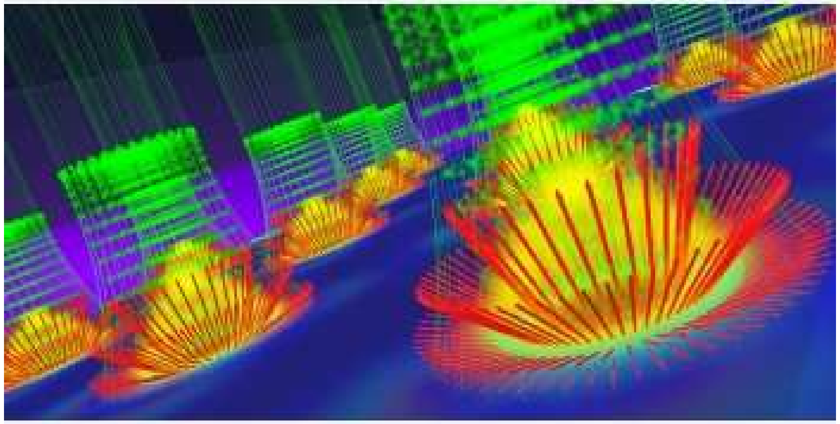
- **The nanoscale problem**
  - **Structure Determination when the Structure is no Longer Highly Periodic**

- **Real-time analysis of complex experimental data (e.g. DANSE)**

- **Big Iron and/or Distributed Computing?**

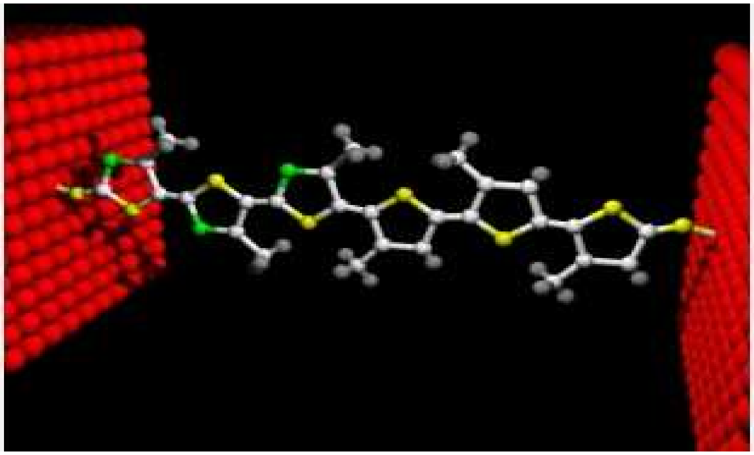
Science & Engineering Beyond "Moore's Law"

New science and technology, including novel algorithms and conceptual frameworks, are needed for future computing



William G. Gilroy, University of Notre Dame

Spintronics, in which information is carried out by electron's intrinsic spin, is one of the possible candidates for future computing



Luping Yu, University of Chicago
Ivan Oleynik, University of South Florida

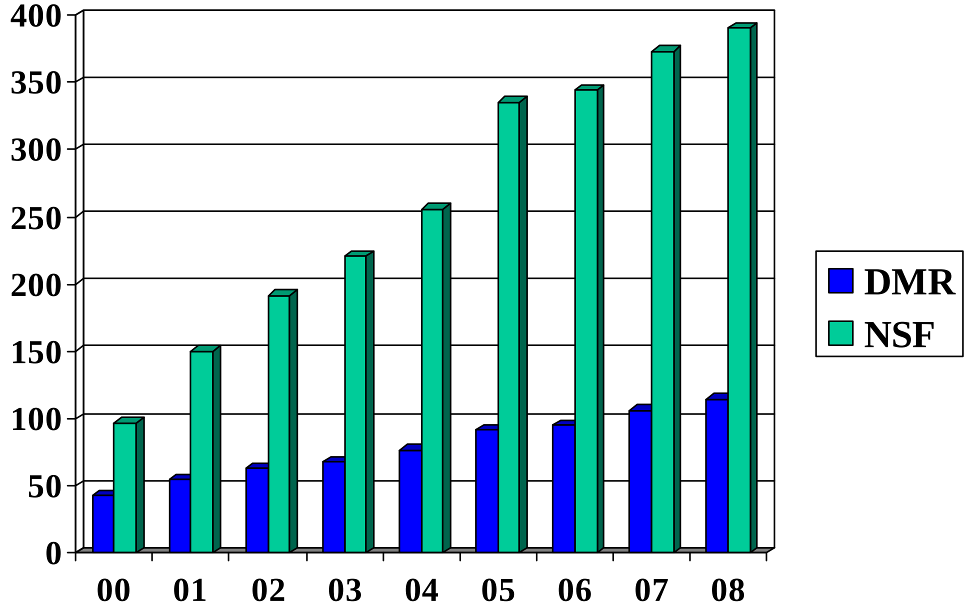
A single-molecule diode was designed to study and learn how to build electronic functionality into molecular architectures

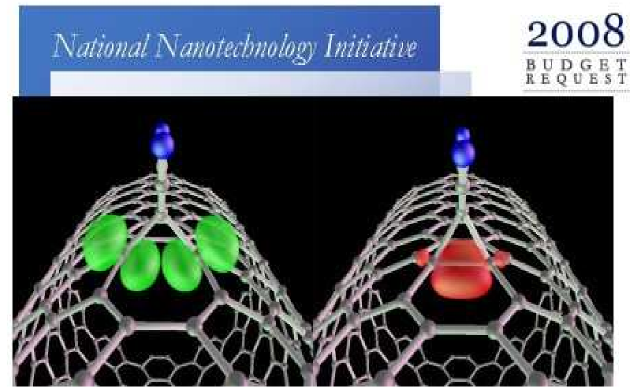
NSF Support for Nano

Wide Spectrum of Topics and Support Modes

Individuals, Groups, Centers, Networks, Facilities, Education, SBIR…

FY 08 ***REQUEST*** $380M (NSF), $114M (DMR)



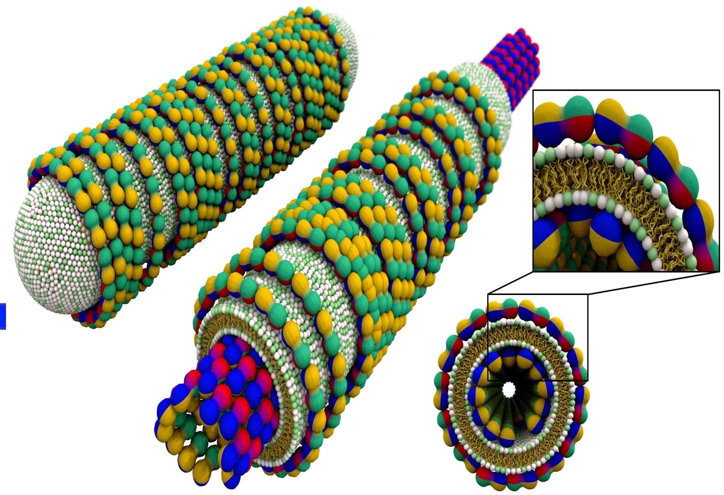


Functionalized nanotubes

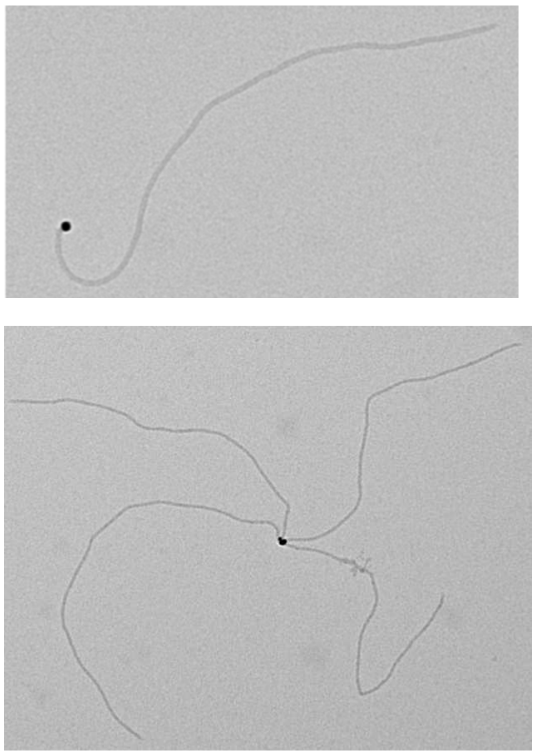
Marzari group, MIT

DMR support for nano is now mostly ‘mainstreamed’ via *unsolicited* proposals (individuals and groups); centers competition; or instrumentation & facilities

THE PHYSICAL / BIOLOGICAL FRONTIER



Cyrus Safinya - UCSB



Seth Fraden - Brandeis

- **Can we understand and control biological function?**
- **Can we create complex hierarchical systems the way nature does?**
- **Can we enable direct electronic communication between computers and living systems?**
- **Can we use biology to understand complex self-assembly and systems far from equilibrium?**
- **Can we develop improved biocompatible materials for implants and artificial organs?**
- **Can we create and guide drug-delivery systems that cause no peripheral damage?**

IMPACT: **"Human repair" and quality of life. Most powerful scientific toolbox. Control of biological processes. Potential for unraveling the physical basis of life.**

BIOMATERIALS PROGRAM (BMAT)

The BMAT Program covers:

- Materials of biological origin, biomimetic and bioinspired materials, and biocompatible materials
- Synthetic and biological pathways to these materials
- Properties of these materials and phenomena associated with them
- Biomolecular assemblies, systems, and composites involving these materials
- Applications of the methods of condensed matter physics and chemistry and biologically-related materials science to study these materials
- With emphasis on discovery of fundamental new knowledge regarding these materials

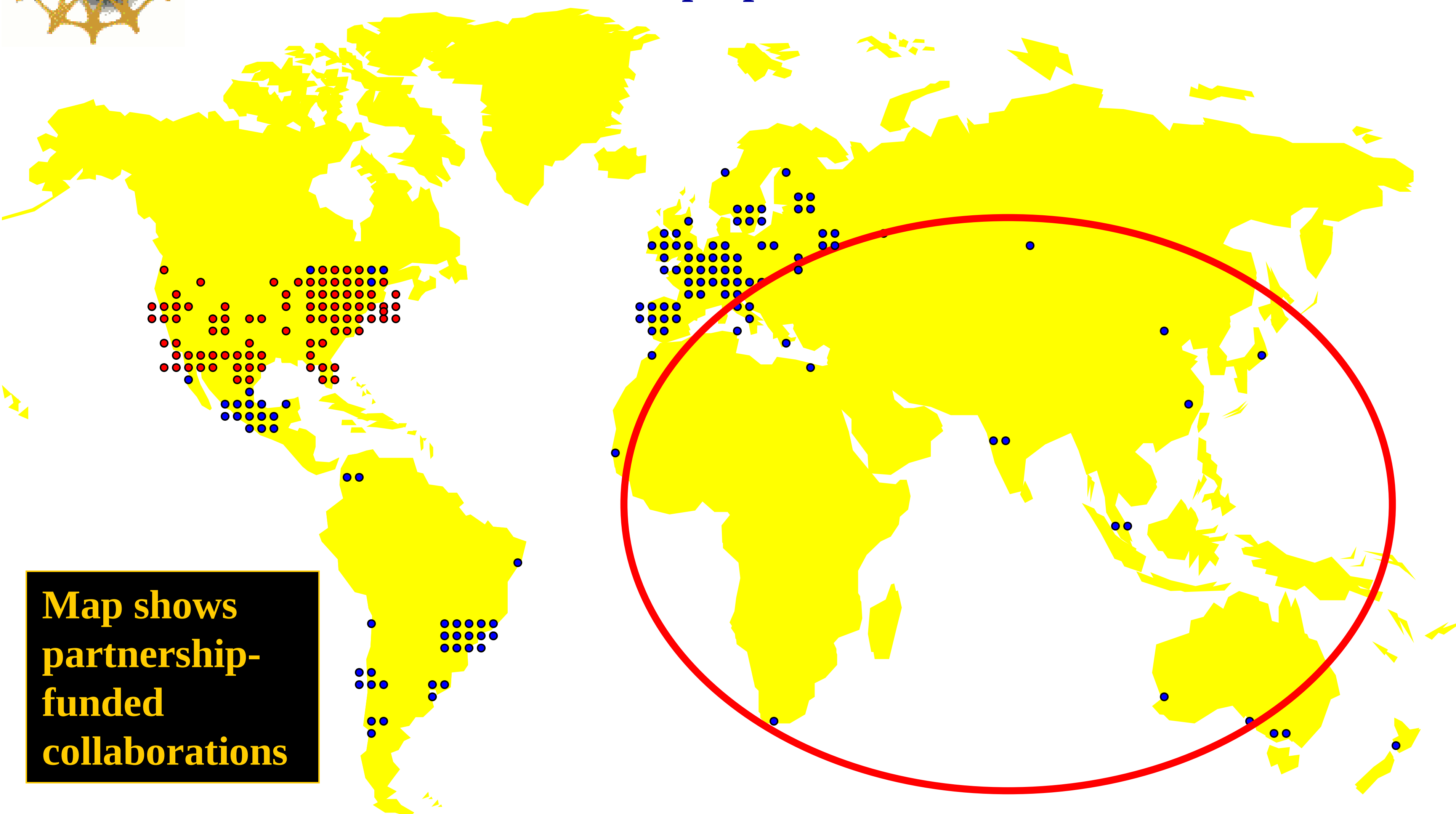
“Biomaterials” in the MRSECs

Interdisciplinary Research Groups FY08

• Programmable Bonding, Biomimetic Synthesis	UCSB
• Patterns, Gradients & Signals in Soft Biomaterials	Cal Tech
• Bio-interfacial Science	Chicago
• Materials & Techniques at Cellular Scales	Harvard
• Synthetic Programmable Membranes	Penn
• De Novo Synthetic Protein Modules	Penn
• Molecular Motors	Penn State
• Response-Driven Systems: Proteins, Polymers, Colloids	Southern Miss
• Functional Biomolecular Membranes	Stanford/Davis/IBM
• Genetically Engineered Biomimetic Materials	U Washington
• Nanostructured Interfaces to Biology	Wisconsin

The Materials World Network - 2007

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



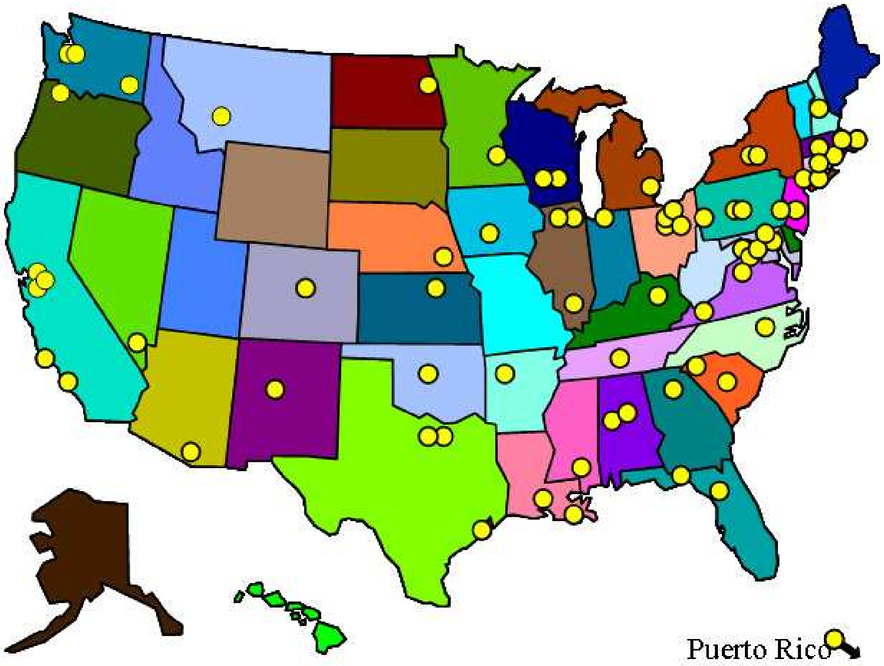
Map shows partnership-funded collaborations

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

Integration of Materials Research with Education

UTeach is featured in *Rising Above the Gathering Storm* as the first model program accompanying recommendation A-1:
TEN THOUSAND TEACHERS FOR TEN MILLION MINDS
(PI is DMR grantee Mike Marder)

- **Students at all levels**
- **Research experience for undergraduates and teachers**
- **Individual investigators & groups**
- **CAREER awards**
- **Centers & user facilities**
- **Partnerships & international activities**



70 DMR REU Sites in 2007

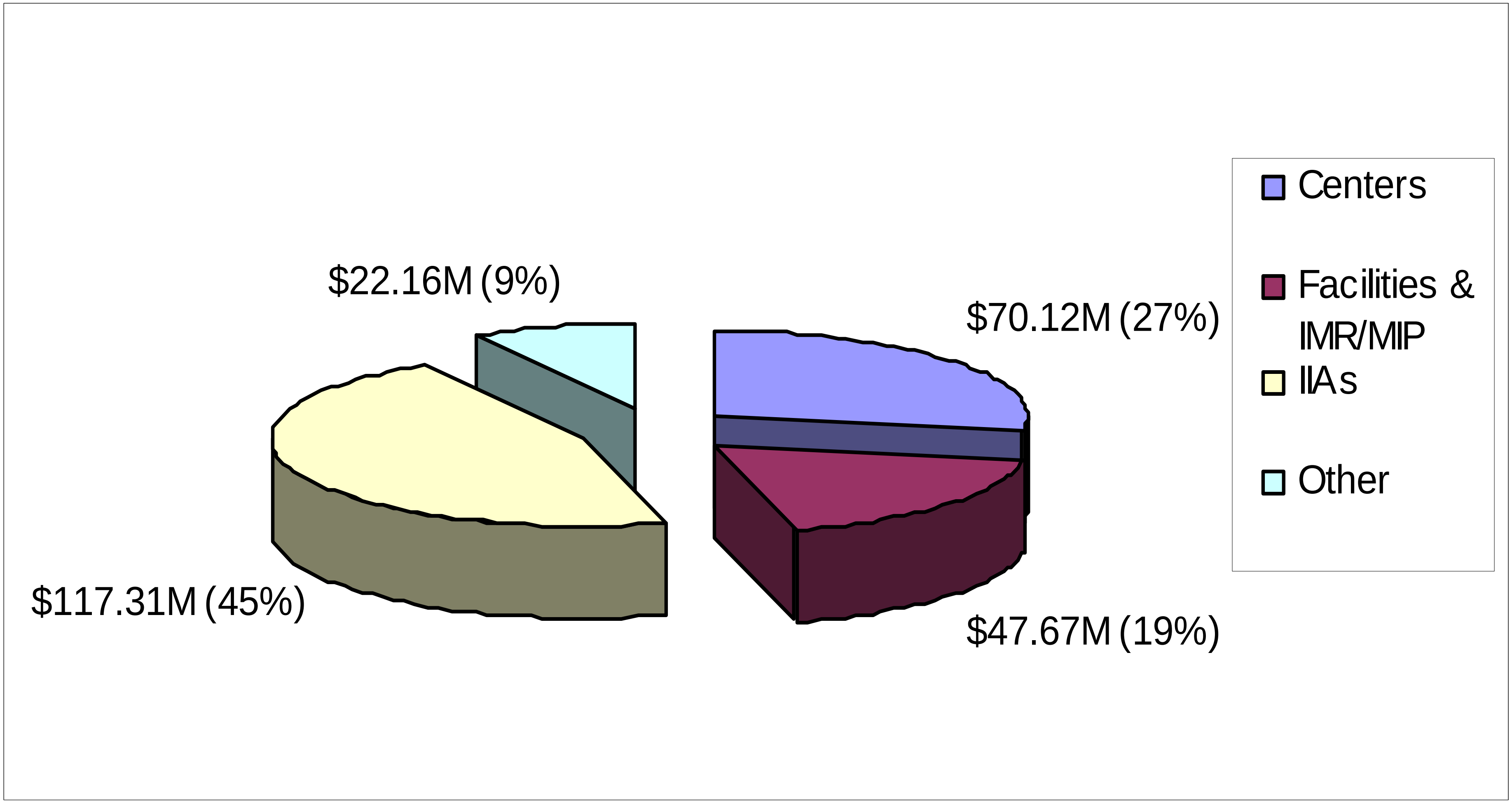
Solicitations in 2009

- CAREER
- REU sites
- CDI
- PREM
- IMI

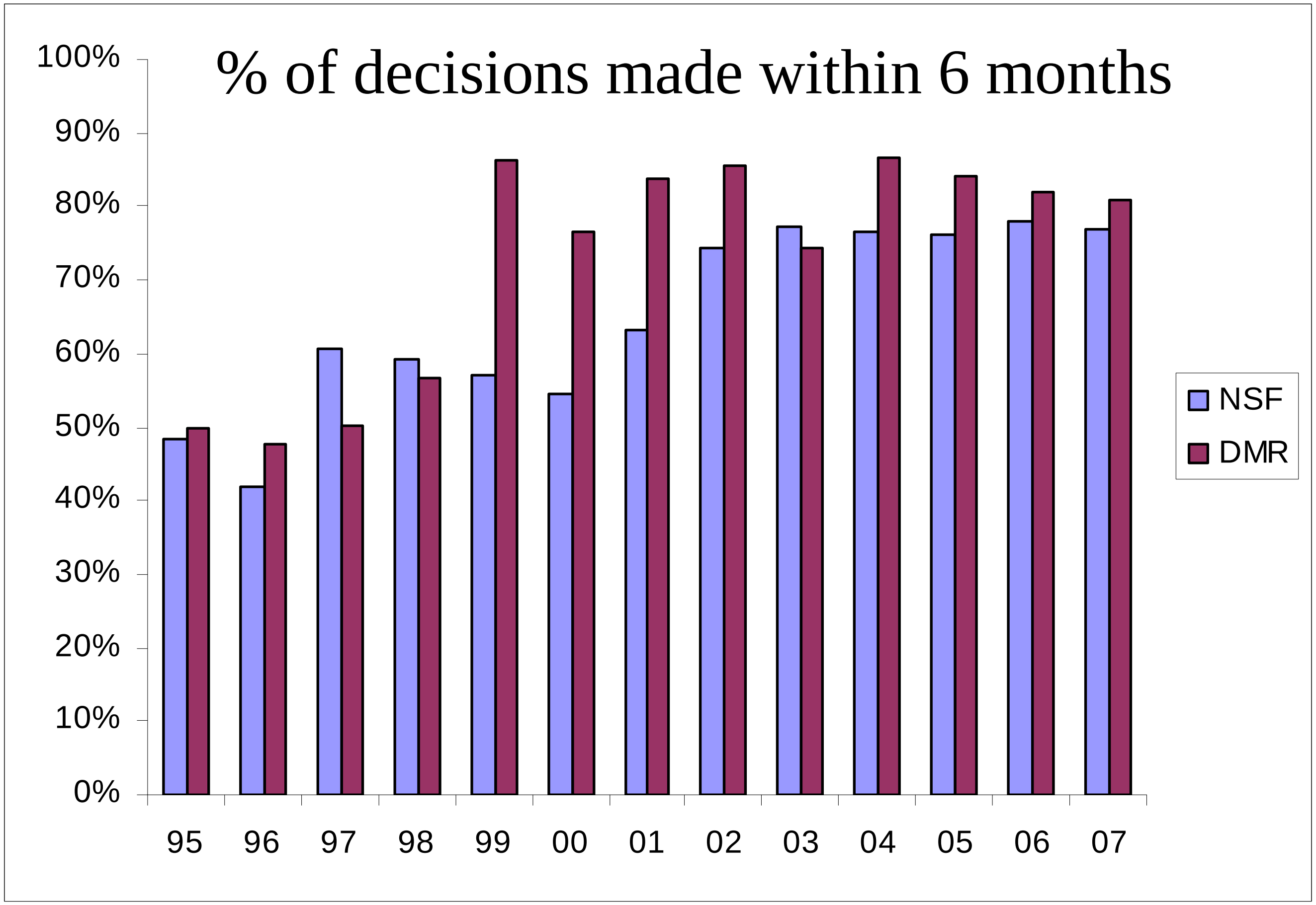
Unsolicited proposal window:

Mid-September to early November
(dates to be determined)

DMR Budget FY 2007
$257.26M



Organizational Excellence



- **We are doing better than NSF average**
- **We promise to increase it close to 90% !**
- **In fact some of the DMR programs have already reached this goal!**

DMR Facilities – Major Challenges

Facility operating costs** are **borne by DMR

I. Stewardship of the NHMFL

- DMR currently provides ~95% of NSF funding
- Serving an increasingly broad user community

Partnership is essential !

II. Stewardship of Future Light Source Facility? Future of University-Based Synchrotron Facility?

A major decision will be made based on the recommendations of the MPSAC panel on NSF role in future light source facilities!

Pilot ACI-Fellows Program in 2008

- Creativity extension awards for young investigators and/or under-represented groups
- Extend support for work that emphasizes:

 * Broadening participation and/or

 * Has a strong potential for transformative research

Diversity & Education Workshops in 2008

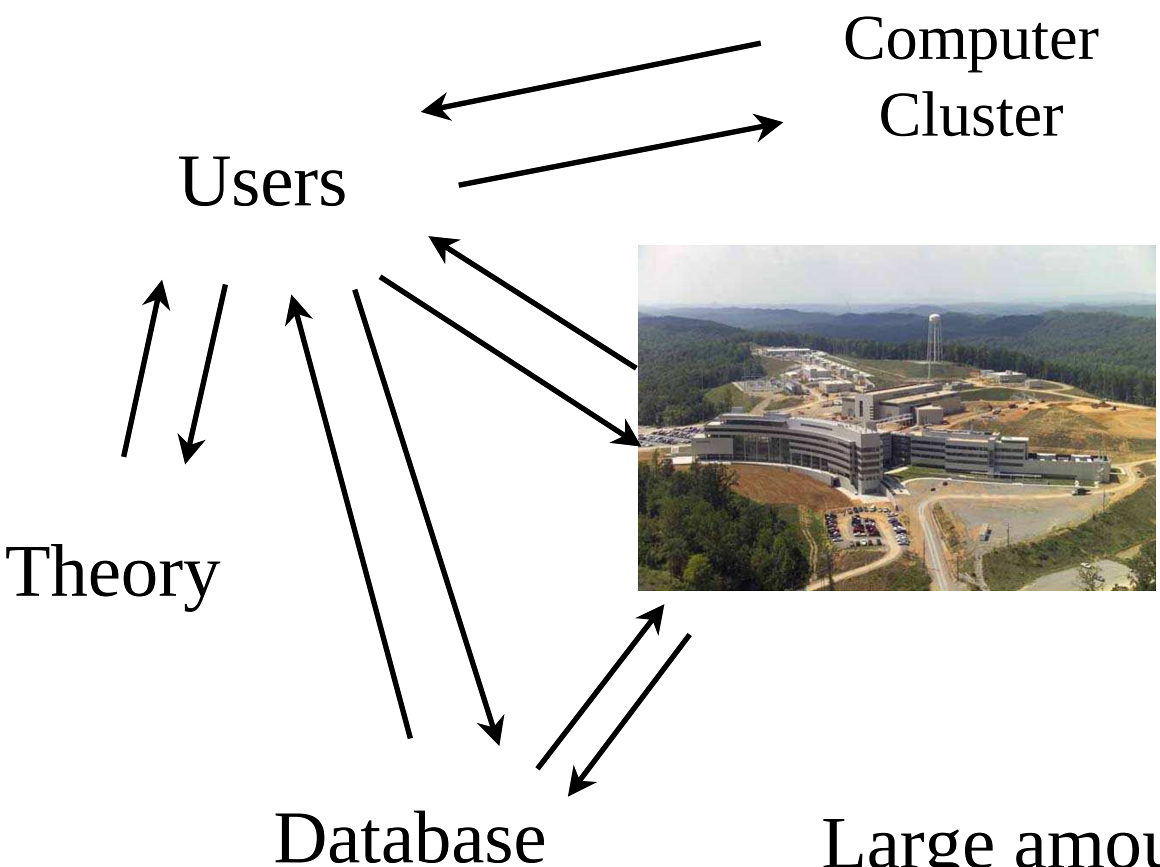
- Gender Equity Workshop (May 18-20, University of Maryland)
- Education Workshop (August 4-5, NSF)
- Workshop for Scientists with Disabilities (TBD)

DANSE

Distributed Analysis of Neutron Scattering Experiments

Spallation Neutron Source

DANSE



$1.2B for SNS

$12M for DANSE

Large amount of beam time
wasted without DANSE

Asia Participation in the Materials World Network

Current Participation

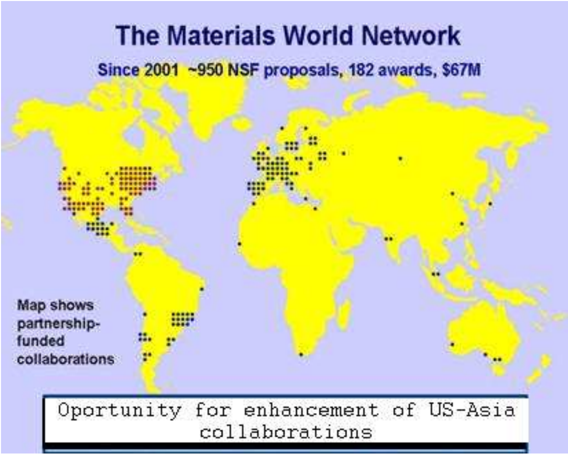
Natural Sciences Foundation-China (NSFC), China

Department of Science and Technology (DST), India

Japan Society for the Promotion of Science (JSPS), Japan

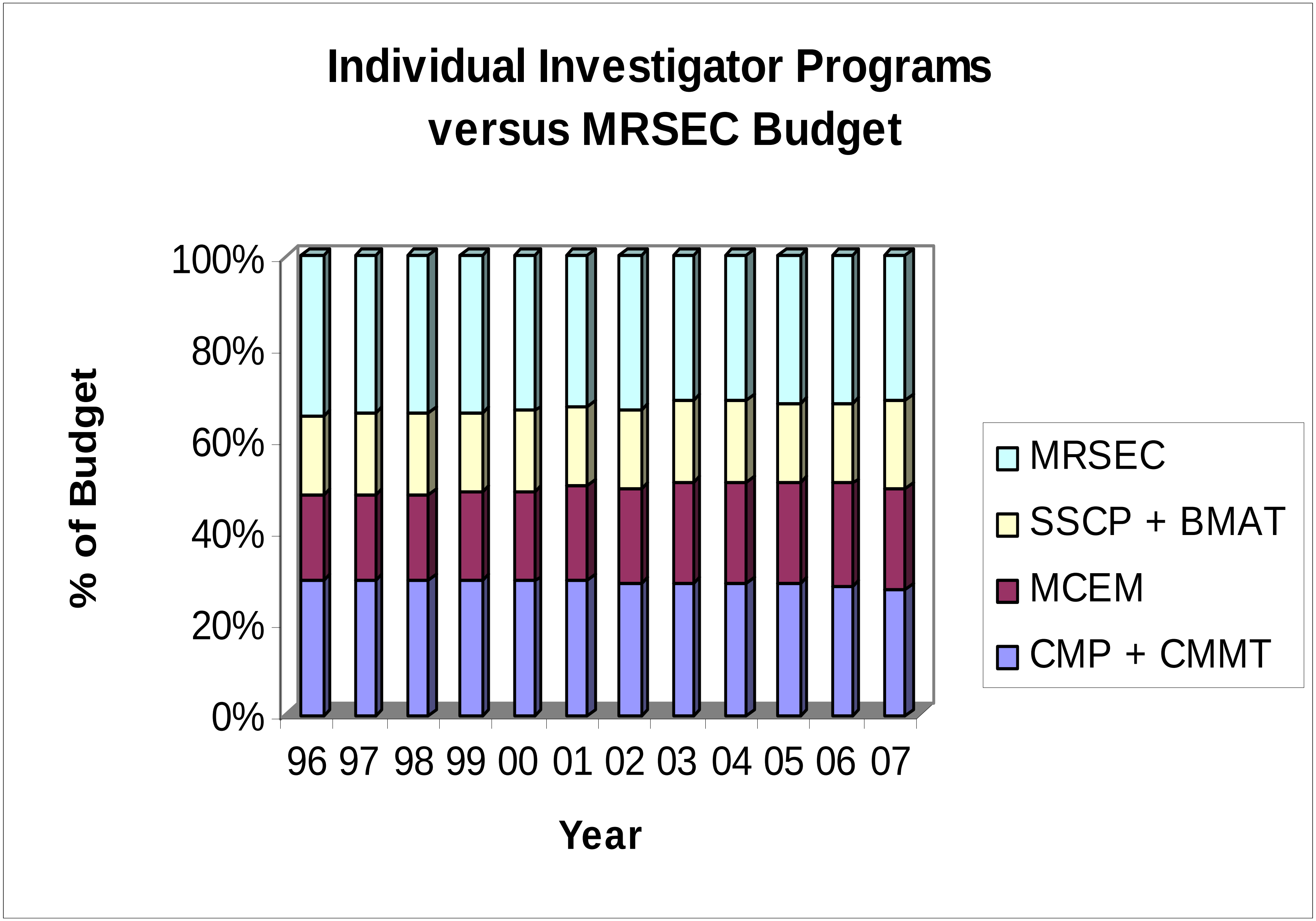
Agency for Science, Technology, and Research (A*STAR),

National Science Council, Taiwan



DMR Visit to China & Japan (10/22-11/2/2007)

- ✓ Expanded participation of NSF-China beyond 'materials science' to include condensed matter physics and polymer science
- ✓ Future yearly NSF-NSFC joint workshops alternating between USA and China
  - First one on "Materials for Renewable Energy" will be held in USA
- ✓ Possible joint summer school with Ministry of Science and Technology (MOST), China
- ✓ Incorporated the participation the following organizations in Japan in the MWN:
  - * National Institute of Materials Science (NIMS)
  - * New Energy Development Organization (NEDO)
  - * Japan Science and Technology Agency (JST)



Individual Investigator Programs
versus MRSEC Budget
100%
80%
60%
40%
20%
0%
% of Budget
96 97 98 99 00 01 02 03 04 05 06 07
Year
MRSEC
SSCP + BMAT
MCEM
CMP + CMMT

Preparing the Workforce of 21st Century

DMR supports workforce development throughout the educational continuum

- **Young investigators (CAREER, ACI-Fellows)**
- **Undergraduate students (REU)**
- **K-12 science educators (RET)**
- **Broadening Participation (PREM, ACI-Fellows, Diversity & Education Workshops)**

Transformative Tune with Quantum Drums