

Atacama Large Millimeter Array

\$3,000,000

The FY 2012 Budget Request for the Atacama Large Millimeter Array (ALMA) is \$3.0 million, which represents the last year of an eleven-year project totaling an estimated \$499.26 million.

**Appropriated and Requested MREFC Funds for the
Atacama Large Millimeter Array**

(Dollars in Millions)

				FY 2010		
				Enacted/ Annualized	FY 2012	Total Project
FY 2007 & Earlier ¹	FY 2008	FY 2009	FY 2010	FY 2011 CR ²	Request	Cost ²
\$255.27	\$102.07	\$82.25	\$42.76	\$42.76	\$3.00	\$499.26

¹An additional \$31.99 million was appropriated through the MREFC account prior to FY 2005 for concept and development.

² A full-year 2011 appropriation was not enacted at the time the budget was prepared; therefore, this project is operating under a continuing resolution (P.L. 111-242, as amended). The amounts shown above for 2011 reflect the annualized level provided by the continuing resolution. The FY 2011 Request based on the project's funding profile is \$13.91 million.

The global ALMA project will be 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, combining sub-arcsecond angular resolution with the sensitivity of a single antenna nearly 100 meters in diameter. The array will provide a testing ground for theories of planet formation, star birth and stellar evolution, galaxy formation and evolution, and the evolution of the universe itself. The interferometer is under construction at 5,000 meters altitude near San Pedro de Atacama in the Antofagasta (II) Region of Chile, the ALMA host country.

Baseline History

A \$26.0 million, three-year design and development phase was originally planned for a U.S.-only project, the Millimeter Array. NSF first requested funding for design and development of this project in FY 1998. In June 1999, the U.S. entered into a partnership via a Memorandum of Understanding (MOU) with the European Southern Observatory (ESO), a consortium of European funding agencies and institutions. The MOU committed the partners to construct a 64 element array of 12-meter antennas. NSF received \$26.0 million in appropriations between FY 1998 and FY 2000. Because of the expanded managerial and technical complexity of the joint U.S./ESO project, now called ALMA, an additional year of design and development was provided by Congress in FY 2001 at a level of \$5.99 million. In FY 2002, \$12.50 million was appropriated to initiate construction of ALMA; the U.S. share of the cost was estimated to be \$344.0 million. The National Research Council (NRC) of Canada joined ALMA as a partner in 2003. In 2004, Japan entered under the provisions of a MOU between NSF, ESO, and the National Institute of Natural Sciences of Japan.

The ALMA Board initiated rebaselining in the fall of 2004 under the direction and oversight of the Joint ALMA Office (JAO) Project Manager. The project was at that point sufficiently mature that the baseline budget and schedule established in 2002, prior to the formation of the partnership, could be refined based on experience. The rebaselining process took approximately one year, scrutinizing cost and schedule throughout the project, assessing technical and managerial risk, and ultimately revising the assumptions on the scope of the project. The new baseline plan developed by the JAO assumed a 50-antenna array as

opposed to the original number of 64, extended the project schedule by 24 months, and established a new U.S. total project cost of \$499.26 million. The FY 2009 Request was increased by \$7.50 million relative to the rebaselined profile in order to allow more strategic use of project contingency to buy down near-term risk, as recommended by the 2007 annual external review. The increase in FY 2009 was offset by a matching decrease in the FY 2011 Budget Request.

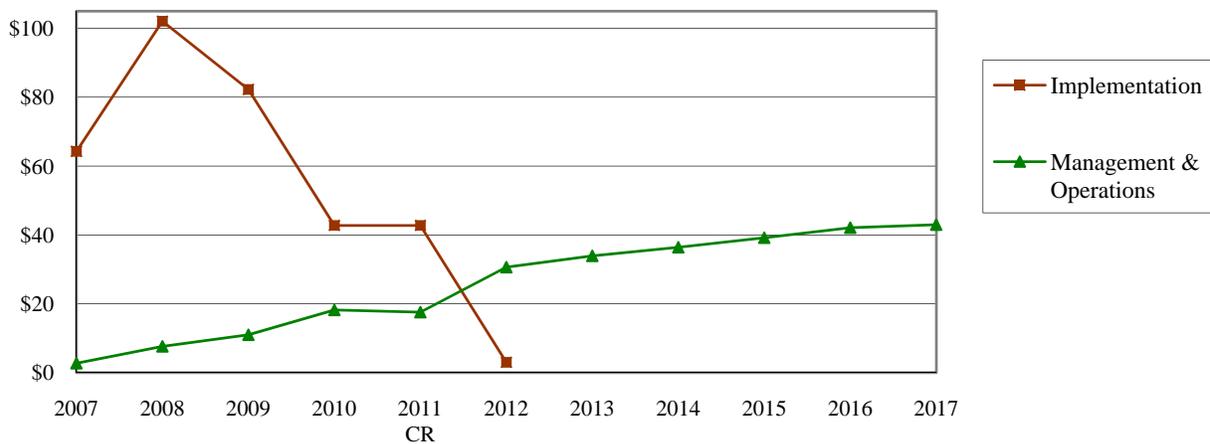
Total Obligations for ALMA
(Dollars in Millions)

	Prior Years	FY 2010 Actual	Enacted/ Annualized FY 2011 CR FY 2011 CR ¹	FY 2012 Request	ESTIMATES				
					FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
<i>R&RA Obligations:</i>									
Concept & Development	\$6.50	-	-	-	-	-	-	-	-
Management & Operations	11.00	18.20	17.57	30.65	33.92	36.41	39.17	42.10	42.98
Subtotal, R&RA Obligations	\$17.50	\$18.20	\$17.57	\$30.65	\$33.92	\$36.41	\$39.17	\$42.10	\$42.98
<i>MREFC Obligations:</i>									
Concept & Development	31.99	-	-	-	-	-	-	-	-
Implementation	439.59	42.76	42.76	3.00	-	-	-	-	-
Subtotal, MREFC Obligations	\$471.58	\$42.76	\$42.76	\$3.00	-	-	-	-	-
TOTAL Obligations	\$489.08	\$60.96	\$60.33	\$33.65	\$33.92	\$36.41	\$39.17	\$42.10	\$42.98

Totals may not add due to rounding.

¹A full-year 2011 appropriation was not enacted at the time the budget was prepared; therefore, this project is operating under a continuing resolution (P.L. 111-242, as amended). The amounts shown above for 2011 reflect the annualized level provided by the continuing resolution. The FY 2011 Request based on the project's funding profile is \$37.41 million: \$13.91 million for MREFC and \$23.50 million for R&RA.

ALMA Funding, by Stage
(Dollars in Millions)



Once completed, ALMA will be the most capable imaging radio telescope ever built and will bring to millimeter and submillimeter astronomy the high-resolution aperture synthesis techniques of radio astronomy. ALMA will image at 1 millimeter wavelength with the same 0.1 arcsecond resolution achieved by the Hubble Space Telescope at visible wavelengths, and will form a critical complement to the leading-edge optical, infrared, ultraviolet, and x-ray astronomical instruments of the 21st century.

ALMA will help educate and train U.S. astronomy and engineering students; at least 15 percent of ALMA's approximately 1,000 yearly users 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, providing an opportunity to broaden participation in science and engineering by members of underrepresented groups.

Extensive public and student ALMA outreach programs will be implemented in North America, Europe, and Chile as ALMA approaches operational status. ALMA education and public outreach (EPO) programs are funded regionally, through the Associated Universities Incorporated/National Radio Astronomy Observatory (AUI/NRAO), ESO, and the National Astronomical Observatory of Japan (NAOJ), and jointly by the ALMA partnership in Chile. AUI/NRAO's request for NSF funding (including partnership activities) was critically evaluated as a component of a proposal review in mid-2010 and assessment will continue as part of the annual external reviews. NRAO's EPO activities are included in their annual program plan and the status, performance, and issues are assessed by program staff through regular quarterly reports. ESO and NAOJ will follow their own processes for review of their contributions. These reviews include consideration of plans for educational evaluation and measurement of all programs. A visitors' center will be constructed at the 2,800 meter-altitude Operations Support Facility gateway to the ALMA site near San Pedro de Atacama in northern Chile. The project also supports a fund for the Antofagasta (II) Region of Chile that is used for economic, scientific, technical, social, and cultural development, particularly within the nearby towns of San Pedro de Atacama and Toconao.

North America and Europe are equal partners in the core ALMA instrument. Japan joined ALMA as a third major partner in 2004, and will deliver a number of enhancements to the baseline instrument. The North American side of the project, consisting of the U.S., Canada, and Taiwan, is led by AUI/NRAO. Funding and execution of the project in Europe is carried out through the ESO. Funding of the project in Japan is carried out through the National Institutes of Natural Sciences of Japan and project execution is the responsibility of the NAOJ.

From an industrial perspective, ALMA instrumentation will push gallium arsenide and indium phosphide transistor amplifier technology to high frequencies, will challenge production of high-density, high-speed integrated circuits for computational uses, and is expected to stimulate commercial device and communication technologies development.

Peer-review telescope allocation committees will provide merit-based telescope time but no financial support. NSF will not provide awards targeted specifically for use of ALMA. Most U.S. users will be supported through NSF or National Aeronautics and Space Administration (NASA) grants to pursue research programs that require use of ALMA.

Construction progress continues in FY 2011, both at the site in Chile and within the ALMA partner countries. In FY 2010, delivery of North American production antennas continued at the planned rate of one every two months, and a total of fifteen antennas were accepted or assembled and tested in Chile. The first antennas were transported to the final, high-altitude site and science commissioning has begun. Early science operations are planned to commence in late FY 2011 and completion of the construction project and the start of full science operations are forecast to occur in FY 2013.

Project Report

Management and Oversight

- NSF Structure: Programmatic management is the responsibility of the ALMA program manager in

the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS). An NSF advisory group consisting of representatives from the Office of General Counsel, the Office of Budget, Finance, and Award Management, the Office of International Science and Engineering, and the Office of Legislative and Public Affairs, serves as a standing ALMA Project Advisory Team (PAT). The NSF Deputy Director for Large Facility Projects (DDLFP) is a member of the PAT and provides advice and assistance.

- **External Structure:** An international ALMA Management Advisory Committee (AMAC) advises AST and the ALMA Board. Management of the NRAO effort on ALMA is carried out under a cooperative agreement with AUI. Oversight of the full international project is vested in the ALMA Board, whose membership includes an NSF member; coordination and management of the merged international efforts is the responsibility of the Joint ALMA Office (JAO), whose staff includes the ALMA Director, project manager, and systems engineer.
- **Reviews:**
 - **Technical reviews:** The JAO holds frequent technical and schedule reviews at appropriate design and fabrication milestones. For example, a series of reviews to assess the schedule, risks and cost to complete was held in October 2009 and March 2010. A review of the science operations implementation plan was held in September 2009 and further science readiness reviews were held in October and November 2010. A function of the AMAC is to conduct project-wide annual external reviews on behalf of the ALMA Board.
 - **Management, Cost, and Schedule reviews:** NSF, through the ALMA Board, holds external reviews of the broad project and in targeted areas. A review of the operations plan was conducted in July 2010. Project-wide annual reviews, last held in November 2009 and October 2010, assessed management, cost, and schedule performance, status, issues, and risks. A follow-up assessment of implementation of the 2009 review recommendations was held in June 2010. A performance review of the labor management and practices at the Chilean sites was held in September 2010.
 - **Upcoming reviews:** The annual external review will occur in October 2011.

Current Project Status

- Major project milestones attained in FY 2010 included:
 - Continued delivery of North American antennas at a rate of one every two months
 - Acceptance of the fourth through ninth North American antennas and the second Japanese 12-meter antenna
 - Transport of eight accepted antennas to the high-altitude site in Chile
 - Installation and acceptance of the central local oscillator (serves the first 16 antennas for early science)
 - Start of commissioning
- Major milestones for FY 2011 are expected to include
 - Continued delivery of North American antennas at a rate of one every two months
 - Acceptance of the first European antennas
 - Acceptance of the remaining Japanese 12-meter and first 7-meter antennas
 - Installation and acceptance of third and fourth quadrants of the correlator
 - Installation and acceptance of the remainder of the central local oscillator (serves all ALMA antennas)
 - Call for proposals for early science
 - Start of early science operations (late FY 2011)

- Major milestones for FY 2012 are expected to include:
 - All North American deliverables made, including final North American antennas and receiver systems
 - Acceptance of the remaining Japanese 7-meter antennas
 - Continued delivery of European antennas at a rate of one every four to six weeks
 - Continued commissioning of accepted antenna and integration into the science array

Cost and Schedule

The current schedule performance is slightly behind plan due to equipment delivery delays, in particular delivery of the receivers and the first European antennas. Consequently, the major milestones of early-science and full-science are forecast to be delayed by six to nine months. Cost performance is very good at this stage in the project — cost variance is +2 percent and schedule variance is –5 percent relative to the reference baseline — with about 20 percent contingency remaining in the uncommitted budget. Significant expenditure of budgeted contingency is foreseen during the remainder of the project.

Risks

- The receiver systems and European antennas are the pacing items for the medium- and long-term schedule, respectively. Fabrication of North American antennas is at the planned rate and testing and handover are catching up with delivery.
- Fabrication of individual receiver components is approaching the production rate and implementation of parallel integration and testing lines is intended to ensure that the receivers stay ahead of antenna delivery in the longer term.
- Timely handover of the first European antennas and production of the remaining units will be required to hold the forecast schedule for completion. Integration of the final antennas and receivers into the science array is projected to continue into 2013.
- The schedule for the start of initial scientific observations in 2011 depends upon successful commissioning of the growing complement of antennas at the final high-altitude site during early 2011. Initial commissioning has been impacted by adverse weather and reliability of the temporary power supply and first, pre-production, units.

Future Operations Costs

Operations and maintenance funds phase-in as initial site construction is completed and antennas are delivered. Funds will be used to manage and support site and instrument maintenance, array operations in Chile, early-science (FY 2011) and eventually full-science operations, and in support of ALMA observations by the U.S. science community. Full ALMA science operations are forecast to begin in 2013. An operations plan and a proposal for North American operations were externally reviewed in FY 2007 and again in July 2010. A funding profile through FY 2011 was authorized by the National Science Board in December 2007 and a renewal through FY 2015 is being prepared for authorization by the National Science Board in FY 2011. The process of a competition for the management and operation of NRAO for a subsequent award in 2016 is expected to begin in FY 2012 provided that ALMA construction is completed as forecast and operations in Chile continue on their path to become sustainable. The operations estimates for FY 2012 and beyond are based on current cost projections. The anticipated operational lifespan of this project is at least 30 years.



Five antennas undergoing science commissioning at the ALMA high altitude site in Chile. *Credit: ALMA/ESO/NRAO/NAOJ.*