Atacama Large Millimeter Array (ALMA)

ALMA VertexRSI test antenna, one of two prototypes constructed at the site of the Very Large Array near Socorro, New Mexico.

Project Description: The global ALMA project will be an aperture-synthesis radio telescope operating in the wavelength range from 3 to 0.4 mm. It grew out of a U.S.-only project called the Millimeter Array (MMA). 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 star birth and stellar evolution, galaxy formation and evolution, and the evolution of the universe itself. The interferometer is under construction at 5,000 meter altitude near San Pedro de Atacama in the Second Region of Chile, the ALMA host country.

Principal Scientific Goals: ALMA will function as 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 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 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.

Partnerships and Connections to Industry: North America and Europe were equal partners in ALMA as originally planned. 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. and Canada, is led by Associated Universities, Incorporated/National Radio Astronomy Observatory (AUI/NRAO). Funding and execution of the project in Europe is carried out through the European Southern Observatory (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 National Astronomical Observatory of Japan. 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 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 Division of Astronomical Sciences (in MPS). An NSF advisory group, consisting of representatives from the Office of General Counsel, the Office of Budget, Finance, and Award Management, and the Office of Legislative and Public Affairs, serves as a standing ALMA Project Advisory Team (PAT). The NSF Deputy for Large Facility Projects is a member of the PAT and provides advice and assistance. AST's external MMA Oversight Committee has been advising NSF on the project since early 1998, and comprises half of the International ALMA Management Advisory Committee. Management of the NRAO effort on ALMA is carried out under 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, whose staff includes the ALMA Director, Project Manager, and Project Engineer.

Current Project Status: Construction progress continued in FY 2005, both at the site in Chile, and within the ALMA partner countries. The most significant event for the project in FY 2005 was the signing of a production contract for North America's share of the array's antennas. NSF gave permission to AUI/NRAO to proceed with the antenna contract, after intensive testing of the ALMA 12m prototypes was completed, and with the consent of the Joint ALMA Office and the ALMA Board, the project's governing body.

The current baseline schedule for ALMA is specified in version 1 of the ALMA Project Plan, adopted by the ALMA Board in February 2003 following the signature of the ALMA Agreement. While the Project Plan has been under configuration control by the Joint ALMA Office since 2004, the current project schedule was developed prior to the start of ALMA construction activities and the entry of Japan into the project. ALMA is currently 9-12 months behind this existing baseline schedule. However, a detailed reexamination of the project construction baseline and schedule, as well as its operating costs, has been underway since the start of FY 2005, and a set of intensive peer reviews of revised baseline strategies, scrutinizing both the full international project as well as North America's detailed responsibilities, began in October 2005. After the completion of these reviews in February 2006, a new project baseline will be established.

Major project milestones attained in FY 2005 included:

Placement of North American production antenna contract
Road from base to high-altitude site 80% complete
Placement of contract for three 12m antennas in compact array
Placement of contracts for foundation and shell of high-altitude Array Operations Site (AOS) technical building

Major milestones for FY 2006 are expected to include:

Completion of all baseline reviews
Completion of ALMA site camp
Critical design reviews for three receiver bands completed
Placement of European production antenna contract
Placement of antenna transporter contract
North American front end integration and test center operational
Prototype integration testing begins at Socorro NM antenna test facility (interferometry)

Although dependent to some extent upon the adopted new project baseline, major milestones for FY 2007 are expected to include:

Completion and provisional acceptance of AOS technical building
Delivery of first North American production antenna to Chile site
Delivery of first front end to Chile site
European front end integration and test center operational

Completion of the construction project and the start of full science operations is expected to occur around the end of 2012 under the new baseline.

Funding Profile: A $26.0 million, three-year Design and Development Phase was originally planned for a U.S.-only project, the MMA. 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. U.S. construction of ALMA was initiated in FY 2002.

The current project schedule, which still reflects the original ALMA baseline, calls for U.S.-funded construction activities to continue through 2010, with full project completion at the end of calendar 2011 (early FY 2012), and full operation beginning in early FY 2013. The estimated cost to construct ALMA is $702.0 million, with the U.S. share of the joint array construction estimated to be $344.28 million.

Appropriated and Requested MREFC Funds for ALMA

(Dollars in Millions)

	FY 03 & Earlier	FY04	FY05	FY06 Plan	FY07 Request	FY08	FY09	FY10	Total
ALMA R&D	31.99								$31.99
ALMA Construction	42.31	50.70	49.30	45.14	47.89	47.07	37.37	20.98	$340.76
Unobligated Balance from FY 2005				3.52					$3.52
Total, ALMA	$74.30	$50.70	$49.30	$48.66	$47.89	$47.07	$37.37	$20.98	$376.27

ALMA Funding Profile

(Obligated Dollars and Estimates in Millions)

	Concept/ Development		Implementation		Operations & Maintenance		Totals		Grand
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	**Total**
FY 2001& Earlier	6.50	31.99					$6.50	$31.99	**$38.49**
FY 2002				12.50			-	$12.50	**$12.50**
FY 2003				29.81			-	$29.81	**$29.81**
FY 2004				50.70			-	$50.70	**$50.70**
FY 2005				49.30	1.00		$1.00	$49.30	**$50.30**
FY 2006 Current Plan[1]				48.66	4.00		$4.00	$48.66	**$52.66**
FY 2007 Request				47.89	6.00		$6.00	$47.89	**$53.89**
FY 2008 Estimate				47.07	10.00		$10.00	$47.07	**$57.07**
FY 2009 Estimate				37.37	14.00		$14.00	$37.37	**$51.37**
FY 2010 Estimate				20.98	19.00		$19.00	$20.98	**$39.98**
FY 2011 Estimate					23.00		$23.00	-	**$23.00**
FY 2012 Estimate					28.00		$28.00	-	**$28.00**
FY 2013 Estimate					30.00		$30.00	-	**$30.00**
Subtotal, R&RA	$6.50		-		$135.00		$141.50		
Subtotal, MREFC		$31.99		$344.28		-		$376.27	
Total, Each Stage		**$38.49**		**$344.28**		**$135.00**			**$517.77**

NOTES: Implementation costs are based on the cost review of the original MMA and then projected to ALMA. The expected operational lifespan of this project is at least 30 years. A steady state of about $30.0 million annually is estimated for operations support beginning in about FY 2013. Operations estimates for FY 2008 and beyond are developed strictly for planning purposes and are based on current cost profiles. They will be updated as new information becomes available. Operations funding is provided through the National Radio Astronomy Observatory.

[1]The FY 2006 Current Plan includes $3.52 million of an unobligated balance from FY 2005.

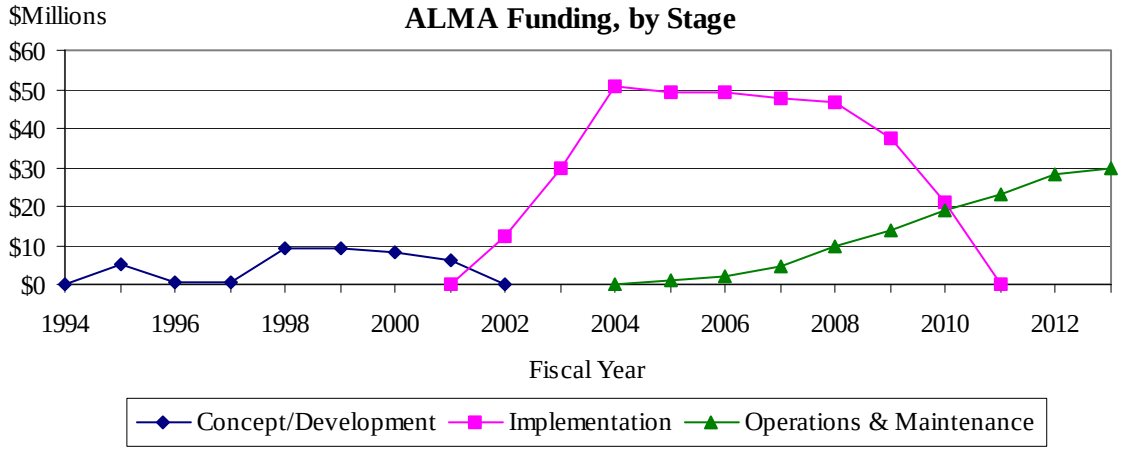
Information pertaining to the data in the table is included below.

- Concept/Development: Prior to FY 1998, 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: Implementation funds support an array of up to 64 12-meter antennas having a total collecting area of 7,200 square meters, with 4 receiver bands extending into the submillimeter. The exact number of antennas will be determined after the completion of the baseline reviews in early 2006. The table describes the U.S. contribution to ALMA. It does not include funds resulting from Canada's participation.

- Operations and Maintenance: Operations and maintenance funds begin to phase in as initial site construction is completed and antennas begin to be delivered. 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. Full ALMA science operations are anticipated to begin in FY 2013.



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.

Associated Research and Education Activities: Extensive public and student ALMA outreach programs will be implemented in North America, Europe, and Chile as ALMA approaches operational status. 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.