Astroparticle Physics – US NSF Perspective

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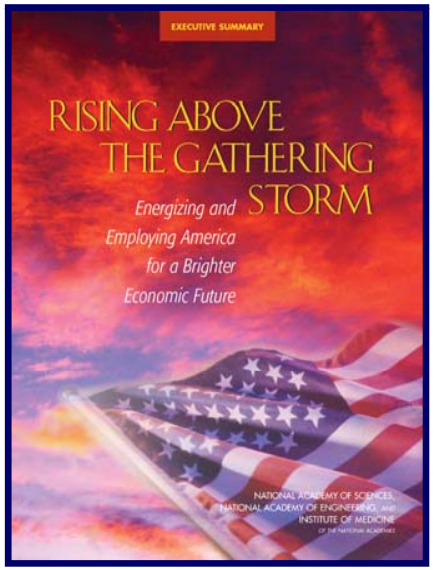
ASPERA, Amsterdam, Sept. 21, 2007

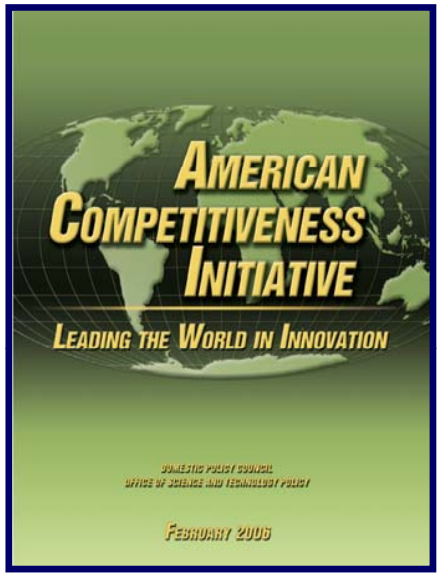
NSF in a Nutshell

- **Independent agency**
- **Supports basic research and education**
- **Uses grant mechanism in two forms**
  - **Unsolicited, curiosity driven**
  - **Solicited, more focused**
- **Peer reviews based on *intellectual merit* & *broader impact***
- **No intramural laboratories**
- **Supports large facilities**
- **Discipline-based structure**
- **Supports all fields of Science/Engineering**
- **Cross-disciplinary mechanisms**

Call for Reinvestment in STEM



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



- **From fundamental discoveries to marketable technologies.**
- **Facilities and instrumentation**
- **World class science and engineering workforce**
- **Focus on Phys Sci & Engineering**
- **Doubles NSF, DOE-OS, NIST over 10 years**

National Science Foundation

National Science Board

Director
Deputy Director

Biological Sciences

Computer & Information Science & Engineering

Engineering

Geo-sciences

Mathematical & Physical Sciences

Social, Behavioral & Economic Sciences

Office of Cyber-infrastructure

Office of Polar Programs

Office of Budget, Finance & Award Management

Office of International Sci & Engr

Office of Information Resource Management

Office of Integrated Activities

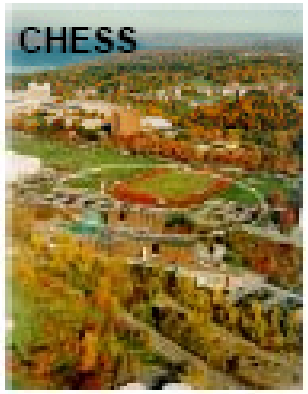
Education & Human Resources

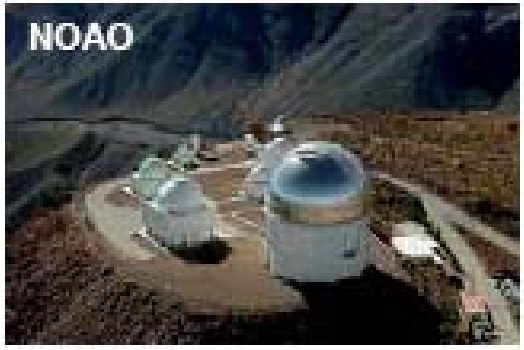
MPS Top Ten List

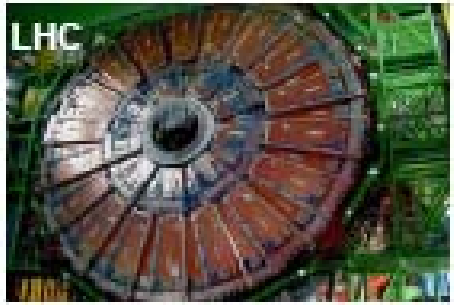
- MPS annual budget of $1.253B (NSF Budget $6.2B)
- Largest of seven directorates and five offices
- Supports 7500 university based investigators, 2300 postdocs, and 14300 students
- Five divisions: astronomy ($233M), chemistry ($211M), materials ($283M), math sciences ($223M), physics ($270M)
- Over a dozen major facilities
- Community input from National Academy, Advisory Committees, workshops, etc.
- Spectrum of research from the most fundamental to applied
- Multidisciplinary activities connecting divisions and beyond
- Strong ties with DOE, NASA, NIH, and other agencies
- Strong international ties throughout programs

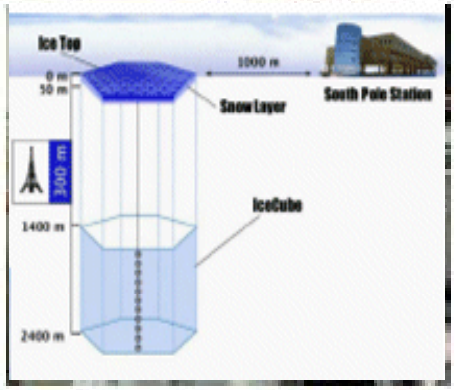
World Class Major Facilities

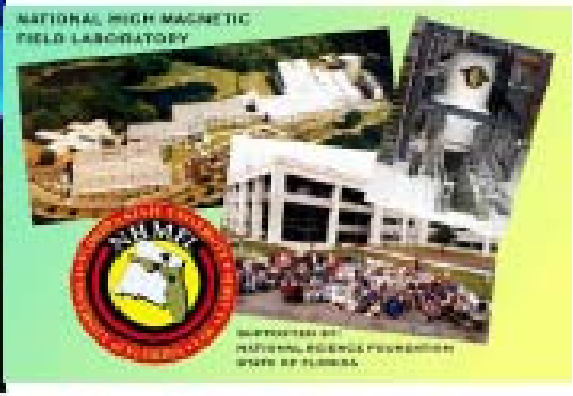
Keep University Researchers at the Frontier

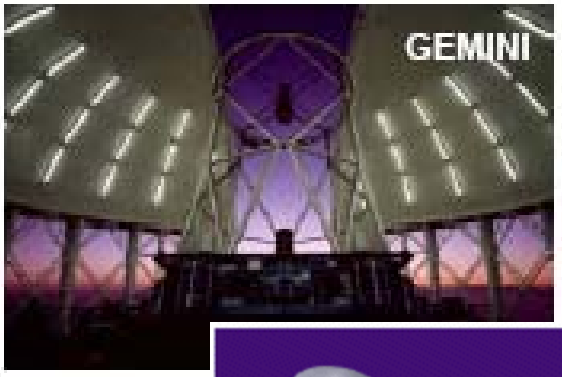


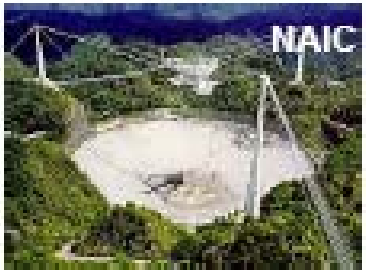








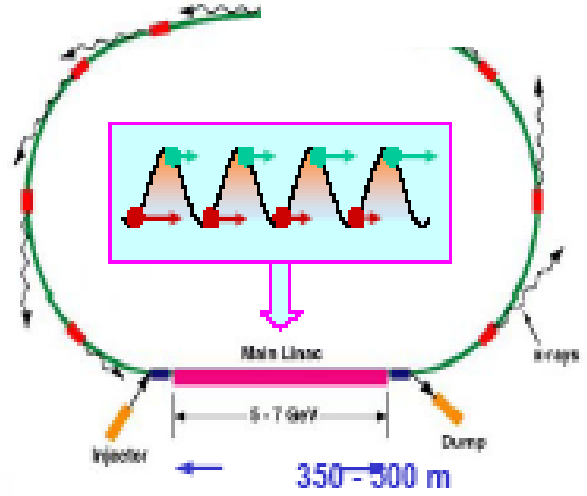


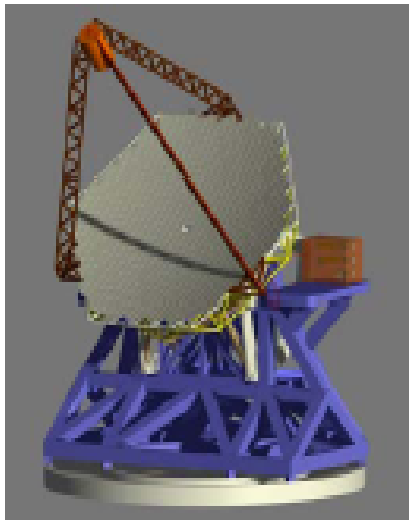


AMERICAN COMPETITIVENESS

Bold Dreams: Horizon to 2020

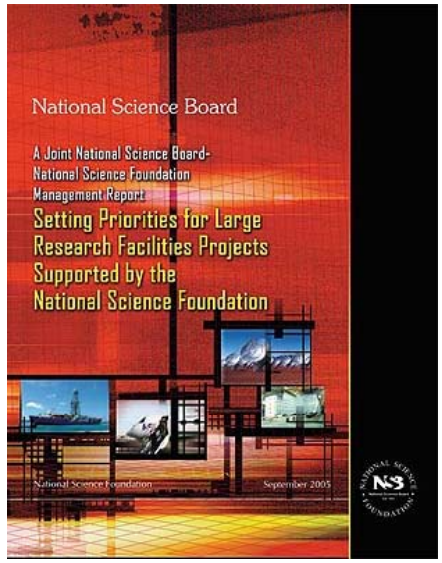
- **Advanced Technology Solar Telescope (ATST)**
- **Deep Underground Science and Engineering Laboratory (DUSEL)**
- **Coherent X-ray Light Source**
- **Giant Segmented Mirror Telescope (GSMT)**
- **Large Synoptic Survey Telescope (LSST)**
- **Square Kilometer Array (SKA)**

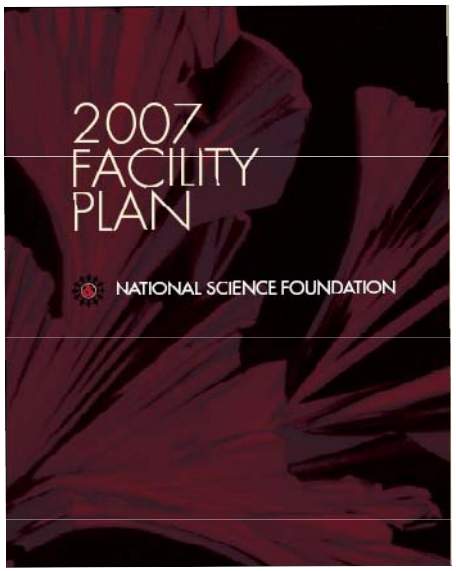




NSF Process for Major Projects

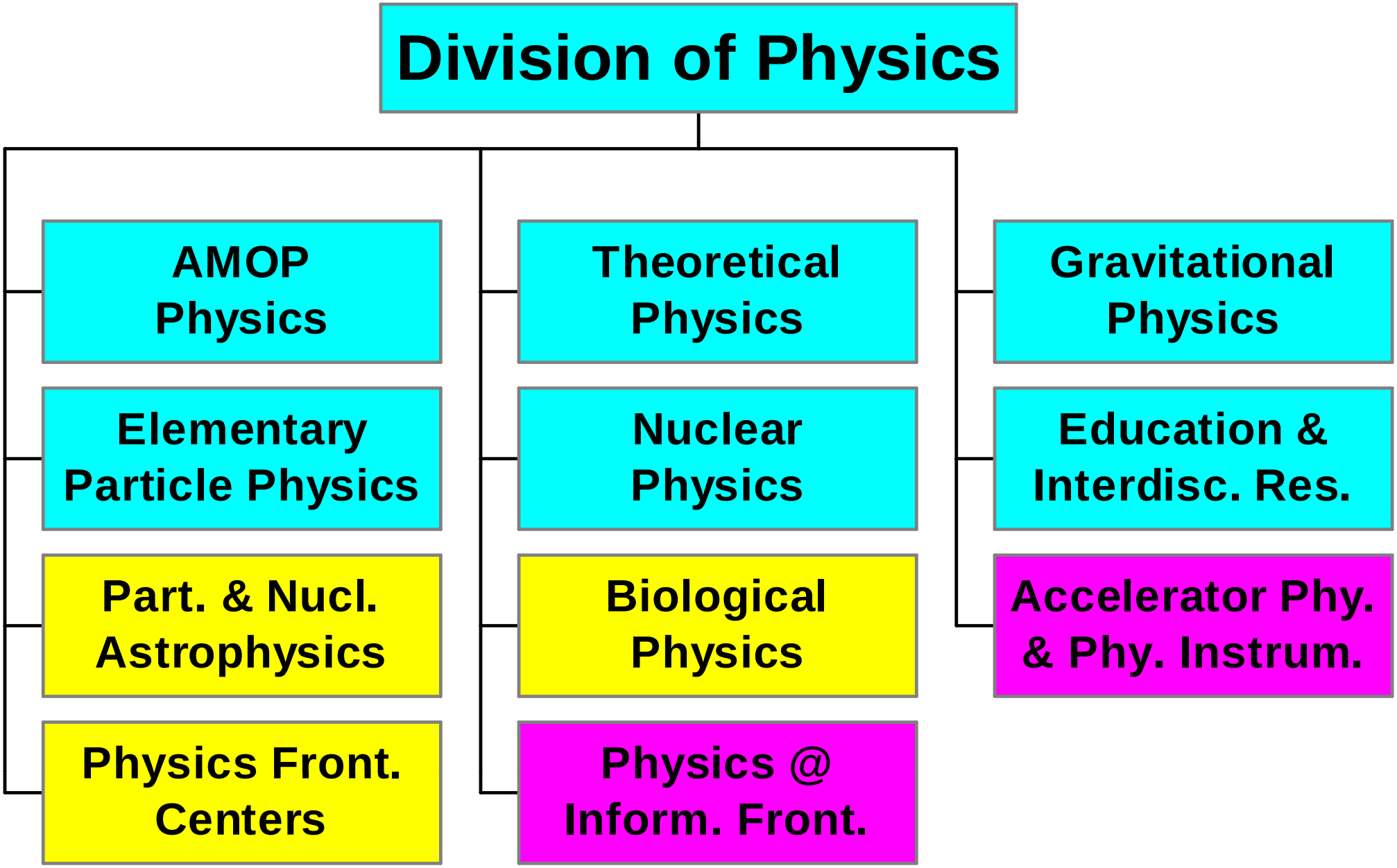
- Input from science community
  - Decadal survey, NRC Studies, HEPAP, AAAC, MPSAC
- MREFC Process
  - R&D (Div) → Construction (NSF) → M&O (Div)
  - Horizon → Readiness → Construction → Oper
  - Competition across Directorate/Divisions
  - Approval by Nat'l Science Board
  - Inclusion in President's Budget (OSTB, OMB)
- Inter-agency coordination (DOE, NASA,..)
- International partnership

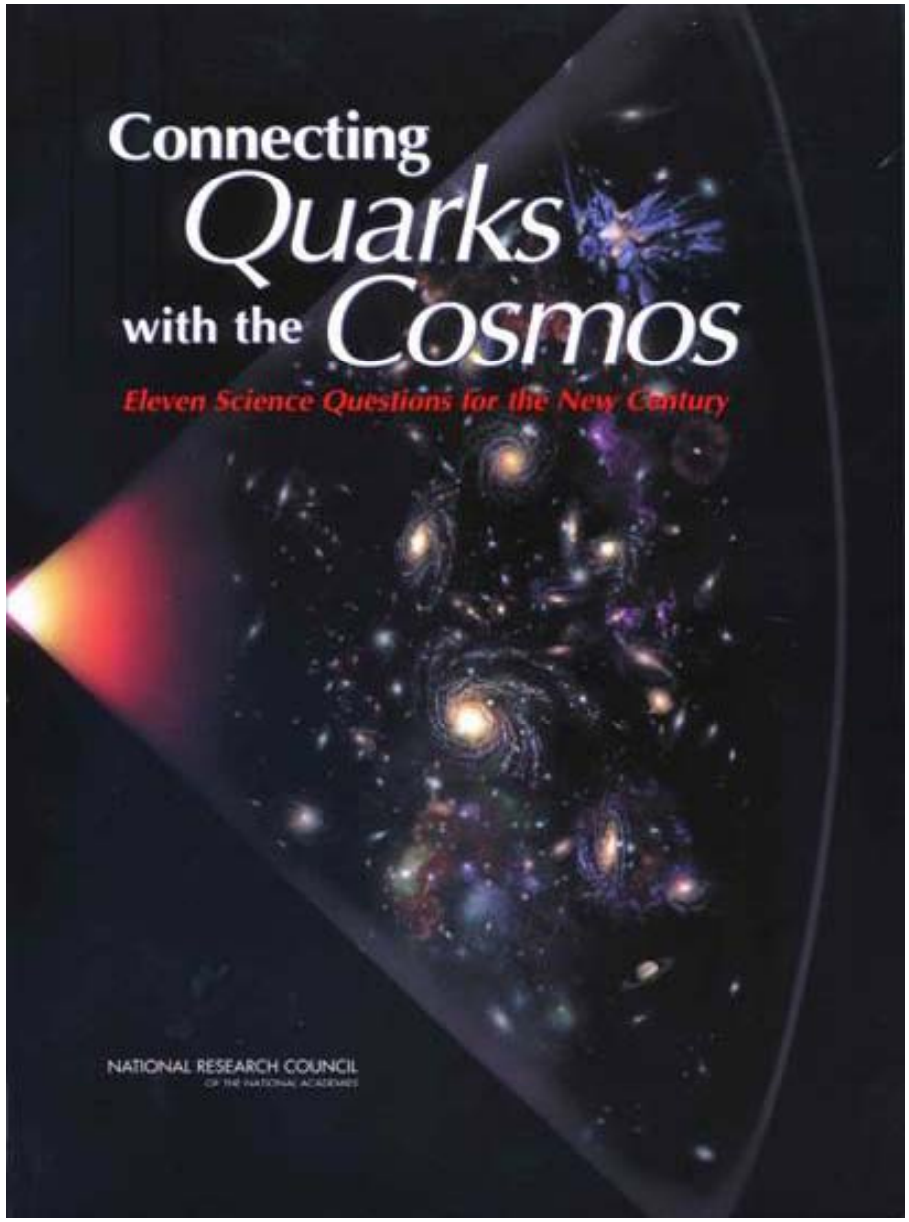




International Perspective

- Present portfolio shows extensive interagency and international partnerships
- Scientific research is intrinsically international and unites disparate cultures
- Large projects increasingly require a global approach
- International cooperation among government sponsors is challenging
- NSF seeks and welcomes partnerships to advance our intellectual frontiers


Division of Physics
AMOP Physics
Elementary Particle Physics
Part. & Nucl. Astrophysics
Physics Front. Centers
Theoretical Physics
Nuclear Physics
Biological Physics
Physics @ Inform. Front.
Gravitational Physics
Education & Interdisc. Res.
Accelerator Phy. & Phy. Instrum.



- What is dark matter?
- What is dark energy?
- How did the universe begin?
- Was Einstein right about gravity?
- How have v shaped the universe?
- What are nature's most energetic particles?
- Are protons stable?
- Are there new states of matter at exceedingly high density/energy?
- Are there additional dimensions?
- How were elements Fe to U made?
- Is a new theory needed at the highest energies and EM Fields?

Physics of the Universe

Summary of Recommendations

Ready for Immediate Investment and Direction Known

Dark Energy

* NASA and DOE will develop a Joint Dark Energy Mission (JDEM). This mission would best serve the scientific community if launched by the middle of the next decade. Studies of approaches to the JDEM mission undertaken now will identify the best methodology.
* A high-priority independent approach to place constraints on the nature of Dark Energy will be made by studying the weak lensing produced by Dark Matter. This is a scientific goal of the ground-based Large-aperture Synoptic Survey Telescope (LSST). Significant technology investments to enable the LSST are required, and NSF and DOE will begin technology development of detectors, optical testing, and software algorithms leading to possible construction with first operations in 2012. NASA will contribute their expertise as appropriate.
* Another priority method to constrain Dark Energy will be to use clusters of galaxies observed by ground-based Cosmic Microwave Background (CMB) and space-based X-ray observations. A coordinated NSF and NASA effort using this technique will provide independent verification and increase the precision of the overall measurements.

Dark Matter, Neutrinos, and Proton Decay

* NSF will be the lead agency for concept development for an underground facility. NSF will develop a roadmap for underground science by the end of 2004.
* NSF and DOE will work together to identify a core suite of physics experiments. This will include research and development needs for specific experiments, associated technology needs, physical specifications, and preliminary cost estimates.

Gravity

* NSF, NASA, and DOE will strengthen numerical relativity research in order to more accurately simulate the sources of gravitational waves.
* The timely upgrade of Laser Interferometer Gravitational wave Observatory (LIGO) and execution of the Laser Interferometer Space Antenna (LISA) mission are necessary to open this powerful new window on the universe and create the new field of gravitational wave astronomy.

Next Steps for Future Investments

Origin of Heavy Elements

* DOE and NSF will generate a scientific roadmap for the proposed Rare Isotope Accelerator (RIA) in the context of existing and planned nuclear physics facilities worldwide.
* DOE and NSF will develop a roadmap that lays out the major components of a national nuclear astrophysics program, including major scientific objectives and milestones, required hardware and facility investments, and an optimization of large-scale simulation efforts.

Birth of the Universe Using Cosmic Microwave Background

* The three agencies will work together to develop by 2005 a roadmap for decisive measurements of both types of CMB polarization. The roadmap will address needed technology development and ground-based, balloon-based, and space-based CMB polarization measurements.

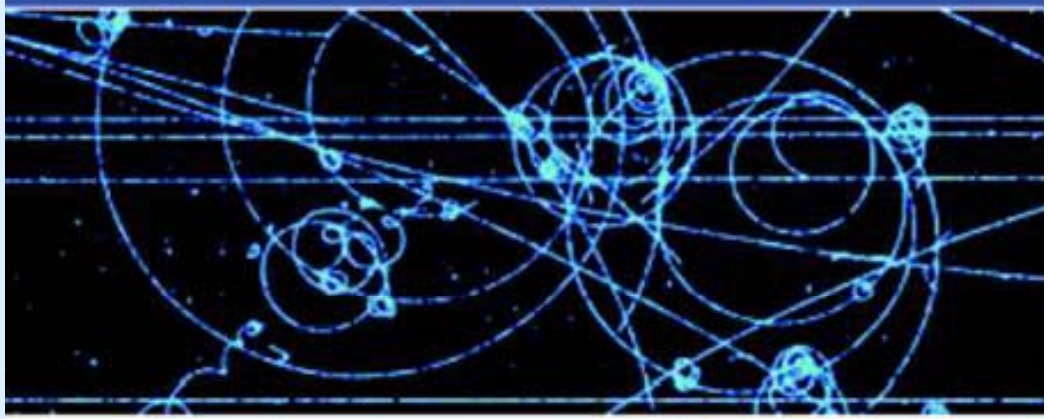
High Density and Temperature Physics

* In order to develop a balanced, comprehensive program, NSF will work with DOE, NIST, and NASA to develop a science driven roadmap that lays out the major components of a national High Energy Density Physics (HEDP) program, including major scientific objectives and milestones and recommended facility modifications and upgrades.
* NNSA will add a high energy high-intensity laser capability to at least one of its major compression facilities in order to observe and characterize the dynamic behavior of high-energy-density matter.
* DOE and NSF will develop a scientific roadmap for the luminosity upgrade of the The Relativistic Heavy Ion Collider (RHIC) in order to maximize the scientific impact of RHIC on High Energy Density (HED) physics.

A 21ST CENTURY FRONTIER FOR DISCOVERY

THE PHYSICS OF THE UNIVERSE

A STRATEGIC PLAN FOR FEDERAL RESEARCH AT THE INTERSECTION OF PHYSICS AND ASTRONOMY

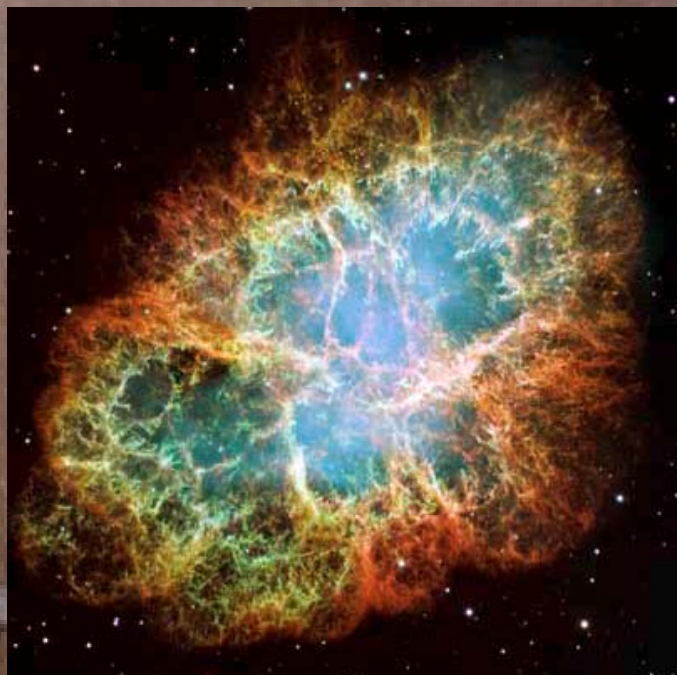


Astroparticle Physics Projects

- **Gravitational Waves: LIGO/AdvLIGO (GEO, VIRGO, TAMA, 11 countries)**
- **Cosmological Neutrinos: IceCube (Germany, Sweden, Belgium)**
- **Underground Infrastructure: DUSEL**
- **Dark Matter: CDMS, XENON, WARP, ZEPLIN, DRIFT, COUPP (DOE-HEP, INFN, PPARC, Germany, Poland)**
- **Cosmic Rays: AUGER, HiRes, TA, Veritas, Milagro (DOE-HEP, Japan, Korea, Canada, Ireland, Smithsonian, 17 more countries)**
- **Neutrinos: Borexino, Double Chooz, CUORE (DOE-NP, INFN, France, Germany, Brazil, Japan, Russia, Spain, UK)**
- **Structure of the Universe: ACT, SPT**
- **B-Mode Polarization of CMB: QUIET**
- **Origin of the Elements: NSCL (DOE-NP)**

LIGO

Part of a global network of gravitational wave detectors, including GEO, VIRGO, TAMA, and future GWDs

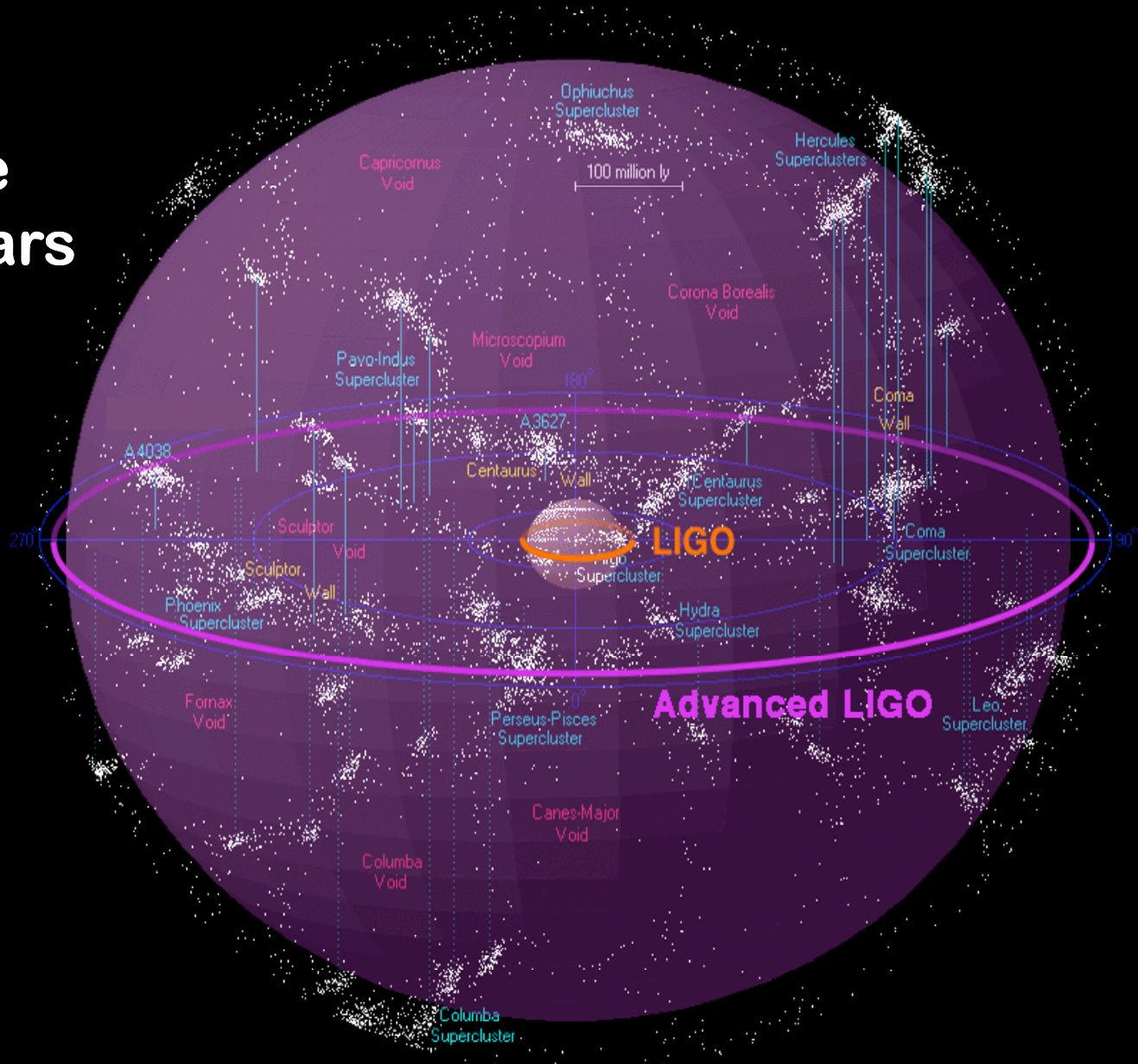


Science Goals of LIGO

- First direct detection of gravitational waves
- Open a new window on the Universe
- Explore the strong-gravity régime of Einstein's General Theory of Relativity
- Explore space and time back through the inflationary epoch, all the way to the Big Bang, when all four fundamental forces of nature were unified.

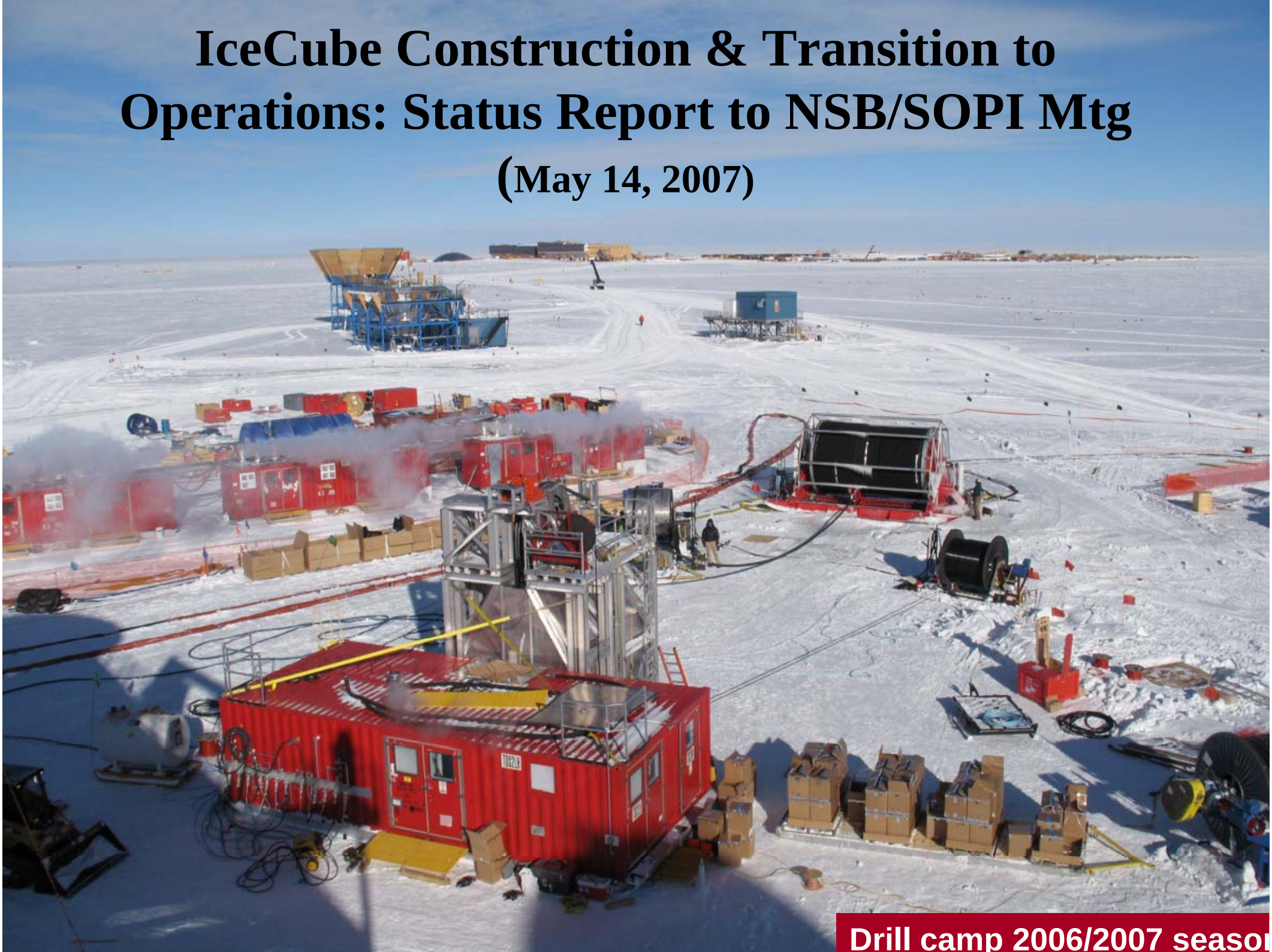
Advanced LIGO promises a 1000-fold increase in event rates

- **LIGO has a range of ~60 M light years for NS-NS mergers;**
- **AdvLIGO will have a range *~10x greater* and sample a volume of space *~1000x larger*.**



IceCube Construction & Transition to Operations: Status Report to NSB/SOPI Mtg

(May 14, 2007)



Drill camp 2006/2007 season

First String Installed at IceCube

IceCube

IceTop

Air shower detector

80 pairs of ice Cherenkov tanks

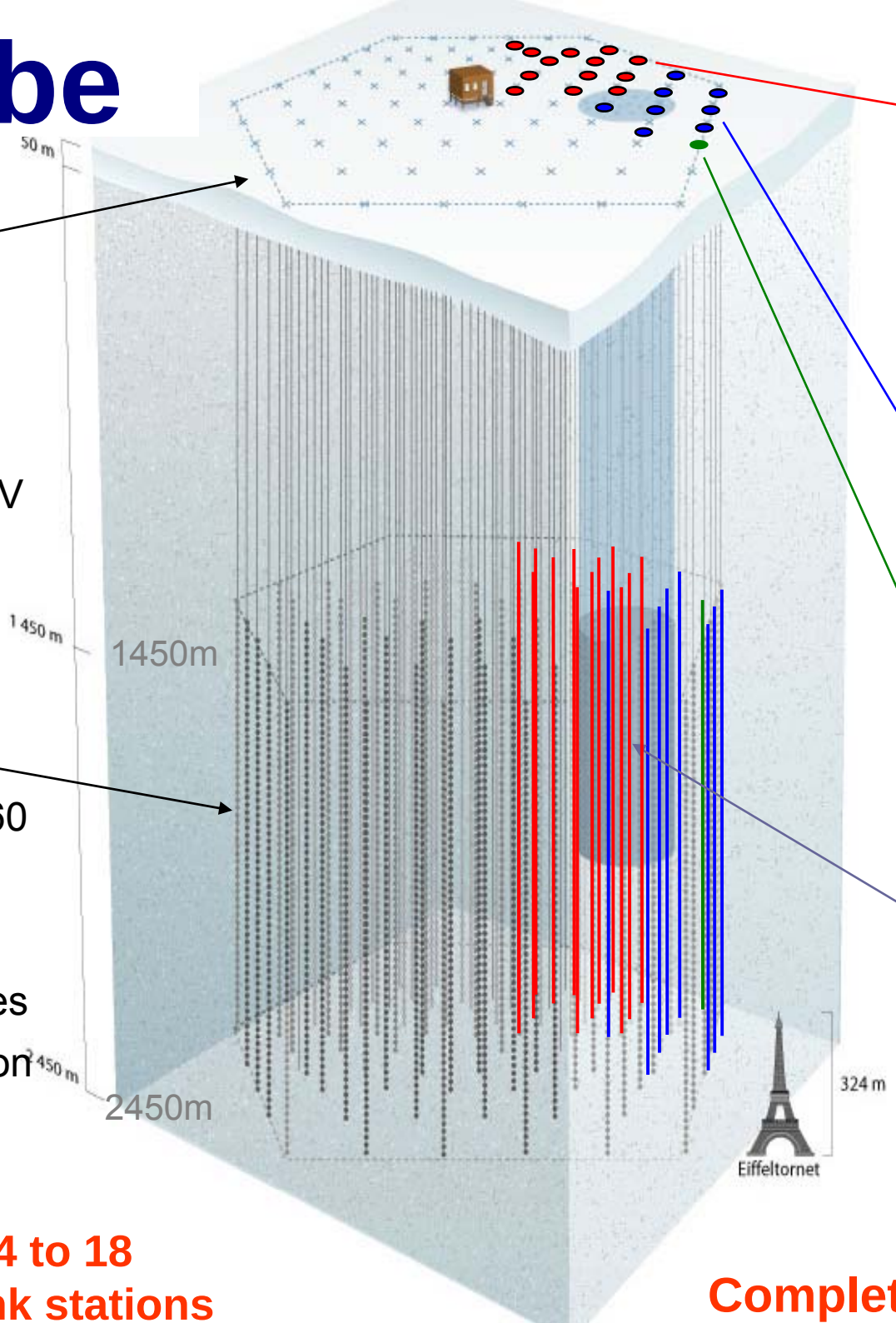
Threshold ~ 300 TeV

InIce

Goal of 80 strings of 60 optical modules each

17 m between modules

125 m string separation



2006-2007:

13 strings deployed

Current configuration
- 22 strings
- 52 surface tanks

2005-2006: 8 strings

2004-2005 : 1 string

AMANDA-II

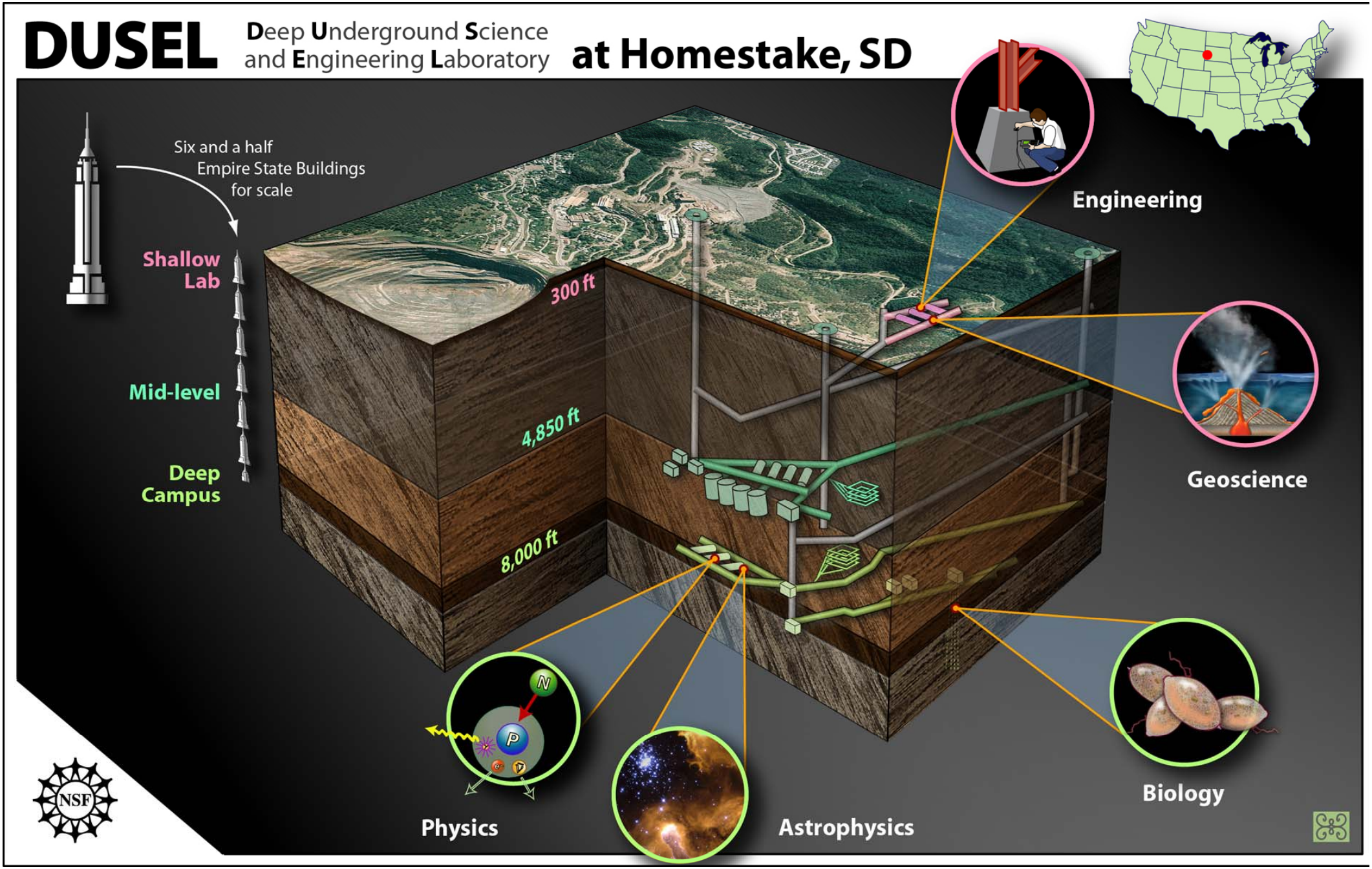
19 strings

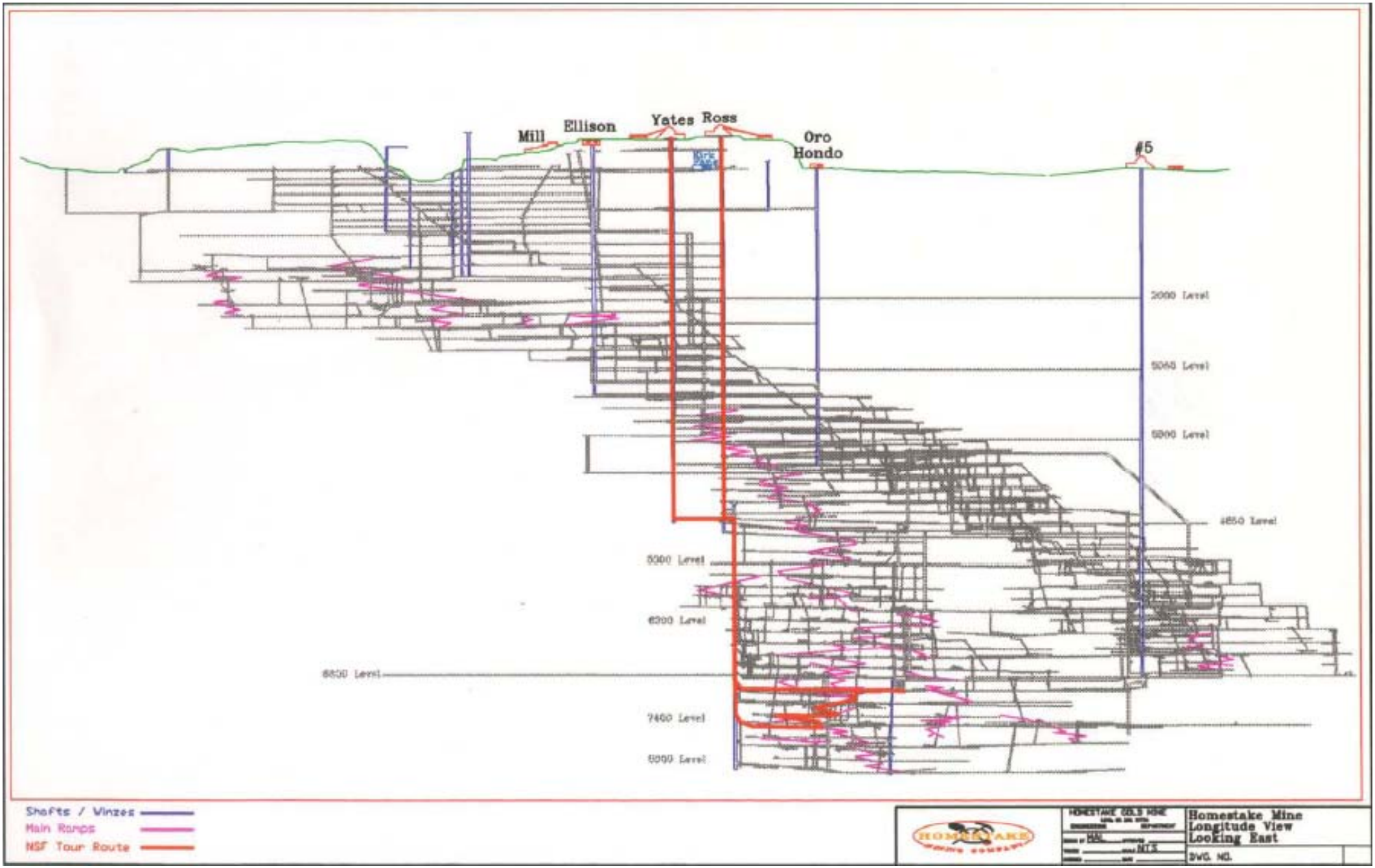
677 modules

AMANDA now operating as part of IceCube

2007/08: add 14 to 18 strings and tank stations

Completion by 2011.


DUSEL
Deep Underground Science and Engineering Laboratory
at Homestake, SD
Six and a half Empire State Buildings for scale
Shallow Lab
Mid-level
Deep Campus
300 ft
4,850 ft
8,000 ft
Engineering
Geoscience
Biology
Physics
Astrophysics
N
P
NSF


Mill
Ellison
Yates
Ross
Oro
Hondo
#5
2000 Level
5040 Level
5800 Level
4850 Level
5300 Level
6300 Level
6800 Level
7460 Level
8000 Level
Shafts / Winzes
Main Ramps
NSF Tour Route
HOMESTAKE GOLD MINE
Homestake Mine
Longitude View
Looking East
DWG. NO.

Science and Engineering Questions

- **Physics – Of what is the universe made? We see only 4 percent of the mass of the universe; what's in the other 96 percent? Is visible matter stable? Do exotic predicted forms of radioactivity actually occur? What is the mass of the neutrino, and what are its fundamental properties? How are the elements of the universe made?**

- **Biology - Did life originate underground? Are there new forms of life at such a great depth? How do microbes evolve in extreme environments? How do biology and geology interact at great depths to shape the world underground?**

- **Geology - How do tectonic forces affect the rock underground? Can seismic forces be characterized and predicted? Experiments at great depth could lead to more reliable models of Earth's crust that would relate thermal, hydrologic, mechanical, chemical, biological and mass-energy transport phenomena in a way that can't be done closer to the surface.**

- **Engineering - What are the mechanical properties of deep rock? How does it respond to human activity? Can large underground stopes be created? How does water flow deep underground, and how can those processes affect environmental concerns? Can we advance technology to make working underground safer?**

Community Planning Activities

- **Bahcall report (2001)**
- **NSAC Long-Range Plan (2002)**
- **NESS 2002**
- **Connecting Quarks to the Cosmos (2003)**
- **HEPAP Long-Range Plan (2003)**
- **Neutrinos and Beyond (2003)**
- **EarthLab (2003)**
- **DOE 20-yr. Facility Plan**
- **Physics of the Universe—A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy (NSTC) 2004**
- **The Neutrino Matrix (Four APS Divisions) 2004**
- **Quantum Universe—The Revolution in 21st Century Particle Physics, 2004**
- **A lot more activity in 2005-6: NuSAG, DarkMatterSAG, EPP2010, DEEP SCIENCE, workshops.**

NSF/Community Process

- Town Meeting at NSF, March 2004
- Solicitation (S1): define site-independent science scope and infrastructure needs; unify the community (awarded in Dec 2004)
- Solicitation (S2): develop conceptual designs for 1 or more sites (2 awarded July 2005)
- Solicitation (S3): full technical design for an MREFC candidate (1 awarded - Homestake)
- Town Meeting at NSF, November 2007
- Solicitation (S4): technical design of initial suite

International Perspective

- DUSEL, if approved, would join a distinguished, pioneering international network of underground labs.
- Coordination, collaboration by the network would greatly benefit the global program.
- DUSEL would enable next-generation experiments of great size to be put deep underground.
- NSF seeks and encourages international participation…let us know how DUSEL might be useful to your programs.