

ICECUBE NEUTRINO OBSERVATORY

\$7,000,000
-\$1,710,000 / -19.6%

IceCube Neutrino Observatory

(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actuals	
			Amount	Percent
\$8.71	-	\$7.00	-\$1.71	-19.6%

IceCube is the world’s first high-energy neutrino observatory, located deep within the ice cap under the U.S. Amundsen-Scott South Pole Station in Antarctica. With the discovery in 2013 of the first neutrinos from beyond our solar system, the Observatory has demonstrated that 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 bursts, the activities surrounding supermassive black holes, and other violent and energetic astrophysical processes.

Approximately one cubic kilometer of ice is instrumented with photomultiplier (PM) tubes 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. The energy and arrival direction of high-energy neutrinos ranging in energy from 100 GeV to 10 PeV (1 GeV is 10⁹ electron Volts [eV]; 1TeV is 10¹² eV; and 1 PeV is 10¹⁶ eV) are derived from the IceCube data stream. The IceCube Collaboration has recently focused on studies of neutrino events with a deposited energy of 1 TeV and above. The deposited energy here is the calculated energy that is released within the detector fiducial volume representing an energy level of the incoming neutrino. These high-energy neutrinos can be produced either by the interaction of cosmic rays in the Earth’s atmosphere, the so-called atmospheric neutrinos, or near distant astrophysical accelerators like black holes and neutron stars, the so-called cosmic neutrinos. Astrophysical neutrinos remain the dominant component above 10 TeV. The number of these cosmic neutrinos (100 TeV - 10 PeV) detected by IceCube has already exceeded 50.



The Observatory includes a Deep Core Array (DCA) with tightly spaced digital optical modules to detect lower energy neutrinos (down to about 10 GeV), thus opening the door to studies of neutrino oscillation measurements and studies of Weakly Interacting Massive Particles (WIMPs) below 250 GeV. The DCA closes the energy gap between the IceCube Neutrino Observatory and the Super-Kamiokande detector in Japan, and allows effective observations of high-energy neutrinos entering from the sky of the southern hemisphere.

The IceCube project has transformed one cubic kilometer of natural Antarctic ice into a particle detector. The sensors keep watch for momentary flashes of blue light made by subatomic particles called muons; some are produced in collisions of neutrinos with atomic nuclei inside or near the detector. Since completion in 2010, the IceCube detector has been taking data in its final configuration with an uptime of well over 99 percent. IceCube detects one neutrino every 6 minutes in a background of 2700 cosmic ray muons per second. To handle the high data rates, initial analysis of the data is performed by a cluster of computers housed in a two-story building placed on top of the array. The filtered data is sent over geostationary satellites to the IceCube Research Center at the University of Wisconsin. *Credit: USAP Photo Library, Sven Lidstrom (sic), NSF.*

Total Obligations for IceCube

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES ¹				
				FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (GEO)	\$5.23	-	\$3.50	\$3.50	\$3.50	\$3.50	\$3.50	\$3.50
Operations & Maintenance (MPS)	3.48	-	3.50	3.50	3.50	3.50	3.50	3.50
Total, IceCube	\$8.71	-	\$7.00	\$7.00	\$7.00	\$7.00	\$7.00	\$7.00

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2021.

The IceCube Neutrino Observatory is presently led by the University of Wisconsin (UW) and was constructed with support from four countries (U.S., Belgium, Germany, and Sweden). The science collaboration is much broader, currently consisting of 23 U.S. institutions and 24 institutions in eleven other countries (Belgium, Germany, Sweden, Australia, Canada, Denmark, Japan, Korea, New Zealand, Switzerland, and the United Kingdom). NSF’s foreign partners contribute a pro rata share of operations and maintenance costs based on the number of PhD-level researchers involved.

Management and Oversight

- **NSF Structure:** Oversight of the IceCube Neutrino Observatory is the joint responsibility of the Geosciences Directorate’s Office of Polar Programs (OPP) and the Mathematical and Physical Sciences Directorate’s Division of Physics (PHY). Support for operations and maintenance, research and education, and outreach are shared by OPP and PHY, as well as other organizations and international partners. NSF provides oversight through regular site visits by NSF managers and external reviewers.
- **External Structure:** The UW management structure for IceCube includes leadership by the project’s principal investigator supported by the director of operations and two associate directors (one for science and instrumentation and one for education and outreach). A collaboration spokesperson is selected from the senior international scientific leaders for a two-year term, with an option to be renewed once for at most four consecutive years. At lower levels, project management includes international collaboration representatives, as well as participation by staff at collaborating U.S. institutions. UW has in place an external Scientific Advisory Committee and a Software and Computing Advisory Panel that meet annually and provide written advice to the project. UW leadership, including the Chancellor, provides additional awardee-level oversight.

Operations Costs

Full operations and maintenance in support of scientific research began in FY 2011. The associated costs are and will continue to be shared by the partner funding agencies – U.S. (NSF) and non-U.S. – proportional to the number of PhD researchers involved (currently about 55:45). The current NSF award for operations and maintenance constitutes the bulk of the U.S. contribution to general operation of the facility. In addition, work in support of facility operations is performed by students, postdocs, and senior researchers who are participating in research on the data produced by the Observatory.

NSF support for U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades is provided through the Research and Related Activities (R&RA) account in response to merit-reviewed proposals (approximately \$4.0 million annually provided jointly by GEO and MPS).

The general operations of South Pole Station, reported in the Polar Facilities and Logistics narrative, also contribute to supporting IceCube. The cost of IceCube operations shown in the table herein includes only those that are project-specific and incremental to general South Pole Station operations. The expected operational lifespan of the IceCube Neutrino Observatory is 25 years, beginning in FY 2011.

Education and Outreach

IceCube provides a vehicle for helping to achieve national and NSF education and outreach goals. Specific outcomes include the education and training of future leaders in astrophysics, including undergraduate students, graduate students, and postdoctoral research associates; K-12 teacher scientific and professional development, including development of new inquiry-based learning materials and use of the South Pole environment to convey the excitement of astrophysics and science generally to K-12 students; increased opportunity for involvement of students in international collaborations; increased diversity in science through partnerships with minority serving institutions; and enhanced public understanding of science through broadcast media and museum exhibits (such as the Adler Planetarium in Chicago, Illinois) based on IceCube science and the South Pole environment. NSF supports evaluation and measurement-based education and outreach programs under separate grants to universities and other organizations that are selected following standard NSF merit review.

Renewal/Recompetition/Termination

NSF re-competed the IceCube operations and maintenance award in FY 2016. The new award was issued on April 1, 2016 for 60 months. Actual obligations for FY 2016 are higher than original estimates due to the extension of the previous cooperative agreement to allow time for the 2016 competition.