

**ICECUBE NEUTRINO OBSERVATORY (ICECUBE)**

**\$7,000,000**  
**\$0 / 0%**

**IceCube Neutrino Observatory Funding**  
(Dollars in Millions)

FY 2017	FY 2018	FY 2019	Change over	
Actual	(TBD)	Request	FY 2017 Actual	Percent
\$7.00	-	\$7.00	-	-

IceCube is the world’s first high-energy neutrino observatory and is 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. The energy and arrival direction of high-energy neutrinos ranging in energy from 100 GeV to 10 PeV (1 GeV is  $10^9$  electron Volts [eV]; 1TeV is  $10^{12}$  eV; and 1 PeV is  $10^{16}$  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. Astrophysical neutrinos remain the dominant component above 10 TeV. The number of these neutrinos, detected by IceCube in the range between 100 TeV and 10 PeV has already exceeded 150, and so will provide a statistically robust basis for determining the extrasolar neutrino flux.

Multi-messenger astrophysics followed the IceCube telegram on 22 September 2017, reporting a well-reconstructed track of a ~290 TeV extraterrestrial muon neutrino that pointed to the location of the bright flaring blazar (a quasi-stellar radio source associated with a supermassive black hole at the center of an active giant galaxy). Three scientific spacecraft (Fermi-LAT, AGILE, SWIFT) and one ground-based telescope (MAGIC) reported ~100 GeV-level gamma-ray observations from a direction that was consistent within  $0.1^\circ$  from the location of the blazar, previously located by the Fermi Large Area Telescope.



*Credit: USAP Photo Library, Sven Lidstrom (sic), NSF.*

Approximately one cubic kilometer of ice is instrumented with photo-multiplier (PM) tubes to detect neutrino-induced, charged reaction products that are produced when a high-energy neutrino interacts in the ice within or near the cubic kilometer fiducial volume. Since completion in 2010, the IceCube detector has been taking data in its final configuration with an uptime of well over 99 percent. 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.

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.

**Total Obligations for IceCube**  
(Dollars in Millions)

	FY 2017	FY 2018	FY 2019	ESTIMATES				
	Actual	(TBD)	Request	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Operations & Maintenance (GEO)	\$3.50	-	\$3.50	\$3.50	\$3.50	\$3.50	\$3.50	\$3.50
Operations & Maintenance (MPS)	3.50	-	3.50	3.50	3.50	3.50	3.50	3.50
<b>Total</b>	<b>\$7.00</b>	<b>-</b>	<b>\$7.00</b>	<b>\$7.00</b>	<b>\$7.00</b>	<b>\$7.00</b>	<b>\$7.00</b>	<b>\$7.00</b>

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 11 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 (MPS) Division of Physics (PHY). Support for operations and maintenance, research and education, and outreach are shared by OPP and PHY, as well as other external 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. The \$ 1.0 million reduction in the U.S. operational cost contribution will likely be taken over by non-U.S. partners. This would shift the ratio of U.S.:non-U.S. PhD researchers from about 55:45 to 47:53. 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.

Approximately \$4.0 million annually is provided in NSF support for U.S. institutions working on more refined and specific data analyses, data interpretation (theory support), and instrumentation upgrades is provided in response to merit-reviewed proposals, through research grants.

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

## *Major Multi-User Research Facilities*

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 U.S. 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.