MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION $202,330,000

The FY 2004 Budget Request for Major Research Equipment and Facilities Construction (MREFC) is $202.33 million, an increase of $76.05 million, or 60.2 percent, above the FY 2003 Request of $126.28 million.

MREFC Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Major Research Equipment & Facilities Construction	$115.35	$126.28	$202.33	$76.05	60.2%

The MREFC Account supports the implementation of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. Implementation projects supported by this account are intended to extend the boundaries of technology and open new avenues for discovery for the science and engineering community. Initial concept and development, and follow on operations and maintenance costs of the facilities are provided through the Research and Related Activities (R&RA) Account.

There can be no doubt that a modern and effective research infrastructure is critical to maintaining U.S. leadership in science and engineering (S&E). The future success of entire fields of research depend upon their access to new generations of powerful research tools. Increasingly, these tools are large and complex, and have a significant information technology component.

Among Federal agencies, NSF plays a major role in providing the academic (non-medical) research community with access to forefront instrumentation and facilities. In recent years, NSF has received an increased number of requests for major research facilities and equipment from the S&E community. Many of these requests have been rated outstanding by research peers, program staff, management and policy officials, and the National Science Board. NSF's request for the MREFC Account fully funds the ongoing projects and the remaining three projects approved for funding by the National Science Board, but not yet funded, and positions the agency to meet the future needs and opportunities of the research community.

Once a project has been submitted for MREFC funding, it must undergo a multi-phase review and approval process. The process begins with a review by the MREFC Panel, which makes recommendations to the NSF Director with attention to criteria such as scientific merit, importance, readiness and cost-benefit. The Director then selects candidates for National Science Board (NSB) consideration. The NSB then approves, or not, projects for inclusion in future budget requests and establishes priorities. The Director selects from the group of NSB-approved projects those appropriate for inclusion in a budget request to OMB, and after discussion with OMB, to the Congress.

In order for a project to be considered for MREFC funding, NSF requires that it represent an exceptional opportunity that enables research and education. In addition, the project should be transformative in nature, in that it should have the potential to shift the paradigm in scientific understanding and/or infrastructure technology. NSF believes that all the projects included in this Budget Request meet these criteria.

As a general framework for priority-setting, NSF assigned priority to projects based on the following criteria:

- First Priority: Ongoing Projects – Projects where outyear funding for the full project has already been included in a Budget Request to Congress, and projects that have received initial funding for startup operations.

- Second Priority: NSB-Approved New Starts – New projects that have received NSB approval for inclusion in a budget request but which have not yet been included in a budget request or received funding.

NSF believes that the highest priority within the MREFC Account must be the current projects. To that end, highest priority in FY 2004 is to continue to request funding for:

- Atacama Large Millimeter Array Construction ($50.84 million);
- EarthScope: USArray, Plate Boundary Observatory and San Andreas Fault Observatory at Depth ($45.0 million);
- The High Performance Instrumented Airborne Platform for Environmental Research ($23.53 million);
- The IceCube Neutrino Observatory ($60.0 million);
- The George E. Brown Network for Earthquake Engineering Simulation ($8.0 million);
- The National Ecological Observatory Network ($12.0 million); and
- South Pole Station ($960,000).

In addition, three new starts are requested in FY 2005 and FY 2006. In priority order, these are: Scientific Ocean Drilling in FY 2005; Rare Symmetry Violating Processes in FY 2006; and Ocean Observatories in FY 2006.

NSF Funding for MREFC Projects, FY 2002 through FY 2008[1]
(Dollars in Millions)

	FY 2002[2] Actual	FY 2003 Request	FY 2004 Request	FY 2005 Request	FY 2006 Request	FY 2007 Request	FY 2008 Request
ONGOING PROJECTS							
ALMA Construction	12.50	30.00	50.84	49.67	48.84	47.89	46.49
EarthScope: USArray, SAFOD, PBO		35.00	45.00	54.26	40.00	23.00	
High-performance Instrumented Airborne Platform for Environmental Research	35.00		25.53				
IceCube Neutrino Observatory	10.12		60.00	33.40	34.30	35.30	36.30
Polar Aircraft Upgrades	0.89						
Large Hadron Collider	16.90	9.72					
Network for Earthquake Engineering Simulation	24.40	13.56	8.00				
National Ecological Observatories Network[3]		12.00	12.00	16.00	20.00	20.00	20.00
South Pole Station	15.55	6.00	0.96				
Terascale Computing Systems		20.00					
NEW STARTS							
Scientific Ocean Drilling				76.85	23.00		
Rare Symmetry Violating Processes					30.00	42.66	44.00
Ocean Observatories					24.76	40.33	72.46
Totals	$115.35	$126.28	$202.33	$230.18	$220.90	$209.18	$219.25

[1]Does not include funding provided for early concept and development or follow-on operations and maintenance. These funds are provided through the R&RA Account and are discussed in the following individual Activity narratives and the Tools section.
[2]FY 2002 Actuals include $16.44 million in carryover from prior year appropriations for the South Pole Station Modernization Project, the South Pole Station Safety and Environment Project, and the Polar Aircraft Upgrades. $39.88 million appropriated in FY 2002 is carried over into FY 2003 for the IceCube Neutrino Observatory and Terascale Computing Systems. This FY 2002 carryover will be reflected in the Current Plan following an FY 2003 appropriation.
[3]FY 2006-08 implementation funding for NEON will be contingent upon the outcome of the feasibility study of the NEON project and the successful review of the prototype NEON sites.
[4]FY 2002 funding for Terascale was carried over into FY 2003 due to the NSB meeting schedule. The award was approved in October, 2002 and the funds have been obligated.

FIRST PRIORITY: ONGOING PROJECTS IN FY 2004

Atacama Large Millimeter Array

Project Description: Originally referred to as the Millimeter Array (MMA), this project was conceived as an aperture-synthesis radio telescope operating in the wavelength range from 3 to 0.4 mm. ALMA will be the world's most sensitive, highest resolution, millimeter-wavelength telescope. It will combine an angular resolution comparable to that of the Hubble Space Telescope with the sensitivity of a single antenna nearly 100 meters in diameter. The array will provide a testing ground for theories of star birth and stellar evolution, galaxy formation and evolution, and the evolution of the universe itself. It will reveal the inner workings of the central black hole "engines" which power quasars, and will make possible a search for planets around hundreds of nearby stars.

The interferometer will be located at 5000m altitude near San Pedro de Atacama, Region II, Chile. The North American side of the project is led by Associated Universities, Inc./National Radio Astronomy Observatory. Europe is an equal partner in ALMA, with funding and execution of the project carried out through the European Southern Observatory (ESO). Japan may join the project at a later date.

Principal Scientific Goals: To be the most capable imaging radio telescope ever built, ALMA will bring to millimeter and submillimeter astronomy the aperture synthesis techniques of radio astronomy, enabling precision imaging to be done routinely on sub-arcsecond angular scales. ALMA will image at 1mm wavelength with the same 0.1" resolution achieved by the Hubble Space Telescope (HST) at visible wavelengths, and will form a critical complement to the leading-edge optical, infrared, ultraviolet and x-ray astronomical instruments of the twenty first century.

Principal Education Goals: ALMA will play a central role in the education and training of U.S. astronomy and engineering students; at least 15% of ALMA's ~1000 users per year are expected to be students. There is already substantial involvement by graduate students in applied physics and engineering at universities participating in the ALMA Design and Development program.

Partnerships and Connections to Industry: Europe is an equal partner in ALMA, and Canada has joined the U.S. in the North American half of the partnership. ALMA instrumentation will push gallium arsenide (GaAs) and indium phosphide (InP) transistor amplifier technology to high frequencies, will challenge production of high-density, high-speed integrated circuits for computational uses, and can be expected to stimulate commercial device and communication technologies development.

Management and Oversight: Programmatic management is the responsibility of the ALMA Staff Associate in the Astronomical Sciences (AST) Subactivity in the Mathematical and Physical Sciences (MPS) Activity. NSF's ALMA advisory group, consisting of representatives from the Office of General Counsel, the Office of Budget, Finance and Award Administration and the Office of Legislative and Public Affairs serves as a standing Project Advisory Team. AST's external MMA Oversight Committee (MMAOC) has been advising NSF on the project since early 1998 and comprises half of the International ALMA Management Advisory Committee. Management of the National Radio Astronomy Observatories effort on ALMA is through a Cooperative Agreement with the Associated Universities Incorporated (AUI).

Current Project Status: The $12.50 million appropriated for the start of ALMA construction in FY 2002 has permitted the Project to make a smooth transition from Design and Development into an efficiently operating, international construction partnership.

Milestones originally set for FY 2002 and their status follows:

Finalize and sign International ALMA Construction and Operations Agreement (3rd quarter) [Cleared by NSF, Department of State and ESO, now awaiting signature ceremony];
Deliver U.S. prototype antenna and radiometric instrumentation to New Mexico test site (3rd quarter) [radiometric instrumentation delivered 3rd quarter; antenna completed 1st quarter FY 2003];
Begin testing prototype antenna at New Mexico test site (4th quarter) [began 1st quarter 2003];
Deliver antenna foundation designs for Chile site (4th quarter) [on time];
Establish precise GPS locations for ALMA antenna stations, and begin advanced engineering and architectural analysis (4th quarter) [on time]; and
Deliver final ALMA site Environmental Impact Survey to Chilean authorities (4th quarter) [on time].

Current FY 2003 milestones are:
Initiate design contracts for site roads, buildings and utilities (3rd quarter);
Complete assessment of antenna prototype performance (4th quarter);
Deliver prototype correlator (4th quarter);
Deliver prototype IF transmission system (4th quarter);
Let contract for fabrication of production quantities of SiS mixers for 211-275 GHz receiver band (4th quarter); and
Release draft RFP for ALMA antenna production units (4th quarter).

Major milestones for FY 2004 include:
Begin integration of backend prototype hardware (2nd quarter)
Begin initial phase of site construction (2nd quarter);
Evaluate proposals for ALMA production antennas (3rd quarter, dependent on procurement strategy).
Award production antenna contract (3rd quarter, dependent on procurement strategy).

Projected Outyear Milestones: The milestones below are based on the current version of the ALMA project plan and represent a general outline of anticipated activities for FY 2005 and beyond.

FY 2005 Milestones:
Complete initial phase of site construction.

FY 2006 Milestones:
First production antenna unit delivered to Chile and installed on site;
First quadrant of correlator (for 32 antennas at full bandwidth) delivered to Chile;
First antenna testing front end delivered to Chile.

FY 2007 Milestones:
Complete infrastructure for engineering and commissioning observations (data pipeline verified, staff fully in place);
First complete production front end delivered to Chile.

FY 2008 Milestones:
First ALMA interim science observations;
A total of 19 antennas will have been delivered to Chile.

FY 2009 Milestones:
Full correlator (for 64 antennas at full bandwidth) completed in Chile;
A total of 34 antennas will have been delivered to Chile.

FY 2010 Milestones:
Begin final phase of site work (antenna foundations for 14km configuration; final road work; complete office/lab facilities);
A total of 49 antennas will have been delivered to Chile.

Funding Profile: The estimated cost to construct ALMA is $702 million. The U.S. share of the joint array construction is estimated to be $344 million; the construction of the array is expected to take 9 years. Joint detailed cost and scope studies of the array by the partners have been carried out, and a high-level agreement, specifying the details of the U.S.-European capital construction partnership, has been drafted. Canada will join the U.S. side of the ALMA partnership and Japan remains interested in the possibility of joining ALMA as a third major partner, possibly as early as 2004.

A $26.0 million, three-year Design and Development Phase was originally planned for the MMA project. However, since the original three-year plan was initiated, the U.S. entered into a partnership with a European consortium to develop ALMA. Because of the expanded managerial and technical complexity of the ALMA concept, an additional year of Design and Development was supported in FY 2001, at a budget level of $5.99 million. Construction was initiated in FY 2002.

MREFC Appropriations for ALMA
(Dollars in Millions)

	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08 Through FY 10	Total
ALMA R&D	9.00	9.00	8.00	5.99								31.99
ALMA Construction					12.50	30.00	50.84	49.67	48.84	47.89	104.39	344.13
Total, ALMA	$9.00	$9.00	$8.00	$5.99	$12.50	$30.00	$50.84	$49.67	$48.84	$47.89	$104.39	376.12

ALMA Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation[1]		Operations & Maintenance[2]		Totals		Grand
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	Total
FY 1994 & Earlier	0.25						$0.25	$0.00	**$0.25**
FY 1995	0.35						$0.35	$0.00	**$0.35**
FY 1996	0.50						$0.50	$0.00	**$0.50**
FY 1997	0.75						$0.75	$0.00	**$0.75**
FY 1998		9.00					$0.00	$9.00	**$9.00**
FY 1999		9.00					$0.00	$9.00	**$9.00**
FY 2000		8.00					$0.00	$8.00	**$8.00**
FY 2001		5.99					$0.00	$5.99	**$5.99**
FY 2002				12.50			$0.00	$12.50	**$12.50**
FY 2003 Req				30.00			$0.00	$30.00	**$30.00**
FY 2004 Req				50.84			$0.00	$50.84	**$50.84**
FY 2005 Est				49.67	1.00		$1.00	$49.67	**$50.67**
FY 2006 Est				48.84	2.00		$2.00	$48.84	**$50.84**
FY 2007 Est				47.89	5.00		$5.00	$47.89	**$52.89**
FY 2008 Est				46.49	10.00		$10.00	$46.49	**$56.49**
FY 2009 Est				37.37	14.00		$14.00	$37.37	**$51.37**
FY 2010 Est				20.53	19.00		$19.00	$20.53	**$39.53**
FY 2011 Est					23.00		$23.00	$0.00	**$23.00**
FY 2012 Est					23.00		$23.00	$0.00	**$23.00**
Subtotal, R&RA	$1.85		$0.00		$97.00		$98.85		
Subtotal, MREFC		$31.99		$344.13		$0.00		$376.12	
Total, Each Phase		**$33.84**		**$344.13**		**$97.00**			**$474.97**

NOTE: A steady state of about $23 million annually is anticipated for operations support beginning in FY 2012. The expected operational lifespan of this project is at least 30 years.
[1]Based on cost review of original MMA and then projected to ALMA.
[2]Estimates for FY 2005 and beyond are placeholders only, and are not intended to reflect actual budget requirements.

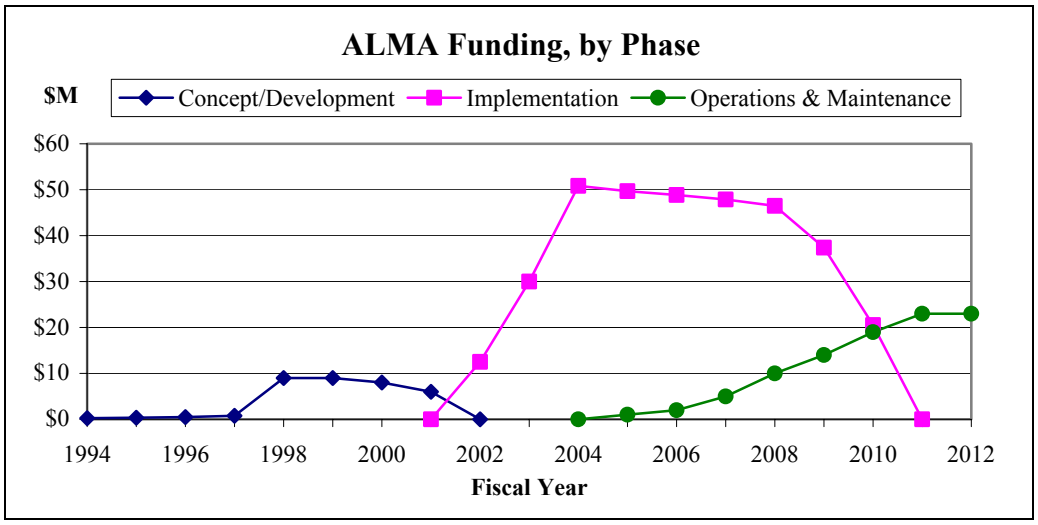
Information pertaining to the data in the table is included below.

- *Concept/Development*: Prior to FY 1998, the National Radio Astronomy Observatory (NRAO) utilized funds provided through the R&RA account to advance the conceptual development of the Millimeter Array, the U.S.-only antecedent to ALMA. Funds were spent on planning workshops, array design and optimization, developing project construction and operations costs, and on site searches and surveys. The planning, design and development supported through the MREFC account achieved the goals set for (i) a refined and audited cost estimate with project milestones, (ii) the selection of a site, (iii) the development of an international partnership with defined shared costs, and (iv) the procurement of prototype antennas.

- *Implementation*: Will fund an array of 64 12-meter antennas having a total collecting area of 7,200 square meters, with 4 receiver bands extending into the submillimeter. The table describes the U.S.

contribution to ALMA and does not address the reduction in costs due to Canada's participation. Outyear costs are adjusted for inflation using the inflators provided by OMB.

- *Operations and Maintenance*: Operations and maintenance funds begin to phase in as initial site construction is completed and antennas begin to be delivered, and are currently only estimates. Funds will be used to manage and support site and instrument maintenance, array operations in Chile, early and eventually full science operations, and in support of ALMA observations by the U.S. science community. The first full year of ALMA science operations is anticipated for FY 2012.



Future Science Support: Along with direct operations and maintenance support for ALMA, NSF will support research performed at the facility, through ongoing research and education programs. The annual support for such activities is estimated to be about $10 million, once the facility reaches full operations.

EarthScope

Project Description: EarthScope is a distributed, multi-purpose geophysical instrument array that will make major advances in our knowledge and understanding of the structure and dynamics of the North American continent. It is planned as a distributed facility – parts of EarthScope are expected to inhabit nearly every county within the U.S. over the project's life span. NSF, the U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the International Continental Scientific Drilling Programme will be funding partners, with USGS and NASA expected as operating partners. Project partners may also include state and local governments, geological and engineering firms, and Canadian and Mexican agencies. Over 3000 earth scientists and students are expected to use the facility annually.

Principal Scientific Goals: Enhanced understanding of earthquakes and seismic hazards, magmatic systems and volcanic hazards, lithospheric dynamics, regional tectonics, continental structure and evolution, fluids in the crust, and associated educational aspects.

Principal Education Goals: To engage science and non-science students in geosciences discovery through the use of technology in real or retrospective time with the aim of integrating research and education.

Partnerships and Connections to Industry: Geotechnical and engineering firms directly use data and models, which will be enabled by EarthScope. Instrumentation firms will collaborate on development for state-of-the-art seismic systems, down-hole instrumentation, and high-precision GPS antenna designs.

Management and Oversight: The NSF coordinator is the Section Head for Special Projects, located in the Earth Sciences (EAR) Subactivity in the Geosciences (GEO) Activity. Other internal oversight is provided by a Project Advisory Team including staff from GEO, the Office of the General Counsel and the Office of Budget, Finance and Award Management. Following the recommendations of a favorable National Academy of Sciences review of EarthScope, an EarthScope Science and Education Committee (ESEC) was formed to provide an advisory structure to ensure coordination of facility construction and operation, science, education and outreach, and information technology efforts.

Current Project Status: FY 2003 highlights include dedicated workshops to refine the EarthScope science plan, organize education and outreach, strengthen coordination with EarthScope partners at NASA and the USGS, and refine communications/information technology capabilities. In partnership with the International Continental Scientific Drilling Programme, work was completed on the pilot hole instrumentation package development. In FY 2003, funds were requested to initiate construction of the EarthScope facility. Major FY 2004 milestones will include the initiation of airborne imaging of potential study sites, beginning of equipment acquisition and installation, awarding of the San Andreas Fault Observatory at Depth drilling contract, and construction of the down-hole monitoring string.

EarthScope's construction schedule is still under review and discussion. The milestones listed below are preliminary and will likely be revised as the project's schedule is finalized.

FY 2003 Milestone:

Award for EarthScope MREFC construction phase completed (4th quarter);

FY 2004 Milestones:

Compete and award contracts for broadband and short-period seismic systems (1st quarter);
Community planning on permanent seismic sites and first array deployment (1st quarter);
San Andreas Fault Observatory at Depth main hole drilling contract competed and awarded (3rd quarter);
Drilling begins at end of year (4th quarter);
Down-hole monitoring equipment constructed (3rd quarter);
Acquisition begins for GPS and borehole strain systems (2nd quarter);
Airborne imaging of potential study sites (2nd quarter);
Delivery of 50 portable GPS systems (4th quarter);
Delivery and installation of 100 GPS and 20 borehole-strain systems (4th quarter); and
NSF conducts first annual review of EarthScope (4th quarter).

FY 2005 Milestones:

Delivery and installation of 50 transportable array sites;
Delivery and installation of 500 flexible pool short period sites;
Delivery and installation of 5 Global Seismic Network (GSN) and 10 National Seismic Network (NSN) permanent stations in cooperation with the Advanced National Seismic System (ANSS);
Main hole completed at San Andreas Fault Observatory;
Down-hole monitoring instrumentation installed;

Airborne imaging of potential study sites;
Delivery and installation of 175 GPS and 30 borehole-strain systems;
Delivery and deployment of 50 portable GPS systems; and
NSF conducts annual review of project status.

FY 2006 Milestones:
Delivery and installation of 200 transportable array sites;
Delivery and installation of flexible pool sites: 200 broadband and 1000 short period seismic systems;
Delivery and installation of 5 GSN and 10 NSN permanent stations (in cooperation with ANSS);
San Andreas Fault site characterization studies carried out;
Delivery and installation of 200 GPS and 50 borehole-strain systems;
Deployment of 50 portable GPS systems; and
NSF conducts annual review of project status;

FY 2007 Milestones:
Delivery of 150 and installation of 200 transportable array sites;
Delivery of flexible pool sites: 200 broadband and 500 short period;
Installation of flexible pool sites: 200 broadband and 1000 short period;
Delivery and installation of 5 NSN permanent stations (in cooperation with ANSS);
Use site characterization and monitoring data to choose four coring intervals at depth in San Andreas Fault Observatory. Commence coring operations;
Delivery and installation of 200 GPS and 50 borehole-strain systems; and
NSF conducts annual review of project status;

FY 2008 Milestones:
Redeployment of USArray;
Install permanent monitoring instrumentation in four core intervals and main hole of San Andreas Fault Observatory at Depth;
Delivery and installation of 200 GPS and 50 borehole-strain systems; and
NSF conducts annual review of project status.

FY 2009 – FY 2013 Milestones:
Redeployment of USArray on a continual basis;
Complete analysis of San Andreas Fault cores, cuttings and logs. Continue monitoring at depth;
Ongoing operation and maintenance of the PBO; and
NSF conducts biennial reviews of project status.

Funding Profile: Conceptual planning for the EarthScope project has developed over the past decade. NSF has funded planning, design and development since FY 1998, and is ready to implement a five-year period of acquisition, construction and commissioning beginning in FY 2003.

MREFC Appropriations for EarthScope
(Dollars in Millions)

FY 2003 Request	FY 2004 Request	FY 2005	FY 2006	FY 2007	Total
$35.00	$45.00	$54.26	$40.00	$23.00	$197.26

EarthScope Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1994 & Earlier									
FY 1995									
FY 1996									
FY 1997									
FY 1998	1.00						$1.00		**$1.00**
FY 1999	1.00						$1.00		**$1.00**
FY 2000	1.00						$1.00		**$1.00**
FY 2001	2.00						$2.00		**$2.00**
FY 2002	1.00						$1.00		**$1.00**
FY 2003 Req				35.00			$0.00	$35.00	**$35.00**
FY 2004 Req				45.00	1.00		$1.00	$45.00	**$46.00**
FY 2005 Est				54.26	3.00		$3.00	$54.26	**$57.26**
FY 2006 Est				40.00	5.00		$5.00	$40.00	**$45.00**
FY 2007 Est				23.00	11.00		$11.00	$23.00	**$34.00**
FY 2008 Est					13.00		$13.00		**$13.00**
Subtotal, R&RA	$6.00				$33.00		$39.00		
Subtotal, MREFC				$197.26				$197.26	
Total, each phase		**$6.00**		**$197.26**		**$33.00**			**$236.26**

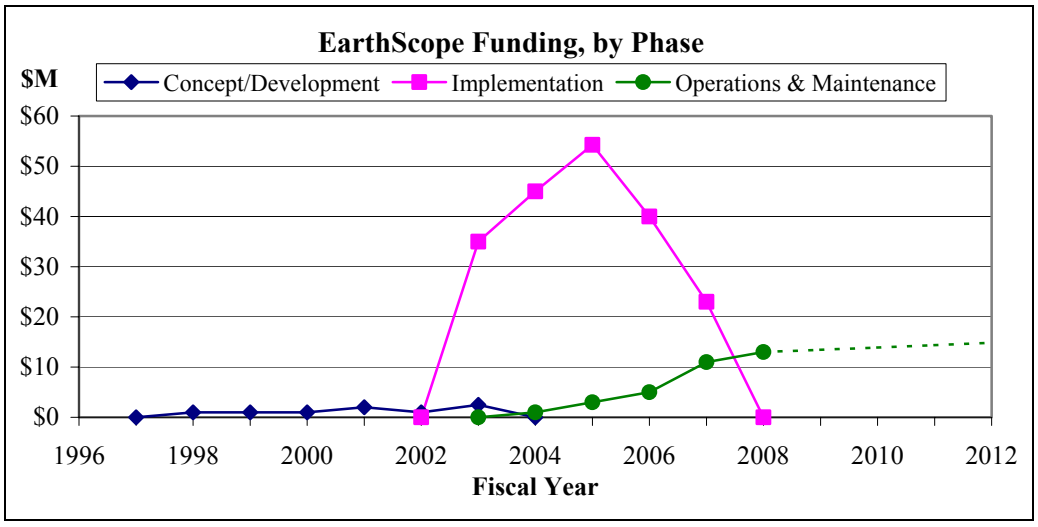
NOTE: A steady state of $13 million in operations support is anticipated by FY 2008. The expected operational lifespan of this project is 15 years after construction is complete in FY 2007.

Information pertaining to the data in the table is provided below.

- *Concept/Development*: FY 1998-FY 2000 funds were used to support workshops, instrument development, and installation technique development appropriate to EarthScope, from existing programs within the Division of Earth Sciences. Dedicated funding was established for FY 2001-03 supporting pre-EarthScope activities that would facilitate the construction and installation. This funding supports meetings, workshops, instrumentation prototype development, installation technique development, and site selection activities.

- *Implementation*: During FY 2003-07, the project will put in place three components of the distributed EarthScope system: (1) the USArray - portable seismometers for deployment across North America; (2) the San Andreas Fault Observatory at Depth - to monitor fault conditions; and (3) the Plate Boundary Observatory – an array of GPS monitors and borehole strain systems to monitor crustal deformation.

- *Operations and Maintenance*: Operations and maintenance will begin to phase-in during the first year of construction. When EarthScope is completed it will be managed, operated and maintained by a consortium including participation from host institutions, affiliate organizations, and the user community.



Future Science Support: Along with direct operations and maintenance support for EarthScope, NSF will support research performed at the facility, through ongoing research and education programs. The annual support for such activities is estimated to be about $15 million, once the facility reaches full operations.

High Performance Instrumented Airborne Platform for Environmental Research (HIAPER)

Project Description: This project is a multidisciplinary high altitude research aircraft capable of conducting science at or near the tropopause with an extensive scientific payload and a range in excess of 6,000 nautical miles. The aircraft will be used approximately 1500 hours a year for research flight hours and integration and testing of instrumentation. It is expected that the research flight hours will be 400-500 per year. The remaining time will be devoted to aircraft maintenance and technology refreshment of the platform infrastructure. Research instrumentation will be developed independently and in partnership with National Center for Atmospheric Research (NCAR) by universities, national laboratories, private companies and international partners. HIAPER will be a national facility, available to the university community as well as to NSF's federal partners such as the National Oceanographic and Atmospheric Administration, the National Aeronautics and Space Administration, the Office of Naval Research and the Department of Energy under existing interagency agreements. HIAPER will be based at NCAR's Research Aviation Facility, Jefferson County Airport, Broomfield, Colorado. Deployments of the aircraft will occur worldwide.

Principal Scientific Goals: HIAPER will be a research aircraft with altitude, range, and endurance capabilities that will enable investigators to perform critical earth system research. With a maximum certified altitude for the aircraft of 51,000 feet, the ability to carry significant payloads to such high altitudes will enable scientists to conduct important atmospheric studies in and near the tropopause. The modified aircraft will be capable of covering a range of 6000 nautical miles in a single flight, which will allow for such missions as a research flight covering the western, southern, and eastern borders of the continental U.S. (from Portland, Oregon to Portland, Maine) and studies of the South Pole environment conducted from South America or New Zealand. The platform will serve the entire geosciences community: atmosphere, cryosphere, biosphere, and hydrosphere.

Principal Education Goals: To engage science and non-science students in geosciences discovery through the use of technology to create a HIAPER "tele-presence" in real or retrospective time with the aim of integrating research and education.

Partnerships and Connections to Industry: The airframe is being acquired from Gulfstream Corporation, with selected airframe modifications by Lockheed-Martin Corporation. Additional support is being received from Aeromet Corporation. Significant participation from smaller private firms in research instrumentation development is also expected.

Management and Oversight: The project is managed and overseen by a project director in the Atmospheric Sciences (ATM) Subactivity in the Geosciences (GEO) Activity. The project director receives advice and oversight support from a NSF Project Advisory Team, which consists of representatives from GEO, the Office of General Counsel, the Office of Budget, Finance and Award Management (BFA), the Mathematical and Physical Sciences (MPS) Activity, and the Office of Polar Programs. A separate HIAPER Advisory Committee, consisting of representatives of the university research community, national laboratories, the University Corporation for Atmospheric Research (UCAR), NCAR and NSF provides advice and recommendations to the Director of NCAR and to the project director at NSF.

Current Project Status: In late December 2001 UCAR and Gulfstream Aircraft Corporation (GAC), a subsidiary of General Dynamics, signed a contract for the acquisition of a Gulfstream V. The green airframe was delivered in June, 2002 and then ferried to Lockheed-Martin for extensive airframe structural modifications to meet science requirements.

Milestones for the project are outlined below:

FY 2002 Milestones:
- Negotiation of final contract between UCAR and GAC (1st quarter);
- Approval of contract by NSF (1st quarter);
- Contract between UCAR and GAC for acquisition of green airframe and structural modifications (1st quarter);
- Production of green airframe (2nd through 4th quarter);
- Staff HIAPER project office at National Center for Atmospheric Research (NCAR) (2nd through 4th quarter).

FY 2003 Milestones:
- NSF Instrumentation Workshop conducted at NCAR
- NCAR Director's Independent Review of Project
- Release of Instrument Development Announcement of Opportunity
- Critical Design Review - Systems
- Structural Modifications Initiated by Lockheed Martin

FY 2004 Milestones:
- Structural Modifications (Continued)
- Award Instrumentation Development Grants
- FAA STC Certificate for Modified Aircraft

FY 2005 Milestones:
- Receipt of Modified Aircraft at UCAR
- Research Infrastructure and Data Systems Installed
- Preparation for Deployments

FY 2006 Milestone:
First Deployment

Funding Profile: In FY 2000, $8.50 million was provided for the project, and an additional $12.47 million was appropriated in FY 2001. In FY 2002 Congress appropriated $35.0 million. The total funding to date, $55.97 million, will allow airframe acquisition and modifications and initiation of core research instrumentation development. The total estimated construction cost for the project is $81.5 million.

MREFC Appropriations for HIAPER
(Dollars in Millions)

FY 2000	FY 2001	FY 2002	FY 2003 Request	FY 2004 Request	Total
$8.50	$12.47	$35.00	$0.00	$25.53	$81.50

HIAPER Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1996 & Earlier									
FY 1997									
FY 1998	0.30						$0.30		**$0.30**
FY 1999	0.40						$0.40		**$0.40**
FY 2000		0.50		8.00				$8.50	**$8.50**
FY 2001		0.40		12.07				$12.47	**$12.47**
FY 2002				35.00				$35.00	**$35.00**
FY 2003 Req									
FY 2004 Req				25.53				$25.53	**$25.53**
FY 2005 Est					0.30		$0.30		**$0.30**
FY 2006 Est					3.00		$3.00		**$3.00**
Subtotal, R&RA	$0.70				$3.30		$4.00		
Subtotal, MREFC		$0.90		$80.60				$81.50	
Total, each phase*		**$1.60**		**$80.60**		**$3.30**			**$85.50**

NOTE: The expected operational lifespan is 25 years, pending the full integration of scientific instrumentation. A steady state of about $3.0 million in operations support would occur in or about FY 2006, assuming completion of the project in FY 2004.

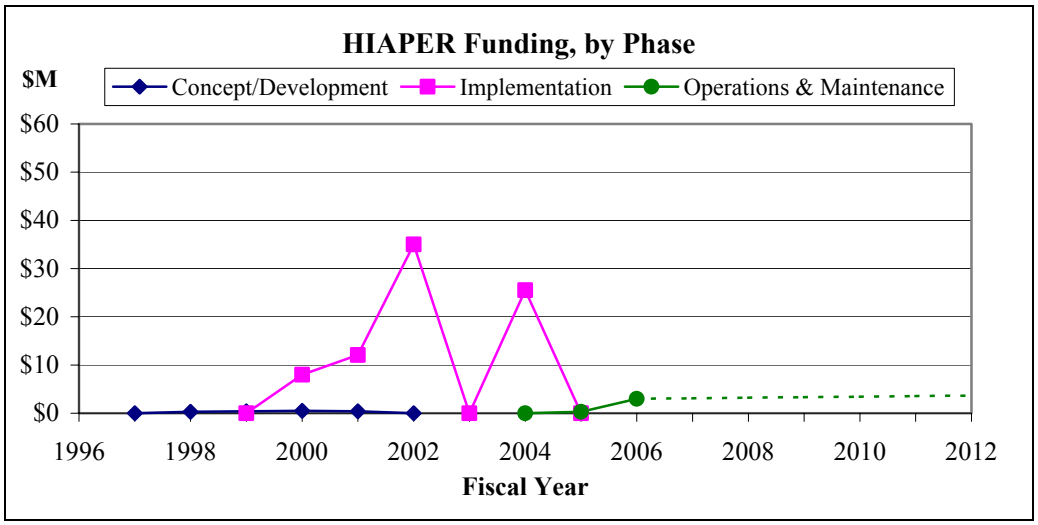
Information pertaining to the data in the table is provided below.

- *Concept/Development*: Initial R&RA funding of approximately $700,000 provided support for workshops to identify the highest priority performance characteristics and platform requirements, and for other workshops, reviews and best practices consultations with federal and nonfederal experts. MREFC funds obligated during this phase of the project include support for the preparation of the

Request for Proposals. After the proposal was received at UCAR, an evaluation and selection team was formed to determine if the proposal met the requirements in the RFP.

- *Implementation*: The full appropriated amounts for FY 2000-02 were required in order to acquire and modify the airframe. Funding was provided to Gulfstream to secure a production slot, and the remainder of the funds were held until the contract was negotiated, approved by NSF and signed by UCAR and GAC. The funding to date allows for green airframe acquisition and the structural modifications required to integrate scientific instrumentation. NSF is requesting $25.53 million in FY 2004 for instrumentation integration and to complete the project. The total construction cost for the project is $81.50 million.

- *Operations and Maintenance*: The aircraft will be maintained and operated by the Research Aviation Facility at NCAR. The intent is to operate the aircraft as a fully certified platform rather than a public use aircraft. Additional follow-on instrumentation will be developed during the operational phase of HIAPER, funded by the R&RA grants program within ATM. HIAPER, in contrast to many research facilities, will accommodate instrumentation from other agencies, international partners as well as new instruments that are developed over the 25-year operational time period through the R&RA Activity. Instruments typically will fly on a variety of platforms, not exclusively HIAPER.



Future Science Support: Along with direct operations and maintenance support for HIAPER, NSF will support research performed at the facility, through ongoing research and education programs. The annual support for such activities is estimated to be about $10.0 to $12.0 million, once the facility reaches full operations.

IceCube Neutrino Observatory

Project Description: IceCube will be the world's first high-energy neutrino observatory and will be located under the ice at the South Pole. It represents a new window on the universe, providing unique data on the engines that power active galactic nuclei, the origin of high energy cosmic rays, the nature of gamma ray bursters, the activities surrounding supermassive black holes, and other violent and energetic astrophysical processes. IceCube will be constructed by the IceCube Consortium, led by the University

of Wisconsin (UW). One cubic kilometer of ice will be instrumented with 4800 photomultiplier (PM) tubes (80 strings of 60 PMs each) to detect neutrino-induced, charged reaction products produced when a high energy neutrino interacts in the ice within or near the cubic kilometer fiducial volume. Optical Modules (OMs), each containing a PM and associated electronics, will be distributed uniformly from 1.5 km to 2.5 km beneath the surface of the South Pole ice cap, a depth where the ice is highly transparent and bubble-free. IceCube will record the energy and arrival direction of high-energy neutrinos ranging in energy from 100 GeV (10^{11} electron Volts[eV]) to 10 PeV (10^{16} eV). The principle tasks in the IceCube Project are: production of the needed OMs and associated electronics and cables; production of an enhanced hot water drill and an OM deployment system capable of drilling holes for, and deploying, 16 OM strings per austral season at the Pole; production of a surface array of air shower detectors, one for each OM string to both calibrate and eliminate background events from the IceCube OM array; construction of a data acquisition and analysis system; and associated personnel and logistics support.

Principal Scientific Goals: IceCube will be the world's first observatory capable of studying the universe with high-energy neutrinos. Measurement of the number, direction, timing, and energy spectrum of such neutrinos will provide unique new insights regarding the dynamics of active galactic nuclei, the acceleration mechanisms and locations of the sources of high energy cosmic rays, the properties and dynamics of gamma ray bursters, and the types of processes that take place near the event horizon of supermassive black holes at the centers of galaxies. Many of these phenomena take place at cosmological distances in regions shielded by matter and shrouded by radiation. Since neutrinos carry no charge and interact very weakly with matter, easily passing through the entire earth, they are unique messenger particles for understanding the astrophysics of such extreme phenomena and are capable of bringing us information about previously undiscovered cosmic objects, ones that are invisible to existing observatories that record electromagnetic signals or charged particles. IceCube data on sources will also complement data from existing astrophysical observatories in the optical, x-ray, and gamma ray regions of the electromagnetic spectrum, providing new tests of theories of the underlying dynamics of these objects.

Principal Education Goals: IceCube provides a vehicle for helping to achieve national and Agency education and outreach goals based on the conduct of visionary science in the exciting South Pole environment. These goals include broadening the scientific workforce base in the U.S. and creating a technologically facile work force with strong ties to fundamental research that is the core of a strong economy. Specific outcomes will include: the education and training of next generation leaders in astrophysics, including undergraduate students, graduate students, and postdoctoral research associates; K-12 teacher scientific/professional development, including development of new inquiry-based learning materials; increased diversity in science through partnerships with minority institutions; and enhanced public understanding of science through broadcast media and museum exhibits. Some of these outcomes will result from separate R&RA grants to universities and other organizations for work associated with IceCube, selected following the standard NSF merit review process.

Partnerships and Connections to Industry: The IceCube Collaboration consists of 11 U.S. institutions and institutions in three other countries, Belgium, Germany, and Sweden. Foreign contributions of $40.0 million U.S. are anticipated. The U.S. Department of Energy, through its Lawrence Berkeley Laboratory, is also participating.

Management and Oversight: With strong international participation, IceCube has a management structure that has been developed from plans used in other successful projects. This structure has been agreed to by all participants and provided the framework for the Start-up Project funded in FY 2002. The University of Wisconsin has in place an External Advisory Committee, providing for their oversight of the project, and has appointed both a Project Director and a Project Manager. Internally, NSF has appointed a Project

Coordinator to manage and oversee the NSF award, and has established an internal Project Advisory Team comprised of representatives from the Office of Budget, Finance, and Award Management, the Office of General Counsel, the Mathematical and Physical Sciences (MPS) Activity, and the Office of Polar Programs (OPP), and chaired by the Project Coordinator. Oversight and funding responsibility for IceCube construction and operations are the responsibility of OPP; support for research, education, and outreach using IceCube will be shared by OPP and MPS as well as other organizations and international partners.

Current Project Status: The IceCube project is currently funded through a $15.0 million 'startup funding' award provided by the FY 2002 appropriation. An award was put into place in August of 2002. The primary tasks of that activity are: production and testing of the Enhanced Hot Water Drill (EHWD) system for drilling the required deep-ice holes into which optical modules (the photo-detectors that are the central elements of the IceCube detector) will be placed; production of the optical module deployment system; design of the data acquisition system and software requirements; specification of the requirements, design, and pre-production testing of the IceTop Surface Array; software system architecture and detector simulations; and planning for detector verification. Progress to date has been according to schedule and is within budget. The major task that must be accomplished within startup funding is the construction of the EHWD. EHWD completion during summer 2003 and shipment to the Pole in the fall of 2003 is essential to maintain the schedule of first drilling in the 2004/2005 austral summer. In addition, the Office of Science and Technology Policy (OSTP) requested in FY 2002 that the National Academy of Sciences review the scientific merit of IceCube and other proposed U.S. neutrino collectors in the context of current and planned neutrino research capabilities throughout the world. That report provides strong support for IceCube construction. Management and technical staff are now in place at UW and the participating institutions to proceed with the full IceCube construction project.

Major milestones for the NSF components for IceCube are outlined below:

FY 2003 Milestones:
Complete development and construction of enhanced hot water drill (EHWD) system; and
Complete design of the data acquisition system architecture and software requirements.

FY 2004 Milestones:
Deliver EHWD system and optical module (OM) deployment system to the South Pole; and
Begin production of optical modules and data acquisition and handling system (DAQ).

FY 2005 Milestones:
Deliver initial OM strings, IceTop modules, and initial elements of the DAQ to South Pole;
Assemble the EHWD and OM deployment systems;
Drill, deploy, and test initial OM strings and corresponding IceTop modules; and
Establish drill camp and move new counting house building into place.

FY 2006 Milestones:
Continue OM and IceTop module production;
Continue to drill, deploy and test OM strings and IceTop modules, including installing and testing the associated DAQ elements; and
Commission new counting house.

Projected Outyear Milestones (FY 2007-2010) are based on current project planning and represent a general outline of anticipated activities. These activities are also dependant on weather conditions and the Antarctic logistics schedule.

FY 2007-10 Milestones:

Continue OM and IceTop module production; and
Continue to drill, deploy and test OM strings and IceTop modules, including installing and testing the associated DAQ elements.

FY 2011 Milestones:

Complete OM and IceTop module production, string deployment, and the DAQ;
Complete the calibration, testing, and commissioning of the full IceCube array; and
Commence full operations.

Funding Profile: $15.0 million was appropriated in FY 2002 for startup activities for the IceCube project. In FY 2004, $60.0 million is requested to initiate construction of the full IceCube project.

MREFC Appropriations for IceCube
(Dollars in Millions)

FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	**Total**
$15.00	$0.00	$60.00	$33.40	$34.30	$35.30	$36.30	$37.30	**$251.60**

IceCube Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		Grand
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	Total
FY 1999 & Earlier									
FY 2000									
FY 2001	0.50						$0.50		**$0.50**
FY 2002[1]				10.12				$10.12	**$10.12**
FY 2003 Req[1]				4.88				$4.88	**$4.88**
FY 2004 Req				60.00				$60.00	**$60.00**
FY 2005 Est				33.40				$33.40	**$33.40**
FY 2006 Est				34.30				$34.30	**$34.30**
FY 2007 Est				35.30				$35.30	**$35.30**
FY 2008 Est				36.30				$36.30	**$36.30**
FY 2009 Est				37.30				$37.30	**$37.30**
FY 2010 Est					10.40		$10.40		**$10.40**
FY 2011 Est					10.60		$10.60		**$10.60**
FY 2012 Est					10.90		$10.90		**$10.90**
FY 2013 Est					11.20		$11.20		**$11.20**
Subtotal, R&RA	$0.50				$43.10		$43.60		**$43.60**
Subtotal, MREFC				$251.60				$251.60	**$251.60**
Total, Each Phase		**$0.50**		**$251.60**		**$43.10**			**$295.20**

NOTE: Operations support in FY 2010 is estimated at $10.40 million, and is estimated to remain at that corresponding level of effort in subsequent years. The expected operational lifespan of this project is 25 years beginning in FY 2011.
[1]Funding of $15.0 million in FY 2002 was for start up costs associated with IceCube construction; $10.12 million was obligated in FY 2002, the remaining $4.88 million is carried over from FY 2002 to FY 2003. The FY 2003 amount reflected in the table above is the carry over; no additional funds were requested in FY 2003.

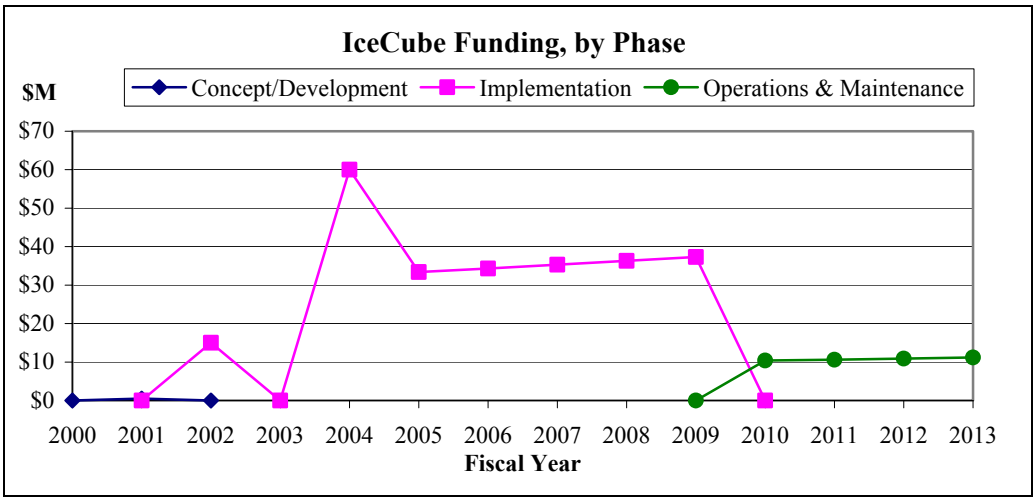
Information pertaining to the data in the table is provided below.

- *Concept/Development:* $500,000 was provided in FY 2001 through the R&RA Account to support drill conceptual development and design, R&D on advanced data acquisition and analysis techniques, and development of interface electronics and associated software for digital detector electronics readout. IceCube builds on the work of the Antarctic Muon and Neutrino Detector (AMANDA), which demonstrated proof-of-principle. NSF's FY 2002 appropriation included $15.0 million for 'start-up' design and development of the IceCube project. That investment focused on state-of-the art drill and electronics development and acquisition.

- *Implementation:* The total cost of the construction project, including the $15.0 million appropriated FY 2002 for start-up activities, is $251.60 million and will extend through FY 2011. $60.0 million is requested in FY 2004 to maintain the schedule. The plan is to drill holes and deploy strings of OMs in each austral summer season (November through mid-February). With good EHWD drill performance, and barring weather-induced complications of logistics support, the full complement of OMs should be in place by about the end of FY 2011.

- *Operations and Maintenance:* Full operation of the IceCube Neutrino Observatory is planned to commence in FY 2011 following completion of drilling and OM deployment and full detector commissioning planned for FY 2011. Transition to full operations will begin in FY 2010. Of this amount, approximately half is for data analysis that will be carried out by the collaborating U.S. IceCube institutions, the other half being for direct operations and maintenance support (IceCube-specific logistics, system engineering, operation and maintenance of the data acquisition and data handling data systems, data quality monitoring, IT upgrades, and calibrations). The general operations of South Pole Station, reported in a separate section, also contribute to supporting IceCube. Costs included for IceCube here include only those that are project specific and incremental to general operations.

Associated Research and Education Activities: Besides the training of next generation astrophysicists, IceCube will encourage the creation of new links to K-12 teachers for purpose of scientific/professional development of secondary school teachers, reaching into the classroom with new inquiry-based IceCube learning materials, as well as using the unique South Pole environment to convey the excitement of astrophysics and science generally to K-12 students. Extra measures will be undertaken to interest underrepresented minorities in science. The plan includes partnership with two largely minority institutions (Clark-Atlanta University, Atlanta GA, and Southern University, Baton Rouge, LA). Public outreach will be carried out through broadcast media and museum exhibits based on the IceCube science and the South Pole environment. Funding for Education and Outreach (E&O) activities will come from the R&RA account. Annual E&O budgets are estimated at $400,000.



Future Science Support: NSF will support activities at institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades, through ongoing research and education programs. The annual support for such activities is estimated at $2.0 million once the facility reaches full operations.

Large Hadron Collider

Project Description: The Large Hadron Collider (LHC) will be the premier facility in the world for research in elementary particle physics. The facility will consist of a superconducting particle accelerator providing two, counter-rotating beams of protons, each beam having an energy up to 7 x 10^{12} electron volts (7 TeV). The U.S. is involved in the construction of two particle detectors, a Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS). They will be constructed to characterize the different reaction products produced in the very high-energy proton-proton collisions which will occur in intersection regions where the two beams are brought together.

The LHC is an international project under construction at the CERN laboratory in Geneva, Switzerland. NSF has awarded grants to Northeastern and Columbia Universities under cooperative agreements with subcontracts to over 50 U.S. universities. A total of 34 international funding agencies participate in the ATLAS detector project, and 31 in the CMS detector project. NSF and DOE are providing U.S. support. CERN is responsible for meeting the goals of the international LHC project. The ATLAS and CMS detectors are expected to take data approximately 200 days/year. The remaining time is used for maintenance and testing.

Principal Scientific Goals: The LHC will enable a search for the Higgs particle, the existence and properties of which will provide a deeper understanding of the origin of mass of known elementary particles. The LHC will also enable a search for particles predicted by a powerful theoretical framework known as supersymmetry which will provide clues as to how the four known forces evolved from different aspects of the same 'unified' force in the early universe.

Principal Education Goals: Through the participation of young investigators, graduate students, undergraduates, and minority institutions in this international project, LHC serves the goal of helping to

produce a diverse, globally-oriented workforce of scientists and engineers. Further, innovative education and outreach activities, such as the QuarkNet project, allow high school teachers and students to participate in this project (see the URL: http://quarknet.fnal.gov/). Many highly-trained students in high-energy physics move into industrial jobs.

Connections to Industry: Major procurements of components of both warm and superconducting magnets, as well as high-speed electronics, are performed through U.S. industries. Major developments in Grid computing are also valuable outcomes.

Management and Oversight: A program director in the Physics Subactivity of the Mathematical and Physical Sciences (MPS) Activity is responsible for day-to-day project oversight. The NSF program director also convenes an internal Project Advisory Team, including staff from the Office of Budget, Finance and Award Management, the Office of the General Counsel, the Office of Legislative and Public Affairs, and the MPS Executive Officer.

U.S. LHC program management is performed through a Joint Oversight Group (JOG), created by the NSF and DOE membership. The JOG has the responsibility to see that the U.S. LHC Program is effectively managed and executed to meet commitments made under the LHC International Agreement and its Protocols.

Current Project Status: An External Review Committee (ERC), reporting to the CERN Council in June, 2002, identified issues relevant to completion of the LHC project. In the report, the ERC stated that it "believes that the design of the LHC is excellent and that it will reach design specifications". However, the ERC did find that the projected cost increases that became apparent before this report arose from "serious weaknesses in cost awareness and control, as well as in contract management and financial reporting." NSF has been working closely with CERN management on these issues.

In September 2002, CERN management released an Action Plan to address the recommendations of the External Review Committee. A schedule delay was foreseen at that time, largely a result of delays in the delivery of superconducting cable for the LHC magnets. In December, 2002, the CERN council accepted a proposal to revise the 1996 financial framework for the LHC. The revised framework makes LHC completion in 2007 a priority, representing a two year delay from the original plan. The proposal addresses items including accountability, staffing, management, cost awareness, control and reporting, and annual reviews. Most of CERN's resources will now be committed to the project, leaving only a very limited non-LHC experimental program.

Under the new schedule, a period of beam commissioning will be followed by start of the LHC Physics Program in the latter half of 2007. While both experiments will profit from the revised LHC schedule by having additional time to optimize its installation plans, the U.S. collaborators will continue on the original baseline schedule, to avoid any increases in labor and costs.

The NSF-supported components of the ATLAS and CMS detectors are estimated for completion in FY 2005, with the final year of appropriated construction funding in FY 2003. The U.S. ATLAS construction project, as of September 30, 2002, was 75 percent complete, reflecting the most recent update of cost and schedule estimates for completing baseline scope. The U.S. CMS project is 71 percent complete. Milestones for both projects are being completed in the anticipated years. U.S. cost performance has been excellent, with material contracts typically below estimates, and labor costs tracking close to plan. The U.S. strategy aims for the completion of the U.S. deliverables within our baseline cost and with a slightly extended schedule that takes the LHC construction delay into account.

Major milestones for the NSF components of LHC are outlined below:

FY 2002 Milestones:

U.S. ATLAS

Complete Shipment of Liquid Argon Barrel Calorimeter to CERN (Shipment of the Barrel Cryostat on schedule, crates delivered to BNL and will be shipped to CERN when ready for installation.);
Complete Tile Calorimeter Photomultiplier Tube Shipments to CERN (Baseline scope completed. Jan '03 forecast date includes full set of goals approved in BCP 57);
Complete Submodule Production for the Tile Calorimeter (Completed);
Complete Shipment of Transition Radiation Tracker Barrel Modules to CERN (Delay due to radiation damage caused by the baseline gas choice. New baseline gas chosen, schedule slipped to Jan '04);
Complete Final Prototypes of Readout Drivers for Liquid Argon Calorimeter (Not on critical path. U.S. not responsible for deliverables. Final Prototype – Sept '04); and
Complete Production of 45% of the Readout Drivers for the Silicon Tracker (Completed).

U.S. CMS

Begin Mounting and Testing Cathode Strip Chamber Electronics at UCAL and Florida Universities (Completed);
Complete Optical Assemblies for Hadron Calorimeter Barrel #1 (Completed for both Barrels);
Procure Hadron Calorimeter Photodiodes (Completed);
Complete Production of 25% of the Readout Drivers for the Silicon Tracker (Delayed until CMS delivers tested parts for assembly. U.S. CMS has set up two assembly lines to be ready as parts are available.); and
Complete Test of Photomultiplier Tubes for the Forward Hadron Calorimeter (Completed).

FY 2003 Milestones:

U.S. ATLAS

Complete Shipment of Liquid Argon Electronics Crates to CERN (1st quarter);
Complete Delivery of Liquid Argon Forward Calorimeter (Section C) (2nd quarter);
Complete Tile Calorimeter Readout Electronics (4th quarter);
Complete Tile Calorimeter Barrel Shipments to CERN (1st quarter); and
Complete Installation of Liquid Argon Cryogenics Installation (4th quarter);

U.S. CMS

Start Production of the Front End Electronics for the Electromagnetic Calorimeter (1st quarter);
Complete Production of the Front End Electronics for the Hadron Calorimeter (2nd quarter);
Complete 100% Testing of the Hadron Calorimeter Photodiodes (4th quarter); and
Complete Deliveries of all 148 Cathode Strip Chambers for Muon Endcap Layer 23/2 (4th quarter).

FY 2004 Milestones:

US ATLAS
Complete delivery of Liquid Argon Forward Calorimeter (Section A);
Complete delivery of Silicon Strip Modules;
Complete production of Transition Radiation Tracker (Modules and Barrel); and
Complete Muon Chamber production.
US CMS
Complete delivery of Electromagnetic (EM) Calorimeter Photodiodes;
50% of Silicon Tracker Rods completed; and
Start production of the Front End electronics for the EM Barrel Calorimeter.

FY 2005-2006 Milestones:
Start ATLAS and CMS detector installation and testing in underground halls.

FY 2007 Milestone:
First data taking using both ATLAS and CMS detectors.

Funding Profile: Funding for the overall LHC project, including the ATLAS and CMS detectors and the accelerator, is provided through an international partnership involving NSF, the Department of Energy (DOE), and the CERN member states, with CERN member states providing the major portion. Other countries that are not member states are also participating.

The total U.S. contribution to the construction project will be $531 million, with $450 million from the DOE and $80.88 million from NSF. NSF and DOE will jointly provide a total contribution of $331 million for the detector construction, while DOE will provide the entire U.S. contribution ($200 million) for the accelerator construction. There are two other major detectors being constructed, ALICE and LHC-B, in which the U.S. does not play a role.

MREFC Appropriations for LHC
(Millions of Dollars)

FY 1999	FY 2000	FY 2001	FY 2002	FY 2003 Request	Total
$22.00	$15.90	$16.36	$16.90	$9.72	$80.88

Large Hadron Collider Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1994 & Earlier									
FY 1995									
FY 1996	1.20						$1.20		**$1.20**
FY 1997	1.50						$1.50		**$1.50**
FY 1998	1.50						$1.50		**$1.50**
FY 1999	1.50		0.15	22.00	0.16		$1.81	$22.00	**$23.81**
FY 2000				15.90	0.53		$0.53	$15.90	**$16.43**
FY 2001				16.36	2.30		$2.30	$16.36	**$18.66**
FY 2002				16.90	1.60		$1.60	$16.90	**$18.50**
FY 2003 Req				9.72	5.00		$5.00	$9.72	**$14.72**
FY 2004 Req					10.00		$10.00		**$10.00**
FY 2005 Est.[1]					15.00		$15.00		**$15.00**
FY 2006 Est.[1]					20.00		$20.00		**$20.00**
FY 2007 Est.[1]					25.00		$25.00		**$25.00**
Subtotal, R&RA	$5.70		$0.15		$79.59		$85.44		
Subtotal, MREFC				$80.88				$80.88	
Total, each phase		**$5.70**		**$81.03**		**$79.59**			**$166.32**

NOTE: NSF's share of operations support is expected to reach a level of effort of about $25.0 million by about FY 2007. The estimated operational lifespan of this project is approximately 20 years.
[1]Operations and Maintenance estimates for FY 2005 and beyond are subject to the availability of funds and appropriate program balance, and are not intended to reflect actual budget requirements..

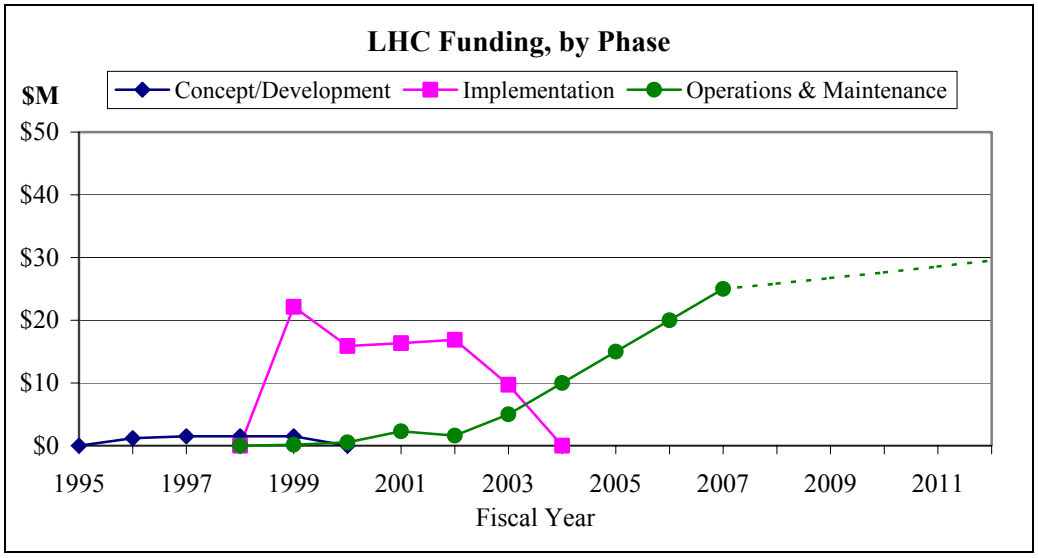
Information pertaining to the data in the table is provided below.

- *Concept/Development:* The LHC has been under discussion since FY 1989. NSF funding in FY 1996-99 supported technical design studies.

- *Implementation:* NSF components of the ATLAS and CMS detectors, constructed with funds provided FY 1999-FY2003, are anticipated to be completed, tested and ready to install in FY 2005. The overall LHC project is now anticipated for completion at CERN in FY 2007. (In FY 1999, $150,000 in R&RA funds were provided to meet the scheduled award total of $22.15 million. This R&RA action was noted in subsequent NSF MREFC budget justifications to Congress.) Final implementation funding is requested in FY 2003.

- *Management & Operations:* FY 1999-2003 funding primarily represents investments in university computing infrastructure and software development for remote access, to allow university scientists and students to participate in LHC research as well as other projects. Estimated funding for FY 2004 and beyond reflects the NSF share of operations as the ATLAS and CMS detectors approach and initiate operations. Estimated funding during the same period also includes the development of LHC grid software and computing. It is anticipated that over the lifetime of the LHC project, upgrades and

new components to address emerging research questions will be considered. Funds for such activities are not included here.



Future Science Support: Along with direct support for operations and maintenance for LHC, NSF will support science and engineering research performed at the facility, through ongoing research and education programs. The annual support for such activities is presently estimated to be about $5.0 million once the facility reaches full operations. Both ATLAS and CMS have well-developed outreach activities (see Education Goals above).

George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

Project Description: NEES will provide a national, networked simulation resource of fifteen geographically-distributed, shared use next-generation experimental research equipment sites with teleobservation and teleoperation capabilities. This facility will transform the environment for earthquake engineering research and education through collaborative and integrated experimentation, computation, theory, databases, and model-based simulation to improve the seismic design and performance of U.S. civil and mechanical infrastructure systems. Research equipment includes shake tables, geotechnical centrifuges, a tsunami wave basin, large-scale laboratory experimentation systems, and field experimentation and monitoring installations. NEES equipment will be located at academic institutions (or at off-campus field sites) throughout the U.S., networked together through a high performance Internet system, and operated during FY 2005-14 by a NEES Consortium. The NEES award for system integration is located at the University of Illinois at Urbana-Champaign. The NEES award for consortium development was made to a non-profit organization, the Consortim of Universities for Research in Earthquake Engineering..

Principal Scientific Goals: Enhanced understanding and more comprehensive, complete, and accurate models of how civil and mechanical infrastructure systems respond to earthquake loading (site response, soil-foundation-structure interaction, tsunami effects, and structural and nonstructural response). This will enable the design of new methods, modeling techniques, and technologies for earthquake hazard mitigation.

Principal Education Goals: To engage engineering, science, and other students in earthquake engineering discovery through on-site use of experimental facilities, telepresence technology, archival experimental and analytical data, and computational resources with the aim of integrating research and education.

Connections to Industry: There are no specific project partnerships at this time. However, through the Congressionally mandated National Earthquake Hazards Reduction Program (NEHRP), Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), NSF, and U.S. Geological Survey (USGS) participate to support research related to earthquake hazard mitigation. Connections to industry include equipment and instrumentation acquisition by awardees from private firms; and private engineering consultants and engineering firms engaging in NEES research or using data and models developed through NEES.

Management and Oversight: The NSF Program Manager for NEES and the NSF Equipment Project Coordinator are located in the Civil and Mechanical Systems (CMS) Subactivity in the Engineering (ENG) Activity. Oversight is supported by the NSF Project Advisory Team consisting of representatives from the Office of General Counsel, the Office of Budget, Finance and Award Management, and the Biosciences, Geosciences, Computer and Information Science and Engineering, and Social and Behavioral Sciences Activities.

Current Project Status: NEES is currently under construction through the end of FY 2004. Under construction are sixteen awards (Phases 1 and 2) to establish equipment sites at fifteen institutions, one award for system integration, and one award for consortium development. All awards are the result of competitive program solicitations. The organizational structure and policies for a NEES Consortium are under development by the earthquake engineering community. Milestones for NEES are outlined below:

FY 2003:
- Continue Phases 1 and 2 equipment construction and begin calibration;
- Establish NEES Consortium entity;
- Initiate system integration test bed operations; and
- Coordinate outreach and training activities for equipment sites as they become operational.

FY 2004:
- Complete equipment construction and calibration of all Phases 1 and 2 equipment;
- All equipment sites networked and operational;
- Coordinate outreach and training activities for equipment sites as they become operational;
- Complete testing of network system;
- Network system operational; and
- NEES Consortium management structure completed for operation in FY 2005.

Funding Profile: NSF received $7.70 million in FY 2000 to initiate construction of NEES. Total MREFC funding for this project will be $81.80 million during FY 2000-04, with an additional $1.10 million provided to the project through the Education and Human Resources (EHR) Account.

MREFC Appropriations for NEES
(Dollars in Millions)

FY 2000	FY 2001	FY 2002	FY 2003 Request	FY 2004 Request	Total
$7.34	$28.11	$24.40	$13.56	$8.00	$81.41

NEES Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation			Operations & Maintenance		Totals			Grand
	R&RA	MREFC	R&RA	MREFC	EHR	R&RA	MREFC	R&RA	MREFC	EHR	Total
FY 1994 & Earlier											
FY 1995	0.15							$0.15			**$0.15**
FY 1996											
FY 1997											
FY 1998	0.11							$0.11			**$0.11**
FY 1999											
FY 2000		0.36		7.34					$7.70		**$7.70**
FY 2001	0.44	0.03		28.11	1.10			$0.44	$28.14	$1.10	**$29.68**
FY 2002				24.40					$24.40		**$24.40**
FY 2003 Req				13.56					$13.56		**$13.56**
FY 2004 Req				8.00					$8.00		**$8.00**
FY 2005 Est						10.00		$10.00			**$10.00**
Subtotal, R&RA	$0.70					$10.00		$10.70			**$10.70**
Subtotal, MREFC		$0.39		$81.41					$81.80		**$81.80**
Subtotal, EHR					$1.10					$1.10	**$1.10**
Total, Each Phase		**$1.09**			**$82.51**		**$10.00**				**$93.60**

NOTE: A steady state of about $10 million in operations support is expected to occur in or about FY 2005. The expected operational lifespan of this project is 10 years, beginning in FY 2005.

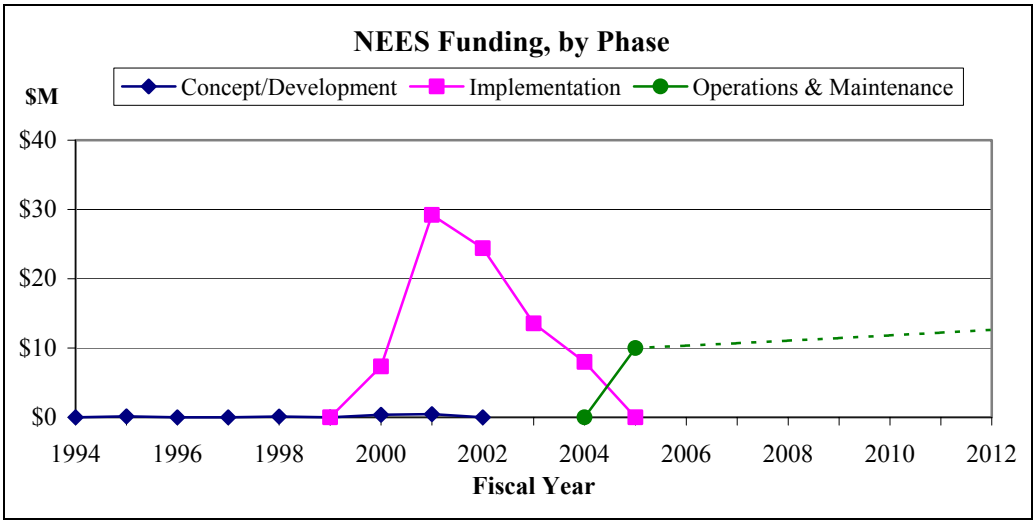
Information pertaining to the data in the table is provided below.

- *Concept/Development:* R&RA support for planning, design and development includes early workshops on experimental needs of the earthquake engineering community and on refinement of ideas for experimental systems in FY 1995 and FY 1998. During this period, the community also developed an action plan at NSF's invitation. Additional R&RA support focused on an international workshop to foster long term working relationships for experimental earthquake engineering research and national workshops and study to develop long-term NEES research concepts and plans (FY 2001). MREFC supported planning design and development specifically for a scoping study of the NEES network system (user and system architecture requirements), including a community workshop for broader input on user requirements prior to the full system integration award being made by NSF.

- *Implementation:* MREFC funds during this phase support a range of equipment acquisition, as well as system integration and consortium development. To encourage the broadest participation for establishment of geographically distributed NEES equipment sites, the FY 2000 competitive program solicitation for NEES research equipment specifically encouraged participation from EPSCoR states. As a result of the merit review process, one award was made to an institution from an EPSCoR state for which the EPSCoR program provided partial funding through the EHR account in FY 2001.

- *Operations and Maintenance:* With completion of the construction period in FY 2004, NEES will enter its 10-year operational period through FY 2014 and will be managed by the NEES Consortium. The NEES Consortium will provide the leadership, management, and coordination for all the NEES resources and will establish a broad and integrated partnership that includes participation of the full membership of the earthquake engineering community, both within the U.S. and abroad.

  As an Internet-based resource, access to the NEES network will be 24/7 to anyone with Internet capabilities. The NEES experimental facilities are expected to be fully utilized annually as shared use research sites coordinated by the NEES Consortium and for research by personnel at the host institution. NEES experimental resources and data are expected to be used annually by approximately 1000 U.S. researchers and students.



Future Science Support: Along with direct operations and maintenance support for NEES, NSF will support research performed at NEES equipment sites through ongoing research and education programs. In addition, NSF plans to initiate grand challenge research projects that will utilize a number of NEES experimental sites, data, and computational resources to comprehensively address major research questions in earthquake engineering and seismic hazard mitigation. The annual support for such activities once the facility reaches full operations is estimated to be about $15 million.

National Ecological Observatory Network (NEON)

Project Description: NEON will be a continental scale research instrument consisting of geographically distributed observatories, networked via state-of-the-art communications. Scientists and engineers will conduct research spanning all levels of biological organization from molecules to whole systems, across scales ranging from seconds to geological time, and from microns to kilometers. Each NEON observatory will include cutting-edge instrumentation, site-based experimental infrastructure, natural history archive facilities and/or computational, analytical and modeling capabilities. In addition, the NEON observatories will be linked via a cutting-edge computational network. The observatories will focus on: deploying field instrumentation; gathering environmental data from field-based arrays; collecting data simultaneously from geographically distributed arrays; integrating data across diverse types of databases; and establishing an informatics infrastructure. The observatories will also be used to

optimize the functionality of a networked, multiscale, integrated infrastructure that will comprise a fully realized NEON.

Principal Scientific Goals: Collectively, the network of observatories will allow comprehensive, continental-scale experiments on ecological systems and will represent a virtual laboratory for research to obtain a predictive understanding of the environment. Important ecological questions confronting the U.S. will be addressed using NEON. Examples of research questions that could be addressed by NEON include: Will northern snakehead fish spread across the U.S. and harm sport fish populations? Can the spread of infectious agents like West Nile or Hanta virus be monitored and predicted? Do western wildfires affect water quality in the central or eastern U.S.?

Principal Education Goals: Undergraduates and graduate students will be trained in the conduct of large-scale and long-term ecological research. K-12 students and teachers will also be involved in NEON projects. The research will develop the knowledge to inform policy and to improve the health of U.S. ecosystems.

Partnerships and Connections to Industry: While there are no explicit partnerships planned at this time, potential federal partners have expressed interest in NEON, such as National Parks, National Forests, Marine Sanctuaries and USDA Agricultural Research Sites. Private foundations, such as the Santa Fe Institute, the Turner Foundation, NatureServe, The Nature Conservancy, and other countries have expressed an interest in NEON but no cost-sharing plans have been initiated. NEON-generated information will be employed by natural resource industries, such as forestry and fisheries, to plan programs and design management strategies.

Management and Oversight: Oversight of NEON is provided through the Biological Infrastructure Subactivity in the Biological Sciences Activity. Each observatory will be selected via a merit-review process resulting in a competitively awarded cooperative agreement. One NSF program director will be dedicated to managing the NEON activity. An Integrated Project Advisory Team, including representatives from the Office of General Counsel and the Office of Budget, Finance and Award Management, will be established to assist with management of the project.

Current Project Status: Initial workshops developed the scientific potential, technological needs, and management structure for NEON. Additional workshops focused on computer networking and information technology. In FY 2003, funds were requested to initiate construction of two observatories. Major first-year milestones included competitions for observatories, and starting development of system architecture for the flow, integration and networking of data, communications and materials across NEON.

Major milestones for NEON are listed below.

FY 2003 Milestones:
Program Announcement for establishment of two (2) observatories; and
Competition for management – NEON Coordinating Unit (NCU).

FY 2004 Milestones:

Initiate construction of experimental, archival and analytical core facilities for first two NEON observatories;
Procure and install analytical instrumentation and research equipment;
Start development of system architecture for the flow, integration and networking of data, communications and materials across the fully operational NEON;
Establish NEON Coordinating Unit (NCU); and
Complete development and begin testing of system architecture for data, communication, and materials flow across NEON.

FY 2005 Milestones:

Finish construction of core facilities for the first two observatories (2);
Begin testing and begin implementation of networking and integration interfaces;
NCU begins to schedule time and allocates resources to user community;
Evaluation and refinement of NEON model sites;
Finalize Strategic Plan for Entire Network of sites; and
Program Announcement for establishment of additional sites.

FY 2006-08 Milestones:

Begin site preparation for construction of additional sites;
Continue implementation of networking and integration interfaces across the fully operational NEON sites;
Release Program Announcement to solicit proposals for research at NEON sites;
Procure and install analytical instrumentation and research equipment;
Complete construction of core facilities; and
Beta test core facilities.

Funding Profile: In FY 2003, NSF requested $12.0 million to establish two NEON observatories. In FY 2004, NSF is requesting $12.0 million to continue construction of the first two observatories. FY 2006-08 implementation funding will be contingent upon the outcome of the feasibility study of the NEON project and the successful review of the prototype NEON sites.

MREFC Appropriations for NEON
(Dollars in Millions)

FY 2003 Request	FY 2004 Request	FY 2005	FY 2006	FY 2007	FY 2008	Total
$12.00	$12.00	$16.00	$20.00	$20.00	$20.00	$100.00

NEON Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1996 & Earlier									
FY 1997									
FY 1998	0.01						$0.01		**$0.01**
FY 1999	0.03						$0.03		**$0.03**
FY 2000	0.17						$0.17		**$0.17**
FY 2001	0.10						$0.10		**$0.10**
FY 2002	1.00						$1.00		**$1.00**
FY 2003 Req				12.00	3.00		$3.00	$12.00	**$15.00**
FY 2004 Req				12.00	6.00		$6.00	$12.00	**$18.00**
FY 2005 Est				16.00	6.00		$6.00	$16.00	**$22.00**
FY 2006 Est[1]				20.00	9.00		$9.00	$20.00	**$29.00**
FY 2007 Est[1]				20.00	12.00		$12.00	$20.00	**$32.00**
FY 2008Est[1]				20.00	15.00		$15.00	$20.00	**$35.00**
Subtotal, R&RA	$1.31				$51.00		$52.31		
Subtotal, MREFC				$100.00				$100.00	
Total, each phase		**$1.31**		**$100.00**		**$51.00**			**$152.31**

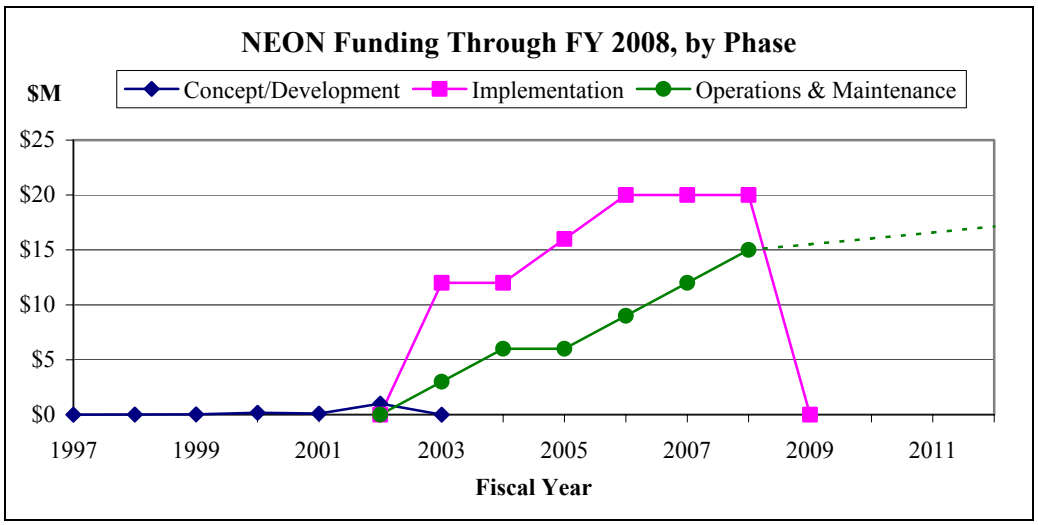
NOTE: A steady state of about $3.0 million per year in operations support per site is expected to occur on or about FY 2025. The expected operational lifespan of this project is 30 years, after construction of each site is completed.
[1]FY 2006-08 implementation funding will be contingent upon the outcome of the feasibility study of the NEON project and the successful review of the prototype NEON sites.

Information pertaining to the data in the table is provided below.

- *Concept/Development*: In FY2002 workshops were funded to specifically address the information technology needs, instrument array design and development, and data and information management architectures. In FY 2003, NSF will issue a call for proposals to establish two prototype NEON observatories. In FY 2004, the first two sites will begin construction.

- *Implementation*: Total construction costs for each site will be $20.0 million. NSF will continually evaluate the success of NEON and together with input from the community develop a strategic plan for the management of the NEON sites.

- *Operations and Maintenance*: NSF is requesting $6.0 million in FY 2004 through the R&RA account to support operation and management of the initial two sites. Initial operations will commence as construction is underway. It is anticipated that NSF will gradually increase funding to support the operations of these sites for the first few years as the network is established.



Future Science Support: Along with direct operations and maintenance support for NEON, NSF will support research performed at the facility through ongoing research and education programs. The annual support for such activities once the facility reaches full operations is estimated to be about $12.0 million.

It is estimated that 1,400 field biologists will use NEON annually. A larger number of scientists, students, resource managers and decision makers will make use of NEON data, both directly and indirectly, through the network capabilities and data distribution and sharing technologies via the network and the internet.

Polar Aircraft Upgrades

Project Description: This project was initiated to modify and upgrade three NSF-owned LC-130's to meet Air Force safety and operability standards that differ from those of the previous U.S. Navy operators. Modifications specified by the Air Force include avionics, airframe, safety, propulsion, and record data; storage and project administration costs are also included. Ski-equipped LC-130 aircraft are the backbone of the U.S. Antarctic Program's air transport system and also support NSF's research in the Arctic. In order to support the Foundation's polar missions, a fleet of ten aircraft is required. In addition to the three aircraft undergoing modification, the Air National Guard has six LC-130's and also flies one NSF-owned aircraft, recently acquired; these seven aircraft already meet the Air Force standards. In parallel with the MREFC project, but funded out of Research and Related Activities, the contract provided for taking care of routine maintenance required on all three aircraft.

Principal Scientific and Education Goals: Support polar research and education by providing necessary air logistics.

Connections to Industry: L3 (formerly Raytheon) and approximately 240 subcontractors for supplies and technical services.

Management and Oversight: The contract for the modifications was awarded and is administered by the Air Force C-130 Systems Program Office at Robins Air Force Base (Warner Robins, GA), which is the

government's C-130 engineering authority office. NSF's Office of Polar Programs (OPP) and Division of Acquisition and Cost Support (DACS) provided input during development of the Request for Proposals in an effort to ensure NSF requirements were met. OPP and DACS work as a team with the C-130 Systems Program Office project managers to approve, fund, and track the progress of the work in an effort to ensure the modifications are completed on schedule.

Current Project Status: Completion is defined technically as acceptance by the government. The Defense Contracting Management Agency (DCMA) has this responsibility. This is followed by post-acceptance functional flight checks and subsequent testing by the 109th Air Wing in New York to assume operational readiness.

Aircraft 3301: The modification of aircraft 3301 was scheduled to be completed in FY 2000, but was delayed because the contractor's original schedule for completion apparently did not realistically account for the complexity of the modifications or for the difficulty in obtaining certain critical parts. 3301 was accepted by the government (DCMA) in FY 2001 and flown to New York. One of the tasks identified by the Air Force for this aircraft was re-winging. During post-delivery inspections by the 109th, the new wings were subsequently found to be corroded and therefore the aircraft was flown back to Waco, Texas, so that this defect could be corrected. This aircraft was finally delivered to the government in January, 2002.

Aircraft 3300 and 3302: These two aircraft were originally scheduled to be completed in FY 2001. Both were accepted by DCMA on behalf of the government and have undergone the post-acceptance inspections. The aircraft modifications were completed in June 2002 for 3300 and July 2002 for 3302. Subsequent inspections of 3300 and 3302 revealed the requirement to re-wing both aircraft in the next planned depot maintenance. This re-winging is being undertaken as part of the maintenance tasking, rather than part of the MREFC project.

Following acceptance by the Defense Contracts Management Agency as the agent for the government, the Air National Guard identified deficiencies with all three aircraft that require additional work to be completed before the aircraft can be put into service; that work is ongoing.

Funding Profile: In FY 1998, in order to meet firm Air Force scheduling requirements, $4.30 million was provided for early engineering design. A total of $32.0 million was appropriated for this project in FY 1999 and FY 2000. A cost-to-complete analysis in 2002 indicated an additional $885,000 was required to complete the project. In order to fund the additional project costs and keep the project moving forward, NSF sought and received Congressional approval to reprogram up to $1.0 million from South Pole Station Modernization, another MREFC project, to the Polar Support Aircraft Upgrade project.

Appropriated and Requested Funds for Polar MREFC Projects[1]
(Dollars in Millions)

	FY 97 Approp	FY 98 Approp	FY 99 Approp	FY 00 Approp	FY 01 Approp	FY 02 Approp	FY 03 Request	FY 04 Request	Total
South Pole Safety and Environment	$25.00					$0.50			$25.50
South Pole Station Modernization		$70.00	$39.00	$5.40	$12.59	-$0.50	$6.00	$0.96	$133.44
Polar Support Aircraft Upgrades			$20.00	$12.00	$0.89				$32.89

[1]In FY 2001, SPSM received an appropriation of $13.50 million, of which $20,000 was rescinded. Of the remaining $13.48 million, NSF was authorized to redirect up to $1.0 million to the Polar Support Aircraft Upgrades project in FY 2002. The table reflects that $885,000 of this authorized redirection of funds has been redirected and obligated for Polar Support Aircraft Upgrades. In addition, $500,000 was redirected from the unobligated authority for SPSM in FY 2002 to the South Pole Safety and Environment project to meet the revised cost estimate for that project.

Polar Support Aircraft Upgrades Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1994 & Earlier									
FY 1995									
FY 1996									
FY 1997									
FY 1998	4.30						$4.30		**$4.30**
FY 1999		2.90		17.10				$20.00	**$20.00**
FY 2000				12.00				$12.00	**$12.00**
FY 2001									
FY 2002				0.89				$0.89	**$0.89**
Subtotal, R&RA	$4.30						$4.30		
Subtotal, MREFC		$2.90		$29.99				$32.89	
Total, each phase		**$7.20**		**$29.99**					**$37.19**

Information pertaining to the data in the table is provided below.

- *Concept/Development:* This project was given very high priority due to the Air Force requirement to upgrade the aircraft. In order to move the project forward promptly, some non-recurring engineering costs were funded by the Office of Polar Programs through the R&RA Account in FY 1998.

- *Implementation:* Supports upgrade of avionics, airframe, safety, propulsion, data, storage, and project administration. In planning for the MREFC project, the Air Force identified one plane that required rewinging; during subsequent inspections associated with the conversion, it was found that the remaining two aircraft also require re-winging. This is being performed under the maintenance tasking and funded out of the Research and Related Activities Account.

- *Operations and Maintenance:* These aircraft are part of a fleet that undergoes routine maintenance, but there are no known additional operating costs for these three aircraft as a result of this project. Routine upgrades and maintenance, funded out of the Research and Related Activities Account, have been undertaken while the aircraft were being reconfigured, as noted above. The lifetime of the aircraft is virtually unlimited with routine maintenance and periodic upgrades, obsolescence being dictated by avionics rather than airframe limitations.

South Pole Station

Project Description: South Pole Station Modernization (SPSM) will provide a new station to replace the current U.S. station at the South Pole, built 30 years ago and currently inadequate in terms of capacity, efficiency, and safety. The new station will be an elevated complex with two connected buildings, supporting 150 people in the summer, and 50 people in the winter.

Principal Scientific Goals: Support science at the South Pole and maintain U.S. presence at the South Pole in accord with U.S. policy.

Principal Education Goals: Support education associated with the research projects at the South Pole.

Connections to Industry: SPSM's primary connection to industry is through the Raytheon Polar Services Company (RPSC), the U.S. Antarctic Program support contractor. In addition, there are approximately 385 separate subcontractors for supplies and technical services.

Management and Oversight: The Office of Polar Programs (OPP) has the overall management responsibility for SPSM, including development of the basic requirements, design, procurement and construction. OPP has contracted for procurement and construction management for all phases of the project, including design reviews of all drawings and specifications; conformance of the designs and procurements with established standardization criteria; assistance in establishing functional interfaces; transition from the existing to the new facilities; and systems integration. Naval Facilities Engineering Command, Pacific Division (PACDIV) selects, monitors, and manages architectural and engineering firms for design, post-construction services, and construction inspection for the project. The project status, including cost expenditures and cost projections, is monitored on a periodic basis by OPP and the project's Project Advisory Team with members from OPP and the Office of Budget, Finance and Award Management.

Current Project Status: The original estimate for SPSM was $127.90 million. A change in project scope was recently proposed to increase station capacity from 110 people to 150 people, following formal approval by the National Science Board. The current cost estimate for SPSM is $133.44 million, including increased scope (+$2.52 million) and revised cost estimates (+$3.02 million), the latter caused primarily by weather-induced schedule delays. The cost estimate is updated annually. The next cost-to-complete estimate will be completed in August 2003.

The original estimated completion date was FY 2005. With the changes in scope and schedule, the new estimated completion date is FY 2007. The revised milestones for the project, taking into account the revised scope and changes in schedule, are below. The original milestones from FY 1998, when different, are in parentheses.

Activity	Procurement	Transport to Antarctica	Airlift to South Pole	Start Construction	Conditional Acceptance
Vertical Circular Tower	FY98	FY99	FY99/00 (00)	FY00 (01)	FY02
Quarters/Galley	FY98	FY99	FY00/FY01	FY01 (02)	FY03
Sewer Outfall	FY98	FY99	FY00	FY01	FY02 (01)
Fuel Storage (100K gallons)	FY98	FY98	FY99	FY99	FY99
Medical/Science	FY99 (98)	FY00 (99)	FY01/02 (00)	FY02	FY04
Communications/Administration	FY99 (98/99)	FY01 (00)	FY02/03 (01)	FY03 (02)	FY05 (03)
Dark Sector Lab	FY98	FY99	FY99/00 (00)	FY00 (01)	FY04 (01)
Water Well	FY00 (98)	FY01 (99)	FY01/02 (00)	FY02 (01)	FY02
Remote RF Building	FY99 (98/99)	FY00	FY01	FY01 (02)	FY01 (03)
Emergency Power/Quarters	FY99	FY01	FY02/03 (01/02)	FY03	FY05
Liquid nitrogen and helium facility	FY02 (99)	FY03 (00)	FY04 (01)	FY04 (02)	FY04 (03)
Quarters/Multipurpose	FY99 (00)	FY02 (01)	FY04 (02/03)	FY05	FY06
Electronic Systems and Communications	FY00/03 (99/00)	FY01/04 (00/01)	FY01/05 (01/02)	FY01 (03)	FY06 (04)
Warehousing, SEH and Waste Management	FY99 (01)	FY02/03 (02)	FY04 (03)	FY06 (04)	FY07 (05)
Station Equipment	FY02/03 (01)	FY03/04 (03)	FY04/05 (04)		FY05

Funding Profile: SPSM has received appropriations totaling $127.90 million through FY 2002 (see table and footnote below). The FY 2003 Request includes $6.0 million and the FY 2004 Request includes $955,000 for the change in scope, the revised schedule estimates, and partial reimbursement of redirected funds. The table below indicates the amounts appropriated for projects related to Polar MREFC projects and describes the redirection of funds.

Appropriated and Requested Funds for Polar MREFC Projects[1]
(Dollars in Millions)

	FY 97 Approp	FY 98 Approp	FY 99 Approp	FY 00 Approp	FY 01 Approp	FY 02 Approp	FY 03 Request	FY 04 Request	Total
South Pole Safety and Environment	$25.00					$0.50			$25.50
South Pole Station Modernization		$70.00	$39.00	$5.40	$12.59	-$0.50	$6.00	$0.96	$133.44
Polar Support Aircraft Upgrades			$20.00	$12.00	$0.89				$32.89

[1]In FY 2001, SPSM received an appropriation of $13.50 million, of which $20,000 was rescinded. Of the remaining $13.48 million, NSF was authorized to redirect up to $1.0 million to the Polar Support Aircraft Upgrades project in FY 2002. The table reflects that $885,000 of this authorized redirection of funds has been redirected and obligated for Polar Support Aircraft Upgrades. In addition, $500,000 was redirected from the unobligated authority for SPSM in FY 2002 to the South Pole Safety and Environment project to meet the revised cost estimate for that project.

The advance funding made possible advance bulk buys of materials, which is ultimately more cost-efficient. However, this project's overall outlay is relatively slow due to the unusual logistics and shortened Antarctic season. As a result, the project has carried over fairly significant amounts each year since FY 1998, resulting in obligations from FY 1998 through FY 2001 that are significantly lower than appropriated amounts.

The following funding profile chart includes actual obligations for past years and anticipated obligations for future years.

South Pole Station Modernization Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	**Total**
FY 1994 & Earlier	12.90						$12.90		**$12.90**
FY 1995	1.10						$1.10		**$1.10**
FY 1996	1.60						$1.60		**$1.60**
FY 1997	0.80						$0.80		**$0.80**
FY 1998				24.93				$24.93	**$24.93**
FY 1999				4.28				$4.28	**$4.28**
FY 2000				15.49				$15.49	**$15.49**
FY 2001				10.14				$10.14	**$10.14**
FY 2002				15.55				$15.55	**$15.55**
FY 2003 Req				22.00				$22.00	**$22.00**
FY 2004 Req				20.00				$20.00	**$20.00**
FY 2005 Est				15.00				$15.00	**$15.00**
FY 2006 Est				5.00				$5.00	**$5.00**
FY 2007 Est				1.04	15.00		$15.00	$1.04	**$16.04**
Subtotal, R&RA	$16.40				$15.00		$31.40		
Subtotal, MREFC				$133.44				$133.44	
Total, each phase		**$16.40**		**$133.44**		**$15.00**			**$164.84**

NOTE: A steady state of operational support is anticipated at $15 million by FY 2007, slightly higher than current operational costs. The expected lifetime of the modernized station is 25 years, through FY 2031.

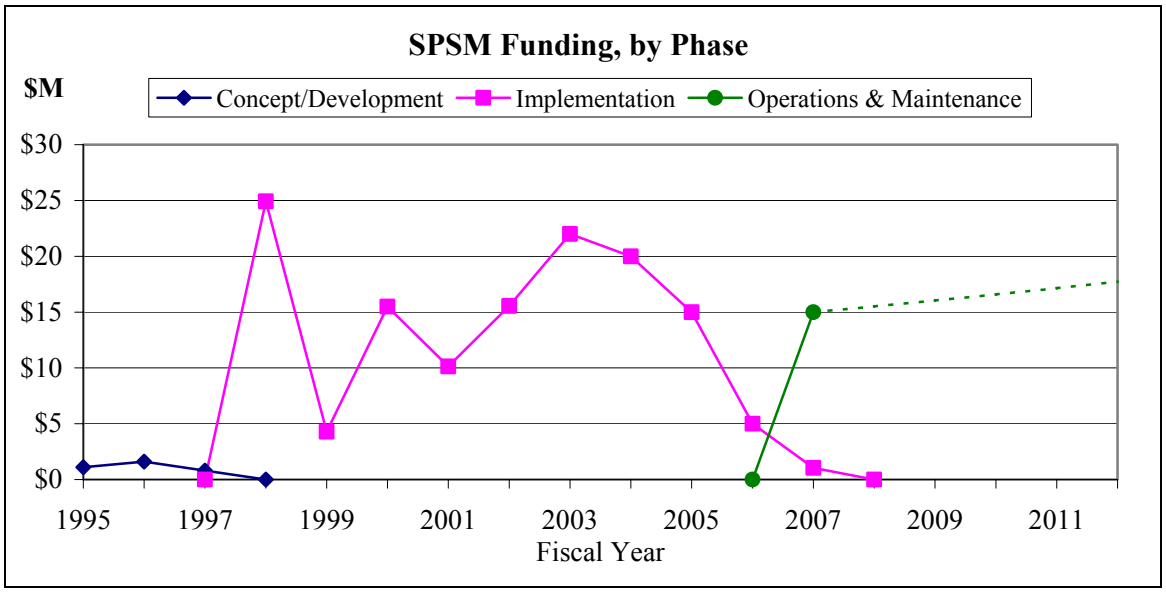
Information on the data in the table is provided below.

- *Concept/Development*: Design, development, planning and closely related activities in support of this project included preparation of more than 40 engineering studies and reports. The documents ranged widely in subject matter including subjects such as snowdrift minimization modeling, detailed analysis of power and heating requirements, preparation of a draft Environmental Impact Statement, energy conservation measures, efficiency and maintainability of diesel generators, fuel storage support system evaluation, design code criteria matrix, concept for signal/communication systems, gray-water system evaluation, minimization of ventilation requirements, control of diesel engine exhaust emissions, and jacking plan and concept.

- *Implementation*: Funding supports construction of an elevated station complex with two connected buildings, supporting 150 science and support personnel in the Austral summer, and 50 science and support personnel in the winter. Costs include materials, labor, logistics for transportation of all material and personnel to the South Pole, construction support, inspection, and equipment, as well as demolition and disposal of the existing station.

- *Operations and Maintenance*: This support represents the continued presence of a U.S. station at South Pole, not new funds. On balance, operation costs of the modernized station are expected to be similar to the former station, with some lower costs due to efficiencies gained, and some possible higher costs due to increased station size and increases in Science Support and Information Systems.

These estimates are currently being reviewed to improve accuracy, taking into account estimated station population and cargo loads.



Future Science Support: Along with direct operations and maintenance support for South Pole Station, NSF will support science and engineering research through ongoing research and education programs. The annual support for such activities is currently estimated to be approximately $8.3 million.

Terascale Computing Systems: Terascale Computing System, Distributed Terascale Facility and Extensible Terascale Facility

Project Description: The NSF Terascale Computing Systems project will provide access to scalable, balanced, terascale computing resources for the broad-based academic science and engineering community served by NSF. A Terascale Computing System (TCS), with peak performance of 6 teraflops, has been built by the Pittsburgh Supercomputer Center (PSC) in partnership with the Compaq Computer Corporation under an award made in FY 2000.

A Distributed Terascale Facility (DTF), initiated in FY 2001, is under construction by The National Center for Supercomputing Applications (NCSA) and the San Diego Supercomputer Center (SDSC), with Argonne National Laboratory (Argonne) and the California Institute of Technology (Caltech), and in partnership with IBM, Intel, Qwest, Oracle and SUN. Based on multiple Linux clusters, DTF will link four sites through high-performance networks to create a very high-performance, distributed facility that allows advanced data handling, remote site interaction, and large-scale storage. Initial operation of the Distributed Terascale Facility will begin in 2003.

In 2002 NSF provided enhancements to the existing Terascale Facilities and initiated the creation of an Extensible Terascale Facility (ETF) by extending the DTF "backbone network" to TCS, and by placing extensible hubs in Chicago and Los Angeles that will permit further expansion of this distributed facility. This ETF "backplane network" will enable science and engineering researchers to conduct analyses at unprecedented scale, to merge multiple data resources seamlessly, and to advance discovery at the

frontiers of science and engineering. This Extensible Terascale Facility will provide the national community with at least 10 teraflops of capability in a single system (NCSA) and over 20 teraflops across the ETF including the 6 teraflop TCS system. Users will have access to at least 500 terabyte of storage at a single site (SDSC) and nearly 1 petabyte across the ETF.

Principle Scientific Goals: To provide state-of-the-art capabilities for simulation and modeling of a vast array of scientific, engineering and mathematical problems in traditional disciplines like physics, chemistry, geosciences, and engineering, as well as in disciplines such as biology and the social and economic sciences, where computing is emerging as a critical new tool. A secondary goal made possible by the distributed architecture of ETF is to seamlessly link large, managed scientific data archives and the high-performance computational resources that can be used to mine, analyze, visualize, and perform related simulations on the data.

Principal Education Goals: The primary education goals are twofold: 1) to provide access and training to U.S. students, graduate students, and postdocs in the use and applications of high-performance computing hardware and software; and 2) to insure that there is a highly-trained scientific workforce with experience in applying state-of-the-art supercomputer technology to basic research problems of national importance in all areas of science and engineering.

Partnerships and Connections to Industry: Several industries are partners in the construction of TCS, DTF, and ETF. Primary industrial partners include Hewlett Packard, IBM, Intel, Qwest, SUN, and Oracle.

Management and Oversight: Oversight of this project is provided through a Program Manager in the Advanced Computational Infrastructure and Research Subactivity in the Computer and Information Science and Engineering (CISE) Activity. Oversight is supported by the NSF Project Advisory Team consisting of representatives from the Office of General Counsel, the Office of Budget, Finance and Award Management, CISE, the Education and Human Resources Account and the Biological Sciences, Geosciences, Mathematical and Physical Sciences, and Engineering Activities. An external Technical Advisory Panel makes periodic site visits to the Terascale facility institutions to review construction progress and provide technical advice to the Program Manager. The Technical Advisory Panel participates in resolution of major technical, managerial, or scheduling concerns; provides technical guidance/advice, especially with regard to the integration and coordination with other NSF Partnerships for Advanced Computational Infrastructure (PACI) program activities; and reviews and, where required, approves technical reports and information to be delivered by Awardee.

The DTF and ETF Terascale Activities have a centralized management organization with a single Project Director. An executive committee, comprised of the Principal Investigators who participated in the Terascale awards, advises the Project Director on the construction, management and operation of the Terascale facilities. Also reporting to the Project Director are an External Advisory Committee, an Institutional Oversight Committee, and a User Advisory Committee.

Current Project Status: TCS was dedicated on October 29, 2001. It began allocated usage in April 2002. The first stage of DTF will be completed in June of 2003, and begin allocated usage in October 2003. ETF construction will be completed by the end of FY 2003, and allocated usage will begin in April of 2004.

Milestones for the Terascale Computing Systems are outlined below:

FY 2002 Milestones (Completed except as noted):

Terascale Computing System

Begin full operations of TCS (initial site – 2nd quarter).

Distributed Terascale Facility:

Begin construction of DTF (second site – 1st quarter);
Complete infrastructure preparation at four DTF sites (power, cabinets, air conditioning – 2nd quarter);
Contract for High Performance Network connections between Chicago and Los Angeles (2nd quarter);
Take delivery of backplane networks (3rd quarter); and
Take delivery of initial DTF cluster computers (4th quarter – Completed in 1st quarter FY 2003).

Extensible Terascale Facility:

Review and award supplements to TCS and DTF awardees for hardware and networking upgrades to fully integrate them with DTF backplane, and to create an Extensible Terascale Facility (ETF); (4th quarter) and
Hold workshop for additional sites that are interested in connecting to ETF.

FY 2003 Milestones:

Terascale Computing System:

Install TCS computing, storage and networking upgrades awarded for integration of TCS into ETF (2nd quarter).

Distributed Terascale Facility:

Complete installation and testing of initial clusters and DTF backplane networks (1st quarter);
Installation and testing of High Performance Network connections (1st quarter);
Complete installation and testing of operating software (OS, middleware, Globus) (2nd quarter);
Complete construction and integration of all DTF clusters (3rd quarter); and
Conduct performance testing on DTF (4th quarter).

Extensible Terascale Facility:

Install Hub Routers in Chicago and Los Angeles (1st quarter);
Complete high speed connection between Chicago and the Pittsburgh Supercomputing Center (2nd quarter);
Install computing and storage upgrades at all 5 ETF sites (3rd quarter);
Complete integration of TCS with DTF (4th quarter); and
Competition to extend ETF to additional sites (2nd quarter).

FY 2004 Milestones:

Terascale Computing System:

Continue full operations.

Distributed Terascale Facility:

DTF construction completed; acceptance and friendly user testing starts (1st quarter); and
DTF enters production use (2nd quarter).

Extensible Terascale Facility:

Full integration of all 5 sites into ETF including ETF hardware upgrades (1st quarter);
Begin Allocated usage of ETF (2nd quarter); and
Begin integration of additional sites into ETF (3rd quarter).

Funding Profile: The recommendation to fund ETF in FY 2002 was presented at the National Science Board meeting in August, 2002. In order to make certain that all questions raised during the review had

been addressed and responded to in writing, the NSB postponed approval of the award to the next meeting, scheduled for October, 2002, which resulted in a carryover of funds into FY 2003. The NSB approved the award at their October meeting, and the funds have subsequently been obligated. The FY 2003 Request includes $20.0 million to extend ETF to additional resource sites that may include: additional computational resources; large data archives; large instrumentation facilities; or large sensor networks.

MREFC Appropriations for Terascale Computing Systems
(Dollars in Millions)

FY 2000	FY 2001	FY 2002	FY 2003 Request	Total
$36.00	$44.90	$35.00	$20.00	$135.90

Terascale Computing Systems Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		Grand Total
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1997 & Earlier									
FY 1998	0.06						$0.06		0.06
FY 1999									
FY 2000				36.00				$36.00	36.00
FY 2001				44.90	2.37		$2.37	$44.90	47.27
FY 2002[1]					7.06		$7.06		7.06
FY 2003				55.00	7.00		$7.00	$55.00	62.00
FY 2004 Req					7.00		$7.00		7.00
FY 2005 Est					11.00		$11.00		11.00
FY 2006 Est									
FY 2007 Est									
Subtotal, R&RA	$0.06				$34.43		$34.49		$34.49
Subtotal, MREFC				$135.90				$135.90	$135.90
Total, Each Phase		**$0.06**		**$135.90**		**$34.43**			**$170.39**

NOTE: A strategic plan for the long-term support of NSF's Terascale Facilities for FY 2005 and beyond is currently under development, and will be presented to the National Science Board for consideration.
[1]FY 2002 funding for Terascale was carried over into FY 2003 due to the NSB meeting schedule. The award was approved in October, 2002 and the funds have been obligated.

Information pertaining to the data in the table is provided below.

- *Concept/Development*: Planning for Terascale Computing Systems began in 1998, with a series of 3 workshops held at NSF to assess the need within the academic research community for computational resources with multi-teraflop capability. Because it was anticipated that Terascale Computing Systems would be constructed by partnerships involving academic institutions and commodity

hardware vendors, NSF employed a peer-reviewed, competitive solicitation process in FY 2000 and 2001 to select the best designed systems for funding. In FY 2002 the original systems have been upgraded, and funding for the extension of DTF to form the ETF was provided. In FY 2003 ETF will be extended by integrating additional sites into it.

- *Implementation*: TCS was funded at Pittsburgh Supercomputer Center in FY 2000. It was fully operational in first quarter of 2002. DTF was funded at UCSD and NCSA in FY 2001. Construction will continue through FY 2003. Funds in FY 2002 will enhance and augment TCS and DTF, fully integrate TCS and DTF into a single grid-enabled facility, and enable the DTF to extend beyond the five initial sites. Funds in FY 2003 will support connections of new nodes, and upgrades as called for by rapid advances in computing technologies and systems.

- *Management and Operations*: The Terascale facilities incurred operations costs of approximately $7 million in FY 2002. Estimated operations costs are $7.0 million in FY 2003, $7.0 million in FY 2004, and thereafter $11.0 million annually, excluding inflation. The increase does not include funding for equipment upgrades. A long-term strategic plan for the maintenance and operations of the Terascale facilities beyond FY 2004, as a component of the NSF's cyberinfrastructure focus, is currently in preparation and will be submitted for National Science Board approval in 2003.

Future Science Support: Along with the direct operations and maintenance support for Terascale Computing Systems facilities, NSF will support science and engineering research performed at the facilities, through ongoing research and education programs. Terascale Facilities provide support for scientists and engineers funded through all programs supported by the NSF. The annual support for research and education using the Terascale facilities is estimated to be about $160.0 million.

SECOND PRIORITY: NEW STARTS IN FY 2005 AND FY 2006

Scientific Ocean Drilling

Project Description: Requested in FY 2005, this project is to support the conversion, outfitting and acceptance trials of a deep-sea drilling vessel for use in a new international scientific ocean drilling program. The Integrated Ocean Drilling Program (IODP), starting in FY 2004, builds on the long track record of success of the Ocean Drilling Program which, as planned, is being phased out at the end of 2003. Commercial drillships are not configured or routinely equipped to meet the requirements for scientific research. To support the IODP, a new vessel is needed; it is planned as a year-around operations platform that will be capable of operating in all ocean environments and that will accommodate a scientific and technical staff of approximately 50. A competitive procurement will be used to select the organization to contract, convert and operate the vessel. Further information on IODP can be found in the Tools section.

Principal Scientific Goals: The converted drillship will provide the United States facility contribution to the Integrated Ocean Drilling Program. The IODP is co-led by the NSF and the Ministry of Education, Culture, Sport, Science and Technology (MEXT) of Japan. European and Asian nations are also participating in the program. The IODP will recover sediment and crustal rock from the seafloor using scientific ocean drilling techniques, and emplace observatories in drillholes to study the deep biosphere, the flow of fluids in sediments and the crust, the processes and effects of environmental change, and solid earth cycles and geodynamics. MEXT will provide a heavy drillship for deep drilling objectives of the

programs. NSF will provide a light drillship and science support services for high-resolution studies of environmental and climate change, observatory and biosphere objectives.

Principal Education Goals: To engage students and the public in geoscience discovery through distance learning initiatives, preparation of classroom modules on IODP research initiatives, and outreach displays at museums and educational/teaching institutions.

Management and Oversight: The project is managed and overseen by a project manager in the Division of Ocean Sciences in the Directorate for Geosciences (GEO). The project manager receives advice and oversight support from a NSF Project Advisory Team, which consists of representatives from GEO, the Office of Polar Programs (OPP), the Office of Budget, Finance and Award Management, and the Office of General Counsel. A scientific-user-community advisory committee has been established to provide recommendations and advice to the contractor and NSF on vessel conversion planning.

Current Project Status: Planning has been completed for the science program, operations and international organizational arrangements for the IODP. Japan has launched and is now outfitting its drilling vessel. The U.S. scientific community has identified the vessel, drilling and laboratory requirements for the NSF drillship. NSF expects to release an RFP for the drillship and operator in FY 2003, with vessel conversion/trials in FY 2005/2006 and scientific drilling operations commencing in FY 2006.

The construction schedule for this project is still under review and discussion. The milestones listed below are preliminary and will likely be revised as the project's schedule is finalized.

FY 2003 Milestones:
- Complete RFP documentation (completed-1st quarter);
- NSB approval for RFP release (completed-1st quarter);
- Issue RFP (2nd quarter);
- Proposals submitted (2nd quarter);
- Proposal evaluation-selection (2nd-3rd quarters);
- Award contract for support of U.S. efforts associated with operational aspects of U.S. participation in the IODP (4th quarter); and
- Initiate development of Project Execution plan (4th quarter).

FY 2004 Milestones:
- Contractor planning/vessel design (1st-2nd quarter);
- MREFC Project Execution plan approved (2nd quarter); and
- Vessel selection (2nd-4th quarters).

FY 2005 Milestones:
- Vessel conversion/outfitting (1st-4th quarters).

FY 2006 Milestones:
- Vessel acceptance trials (1st quarter); and
- Vessel scientific operations begin (2nd quarter).

Funding Profile: Planning through FY 2002 has cost approximately $600,000. In 2003 and 2004, approximately $4.20 million will be provided to initiate contract activity, planning and design. In FY 2005 and FY 2006, $99.85 million of funds from the MREFC account will be required for conversion/equipping/testing of the drillship.

Scientific Ocean Drilling Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand Total**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	
FY 1999 & Earlier									
FY 2000	0.10						$0.10		**$0.10**
FY 2001	0.20						$0.20		**$0.20**
FY 2002	0.30						$0.30		**$0.30**
FY 2003 Req	2.10						$2.10		**$2.10**
FY 2004 Req	2.10				4.90		$7.00		**$7.00**
FY 2005 Est	0.50	4.00		72.85	6.50		$7.00	$76.85	**$83.85**
FY 2006 Est		1.00		22.00	32.70		$32.70	$23.00	**$55.70**
FY 2007 Est					53.00		$53.00		**$53.00**
FY 2008 Est					54.80		$54.80		**$54.80**
FY 2009 Est					56.67		$56.67		**$56.67**
FY 2010 Est					58.59		$58.59		**$58.59**
FY 2011 Est					60.58		$60.58		**$60.58**
FY 2012 Est					62.64		$62.64		**$62.64**
Subtotal, R&RA	$5.30				$390.39		$395.69		**$395.69**
Subtotal, MREFC		$5.00		$94.85				$99.85	**$99.85**
Total, each phase		**$10.30**		**$94.85**		**$390.39**			**$495.54**

NOTE: A steady state of about $53 million in operations support is expected to occur in or about FY 2007. The expected operational lifespan of this project is 15 years, beginning in FY 2006.

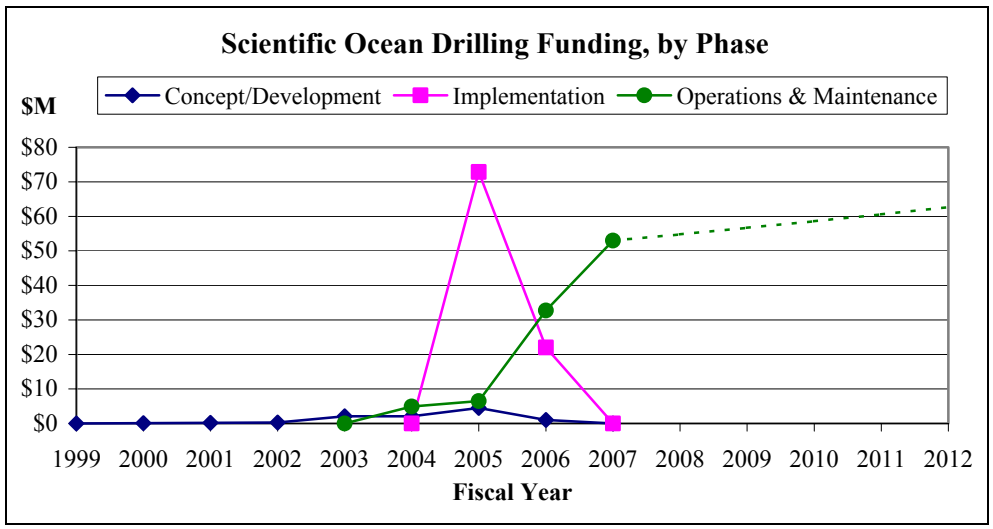
Information pertaining to the data in the table is provided below.

- *Concept/Development*: Activities supported by the R&RA Account will commence immediately upon contract award. This will include: efforts necessary to begin IODP planning in FY 2003 with Japanese partners and the scientific user community; development of the Project Execution Plan by the contractor; development of the Environmental Impact Statement for the non-riser drilling vessel; and initiation of planning for shorebased support of the program, including core storage, data management systems, and logistics.

  Several ship-specific planning activities will be undertaken utilizing MREFC support as soon as the ship to be converted is identified. These include: modification of the ship to provide laboratories for geochemical, geologic and biologic analysis of samples and data; improvements to ship habitability (accommodations, storage, etc.) for cruises of up to 2 months duration, since industry vessels generally operate in a mode where personnel are rotated on a 2 to 3 week cycle; and upgrade of the drilling-coring capability of the vessel.

- *Implementation*: The MREFC funds in FY 2005-06 will be required for the vessel conversion, including construction of laboratory and other scientific spaces, equipping of laboratories with instrumentation, computers and support equipment, and modifications to the drilling equipment of the contracted vessel. Funding is also required for vessel lease during modification and for sea-trial operations of approximately four months duration in FY 2006.

- *Operations and Maintenance:* Following conversion, the drillship will be managed, operated and maintained by the selected contractor (and subcontractors) with funding from the R&RA account, for use in the Integrated Ocean Drilling Program. Operations cost estimates are based on NSF experience in management of the IODP precursor, the Ocean Drilling Program. Specific missions will be reviewed and prioritized by a science advisory committee composed of representatives from IODP member nations. Significant coordination and integration of planning, procedures and operations will be required with Japanese operators of their drillship in the IODP.



Future Science Support: Along with direct operations and maintenance support for IODP, NSF will support research performed at the facility, through ongoing research and education programs. The annual support for such activities is estimated to be about $31 million.

Rare Symmetry Violating Processes (RSVP)

Project Description: A collaboration representing almost 30 institutions from the U.S., Canada, Switzerland, Italy, Japan and Russia submitted a proposal through New York University for RSVP in FY 2000. This project will address new physics at the cutting edge of the sensitivity frontier and represents an extraordinary opportunity to empower a large and growing community to make major discoveries. Two major experiments are to be pursued through this proposal: MECO (Muon to Electron Conversion) and KOPIO ($K^o_L \rightarrow \pi^o \nu$ ν-bar). These experiments will be performed at the DOE's Brookhaven National Laboratory (BNL) Alternating Gradient Synchrotron (AGS), which has the highest intensity in the world at the energies required for these experiments. The AGS is currently being used as an injector for the Relativistic Heavy Ion Collider (RHIC), for which it is needed only a few hours per day. MECO and KOPIO will extend the sensitivity of probes of rare symmetry violating processes by many orders of magnitude. At this level, the experiments have the opportunity to uncover fundamental new physics relating to the unexplained absence of anti-matter in the universe, and to the postulated existence of "supersymmetric particles" that existed in the early universe. The scale, both in cost and technical complexity, is set by the extraordinary sensitivity required to do this science. RSVP will, through an NSF/DOE memorandum of understanding, be an NSF-supported activity, running concurrently with

RHIC, and with the NSF funding only incremental operating costs. AGS "landlord responsibilities" rest with the DOE Nuclear Physics program.

Principal Scientific Goals: RSVP consists of two complementary experiments:

- MECO is a search for the conversion of muons to electrons and would be able to detect this process even if it is as rare as 1 event for 10^{17} detected muons. The goal is to understand better the family structure of leptons: why do there exist two extra, unstable heavy copies of the electron?
- KOPIO is a search for the decay of a neutral kaon (K^{o}_{L}) to a neutral pion, a neutrino and an anti-neutrino. The goal is to understand better a process called CP violation that is required to produce a Universe containing matter rather than a mixture of matter and anti-matter.

Principal Education Goals: RSVP is planning the PRINCIPLES Project, a mathematics, science and technology educational enrichment program for fourth grade teachers and students. BNL, SUNY/Stony Brook and other partners will establish an Elementary Teachers Academy at BNL. The keystone of the Academy will be an in-service seminar course at BNL for elementary school teachers that will address the teaching of MST through investigations or projects by elementary students - focusing on the fourth grade level. Objectives are to show teachers first-hand (1) how and what general principles underlie specific inquiry-based learning activities, and (2) how recourse to such principles can support use of observation and reasoning by their students as they learn. The ultimate goal is to improve student performance in assessments requiring use of these skills. In addition, the strong university makeup of the RSVP collaborations lends itself well to graduate student and postdoctoral educational opportunities. Each of the institutions will train graduate students and postdocs. They will receive a broad education in detector construction and operation and in data analysis and the interpretation of results. This opportunity is increasingly rare in particle physics, as most experiments are carried out by much larger collaborations.

Partnerships and Connections to Industry: RSVP will have strong connections to industry through instrument development and construction, but the specifics are not known at this time.

Management and Oversight: RSVP will be managed through the Physics (PHY) Subactivity in the Mathematics and Physical Sciences (MPS) Activity. One Program Officer within PHY will maintain primary oversight responsibility, with assistance from a Project Advisory Team composed of staff from MPS, the Office of Budget, Finance and Award Management, the Office of General Counsel and the Office of Legislative and Public Affairs. Additional staff may be required during construction, particularly staff trained in large project management principles. From 2000-02, NSF conducted cost, management, and scientific and technical reviews of RSVP. Each panel consisted of external reviewers, and each rated the project very highly. The management review indicated areas for improvement, which have since been implemented by the collaborators.

A comprehensive project management plan is in development and has been reviewed favorably, with minor improvements suggested. The collaboration has benefited from the rigorous and well-tested BNL methodology for the development, management, and oversight of large projects. The final version will include a Work Breakdown Structure detailing costs, schedule, milestones, oversight responsibilities, change control, and tracking. The plan includes experienced university-based project managers, a host laboratory role for BNL that involves environment, health and safety responsibilities for the entire project, and internal review procedures by the experimenters, by BNL, and by the NSF. A direct reporting path from the project manager to the NSF Physics Division is part of this plan, and NSF management and oversight includes periodic cost, schedule, and technical reviews of the project.

Current Project Status: R&D is continuing on critical project components and is expected to continue through FY 2006. RSVP's construction schedule is still under review and discussion. The milestones listed below are preliminary and will likely be revised as the project's schedule is finalized.

FY 2005 Milestone:
Complete magnet design

FY 2006 Milestones (Construction Start):
Complete AGS design modifications.
Deliver and integrate magnet coils

FY 2007 Milestones:
Complete detector component prototypes.
Complete construction of AGS beam

FY 2008 Milestones:
Start detector component production
Complete initial modules

FY 2009 Milestones:
Complete data acquisition system and trigger design
Deliver detector components
Complete magnet tests with installed detector elements

FY 2010 Milestones:
Perform engineering run
Complete construction

Funding Profile: Including FY 2003, $3.3 million has been spent for concept and development of RSVP through the R&RA Account. The total construction cost of the project is estimated at $144.91 million.

RSVP Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		Grand
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	Total
FY 2000 & Earlier									
FY 2001	0.90						$0.90		**$0.90**
FY 2002	1.20						$1.20		**$1.20**
FY 2003 Req	1.20						$1.20		**$1.20**
FY 2004 Req	1.50						$1.50		**$1.50**
FY 2005 Est	2.00						$2.00		**$2.00**
FY 2006 Est	2.00			30.00	5.30		$7.30	$30.00	**$37.30**
FY 2007 Est				42.66	8.50		$8.50	$42.66	**$51.16**
FY 2008 Est				44.00	8.50		$8.50	$44.00	**$52.50**
FY 2009 Est				20.25	13.50		$13.50	$20.25	**$33.75**
FY 2010 Est				8.00	14.30		$14.30	$8.00	**$22.30**
FY 2011 Est					14.80		$14.80		**$14.80**
Subtotal, R&RA	$8.80				$64.90		$73.70		**$73.70**
Subtotal, MREFC				$144.91				$144.91	**$144.91**
Total, Each Phase		**$8.80**		**$144.91**		**$64.90**			**$218.61**

NOTE: NSF's share of operations support is expected to reach a level of effort of about $15.0 million by about FY 2011. The estimated operational lifespan of this project is approximately 20 years.

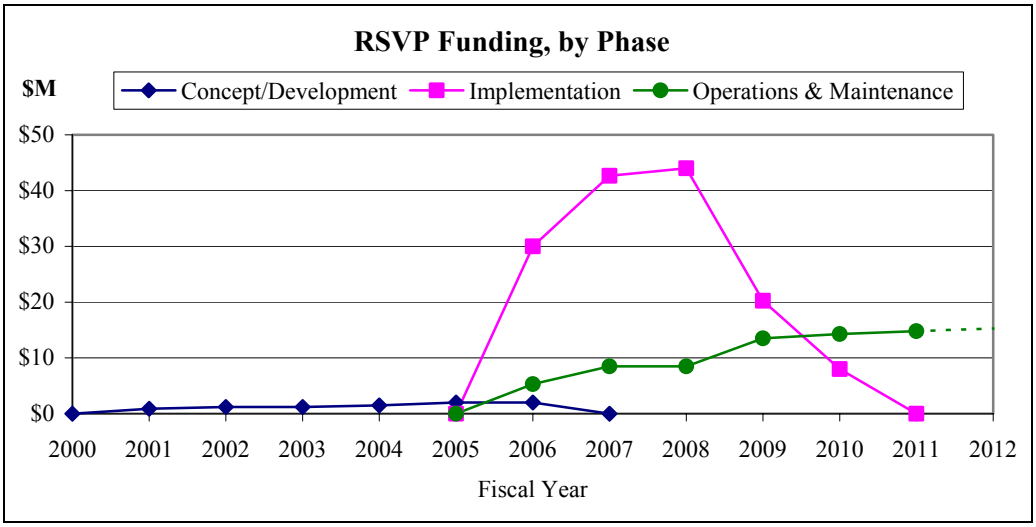
Information on the data in the table is provided below.

- *Concept/Development*: The technical needs of RSVP require a strong R&D program that is now in progress. In addition to R&D on all KOPIO and MECO components, a major component of MECO is a sequence of high-field, superconducting solenoids appropriately instrumented for particle detection and readout. These solenoids have very tight and challenging field requirements, and the MECO collaboration, with a group at the MIT Plasma Science & Fusion Center, has completed a detailed conceptual design of the magnet system that proves its feasibility and lays the groundwork for industrial production. KOPIO requires a low-energy, time-structured K^o beam, which allows a precise determination of the incident kaon momentum on an event-by-event basis using time-of-flight techniques. R&D is underway on the KOPIO Alternating Gradient Synchrotron (AGS) modifications that match the proposed Canadian contribution.

- *Implementation*: Funding during this phase of the project will provide support for the construction of two beamlines at the AGS and associated Beam instrumentation at the site. This work will be performed by BNL personnel. For the KOPIO detector, universities will construct the critical beam, catcher, radiator and veto counter assemblies. The MECO superconducting magnets will be constructed by industry after a conceptual design is complete, but MECO collimators, targets, beam stops, and calorimeters will be constructed at universities.

- *Operations and Maintenance*: Support for operations and management will phase in as the project is under construction. Initial funds provided through R&RA will support project managers for MECO and KOPIO and a project management office. Test beam operations can begin in FY 2007 and will

ramp up as detector elements are completed. Full operations costs are expected to be approximately $15 million beginning in about FY 2010.



Future Science Support: Along with direct support for operations and maintenance, NSF will also support research performed at this facility, through ongoing research and education grants. Support for such activities is presently estimated to be about $4.0 million per year from NSF, once the facility reaches full operations.

Ocean Observatories Initiative (OOI)

Project Description: This project will construct an integrated observatory network that will provide the oceanographic research and education communities with continuous access to the ocean. The OOI will have three elements: 1) a regional cabled network consisting of interconnected sites on the seafloor spanning several geological and oceanographic features and processes, 2) several relocatable deep-sea buoys, and 3) an expanded network of coastal observatories, developed through new construction or enhancements to existing facilities. The primary infrastructure for all components of the OOI consists of an array of seafloor junction boxes connected to cables running along the seafloor to individual instruments or instrument clusters. Depending upon proximity to the coast and other engineering requirements, the junction box is either terminated by a long dedicated fiber-optic cable to shore, or by a shorter cable to a surface buoy that is capable of two-way communications with a shore station. The observatory infrastructure of the OOI will be operated as a shared-use facility with open community access to data.

Principal Scientific Goals: Scientific problems requiring OOI infrastructure are broad in scope and encompass nearly every area of ocean science. Once established, seafloor observatories will provide earth and ocean scientists with unique opportunities to study multiple, interrelated processes over timescales ranging from seconds to decades; to conduct comparative studies of regional processes and spatial characteristics; and to map whole-earth and basin scale structures. This project will establish facilities to meet the following goals: continuous observation at frequencies from seconds to decades; spatial scales of measurement from millimeters to kilometers; high power and bandwidth capabilities as well as two-way data transmission; an ability to operate during storms; an ability to accommodate plug

and play sensors, instruments, and imaging systems; bottom-mounted winches for cycling instruments up and down the water column, either autonomously or on command; docking stations enabling autonomous underwater vehicles to download data and recharge batteries; ability to assimilate data into models and make three-dimensional forecasts of the oceanic environment; means for making data available in real time to researchers, schools, and the public over the Internet; and low cost relative to the cost of building and maintaining ships and manned submersible systems.

Principal Education Goals: Scientific discoveries arising from the OOI will provide new opportunities for ocean education and outreach through the capabilities for real-time data transmission and, particularly, real-time display of visual images from the seafloor. Educational links will be made with GEO's Digital Library for Earth Science Education (DLESE), and OCE's Centers for Ocean Science Education Excellence (COSEE). In addition, with the planned establishment of the National Integrated Ocean Observing System, there will be an unprecedented need for oceanographers skilled in the use and manipulation of large, oceanographic, time-series datasets. The facilities comprising the OOI will provide the ideal platforms to train this new generation of oceanographers.

Partnerships and Connections to Industry: Some of the component technologies that are part of the OOI are currently in use or in development as part of the telecommunication and exploration industries. These groups have been involved in conceptual design reviews of proposed OOI components and systems and will be important participants in the construction and implementation phase of the OOI.

Management and Oversight: The project will be managed and overseen by a program manager in the Ocean Sciences Subactivity in the Geosciences Activity. The program manager will receive advice and oversight support from an NSF Project Advisory Team that includes representatives from GEO, the Office of Budget, Finance and Award Management, the Office of International Science and Engineering, the Office of General Counsel, and the Office of Legislative and Public Affairs. The management structure proposed for the acquisition and implementation phase of the OOI is based on a structure that has been successfully used by the Ocean Drilling Program. In this structure, management, coordination, and oversight of the OOI will be the responsibility of the Executive Director of the OOI Program Office, to be established through a cooperative agreement with NSF. This Director will be accountable to an Executive Committee under which will be established Scientific and Technical Advisory Committees. The Executive and Advisory Committees will draw their membership from individuals with expertise in ocean observing science and engineering. Experiments utilizing OOI infrastructure will be selected on a peer-reviewed basis. This project will be coordinated with the National Integrated Ocean Observing System (IOOS) that will support operational mission objectives of agencies such as the National Oceanic and Atmospheric Administration (NOAA), Navy, the National Aeronautics and Space Administration (NASA), and the Coast Guard.

Current Project Status: Current activities are concentrating on the development of implementation plans for the three components of the OOI to facilitate the high priority science developed through community input. The first of these activities was a workshop organized through the Coastal Ocean Processes Program (May 2002) to provide advice on the use of observing infrastructure for advancing coastal science. The report was published in December 2002. Another community activity provided advice on the implementation of a network of regional cabled observatories as a result of a workshop held in August 2002. The report from this workshop will be published in January 2003. There is a third community activity underway to develop a plan for the deployment of a global network of moored buoy systems to facilitate multi-disciplinary science. The report of this group will be completed in Spring 2003. In addition to these activities, OCE has sponsored a National Research Council study to provide recommendations for an overall implementation plan for the OOI. The Dynamics of Earth and Ocean

Systems (DEOS) committee, made up of members of the academic research community, provides a focus for coordinated scientific planning and oversight of these activities.

The construction schedule for this project is still under review and discussion. The milestones listed below are preliminary and will likely be revised as the project's schedule is finalized.

FY 2002 Milestone:
- Establish NSF Program Management Team (3rd quarter 2002)

FY 2003 Milestones:
- Project Management
  - Complete Program Solicitation for the OOI Program Office (3rd quarter 2003)
  - Issue Program Solicitation (4th quarter 2003)

FY 2004 Milestones:
- Project Management
  - Proposals submitted (2nd quarter 2004)
  - Proposal evaluation and selection (3rd and 4th quarters 2004)

FY 2005 Milestones:
- Project Management
  - Issue award for Program Office (1st quarter 2005)

FY 2006 Milestones:
- Project Management
  - Design and implementation of data management and archiving system
- Coastal Observatories
  - Design of relocatable coastal observing infrastructure
  - Issue of a Program Solicitation for enhancements to current coastal observing infrastructure (1st quarter 2006)
- Deep-Sea Buoys
  - Design and testing of moored buoyed systems
- Regional Cabled Network
  - Cable-route surveys and planning
  - Final design, inspection and testing of cables, connectors, nodes, and shore equipment.

FY 2007 Milestones:
- Coastal Observatories
  - Construction and Testing of relocatable coastal observing infrastructure
  - Issue of a Program Solicitation for enhancements to current coastal observing infrastructure (1st quarter 2007)
- Deep-Sea Buoys
  - Design and testing of capabilities needed for buoy installation
- Regional Cabled Network
  - Physical (hardware and software) system integration and testing prior to deployment
  - Preparation of shore facilities and installation of equipment.

FY 2008 Milestones:
- Coastal Observatories
  - Construction and deployment of relocatable coastal observing infrastructure to be integrated into the OOI coastal observing system
  - Issue of a Program Solicitation for enhancements to current coastal observing infrastructure (1st quarter 2008)
- Deep-Sea Buoys
  - Construction and deployment of three moored buoyed systems
- Regional Cabled Network
  - Installation and subsequent inspection of first cable backbone section
  - Installation of science nodes on first backbone section

FY 2009 Milestones:
- Coastal Observatories
  - Construction and deployment of relocatable coastal observing infrastructure to be integrated into the OOI coastal observing system
  - Installation of a new coastal observational system
  - Issue of a Program Solicitation for enhancements to current coastal observing infrastructure (1st quarter 2009)
- Deep-Sea Buoys
  - Construction and deployment of six moored buoyed systems
- Regional Cabled Network
  - Testing and commissioning of first backbone section
  - Installation and subsequent inspection of second cable backbone section
  - Installation of science nodes on second backbone section
  - Installation of initial science experiments on first backbone section

FY 2010 Milestones:
- Coastal Observatories
  - Installation of two new coastal observational systems
  - Issue of a Program Solicitation for enhancements to current coastal observing infrastructure (1st quarter 2010)
- Deep-Sea Buoys
  - Construction and deployment of six moored buoyed systems
- Regional Cabled Network
  - System testing and commissioning
  - Installation of initial science experiments on second backbone section

Funding Profile: NSF expects to spend approximately $14.2 million in concept and development activities through FY 2003. An additional $1.3 million will be spent on such activities through FY 2005. The total construction cost for OOI is $208.81 million beginning in FY 2006. Management, operations and maintenance will be funded through the R&RA Account.

Ocean Observatories Initiative Funding Profile
(Dollars in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		**Grand**
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	**Total**
FY 2000 & Earlier							$0.00	$0.00	**$0.00**
FY 2001	1.60						$1.60	$0.00	**$1.60**
FY 2002	11.00						$11.00	$0.00	**$11.00**
FY 2003 Req	1.60						$1.60	$0.00	**$1.60**
FY 2004 Req	0.70						$0.70	$0.00	**$0.70**
FY 2005 Est	0.60						$0.60	$0.00	**$0.60**
FY 2006 Est				24.76	2.00		$2.00	$24.76	**$26.76**
FY 2007 Est				40.33	4.00		$4.00	$40.33	**$44.33**
FY 2008 Est				72.46	7.00		$7.00	$72.46	**$79.46**
FY 2009 Est				35.89	7.00		$7.00	$35.89	**$42.89**
FY 2010 Est				35.37	9.00		$9.00	$35.37	**$44.37**
FY 2011 Est					10.00		$10.00	$0.00	**$10.00**
FY 2012 Est					10.38		$10.38	$0.00	**$10.38**
Subtotal, R&RA	$15.50		$0.00		$49.38		$64.88		
Subtotal, MREFC		$0.00		$208.81		$0.00		$208.81	
Total, each phase		**$15.50**		**$208.81**		**$49.38**			**$273.69**

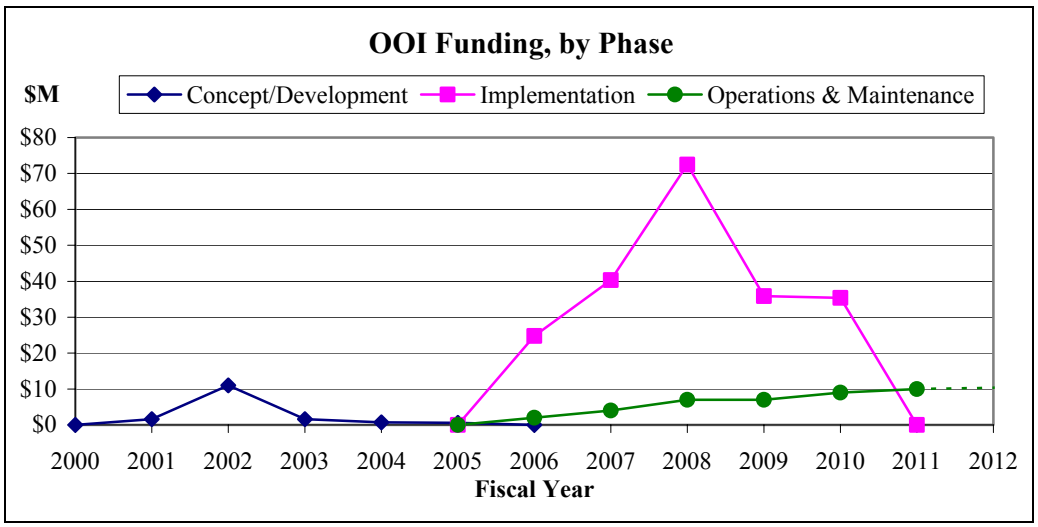
NOTE: A steady state of about $10 million in operations support is expected to occur in or about FY 2011. The expected operational lifespan of this project is 30 years, beginning in FY 2011.

Information pertaining to the data in the table is provided below.

- *Concept/Development:* R&RA funding has supported workshops to identify the observatory infrastructure needed to address the high priority science requiring time-series measurements. Specific design characteristics and platform requirements were developed through conceptual design reviews and best practices consultations with industry and academic experts. In FY 2002 an unsolicited proposal from the Monterey Bay Aquarium Research Institute resulted in a $6.9 million award to establish an advanced cabled observatory in Monterey Bay to both advance scientific goals as well as create a valuable systems and instrumentation testbed for potential future cabled ocean observing systems.

- *Implementation*: Funds requested for this phase will construct: a regional cabled network consisting of interconnected sites on the seafloor spanning several geological and oceanographic features and processes; several relocatable deep-sea buoys; and new construction or enhancements to existing facilities leading to an expanded network of coastal observatories.

- *Operations and Maintenance*: Access to OOI Infrastructure will be determined by peer review and all data will be openly accessible. OOI Infrastructure will be maintained and operated by the OOI Program Office. Future development of more complex sensor packages for the OOI infrastructure will be funded using R&RA funds within OCE. Observing platforms of the OOI will accommodate instrumentation from other agencies, international partners, as well as new instruments that are developed.



Future Science Support: Along with direct operations and maintenance support for the OOI, NSF will support research performed using this infrastructure through ongoing research and education programs. The annual support for such activities is estimated to be about $10.0 million, once the network is fully implemented.