Organisation and Management of the ALMA Project

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ABSTRACT

The Atacama Large Millimeter/submillimeter Array (ALMA) is the largest astronomical ground based global collaboration. The project is a partnership of organisations and institutes located in four continents, each bringing its own organisational structures, scientific objectives, and management. This brings a richness of different experiences and expertise to the project, but is also a challenge to build and provide the public and the science users a unified project. In this talk we will review the ALMA organisation and management structure, its successes, difficulties and experience gained for future projects of similar complexity and challenge.

1. THE ALMA PROJECT AND PARTNERS

The Atacama Large Millimeter/submillimeter Array (ALMA) is a highly sensitive, high resolution array of antennas. Once completed, the Joint ALMA Observatory will operate 54 antennas of 12 meter diameter and 12 antennas of 7 meter diameter in an interferometric and single dish mode. All antennas will be equipped with seven receiver bands, with the possibility to install three more receiver bands, thus covering the atmospheric transmissions regions in the frequency range from 30 GHz to 950 GHz.

The ALMA Array Operations Site (AOS) will be located at a truly unique and unusual place: the Altiplano de Chajnantor, a plateau at an altitude of 5.000 meters in the Atacama Desert in Chile. This location has been selected because of its dryness and altitude. Considering these aspects, the ALMA Observatory will not only be unique for its ambitious scientific goals, and the unprecedented technical requirements, but also because of the very specific, harsh environment and living conditions. ALMA must be operated in this challenging environment with high efficiency and accuracy.

ALMA is a partnership between Europe, North America and Japan, in cooperation with the Republic of Chile. ALMA construction and operations are led on behalf of Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO, Garching, Germany), on behalf of North America by the National Radio Astronomy Observatory (NRAO, Charlottesville, USA), which is managed by Associated Universities Inc. (AUI), and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ, Mitaka, Japan).

1. 1 Science Objectives

ALMA will provide an unprecedented combination of sensitivity, angular resolution, spectral resolution, and imaging fidelity at the shortest radio wavelengths for which the Earth's atmosphere is transparent. With ALMA, astronomers can:

- Image the redshifted dust continuum emission from active star forming galaxies at epochs of formation as early as z=10;
- Trace through molecular and atomic spectroscopic observations the chemical composition of gas in galaxies like the Milky Way, but at a redshift z~3 in less than 24 hours of observation;
- Reveal the kinematics of obscured galactic nuclei and quasars on spatial scales smaller than 100 pc;
- Assess the influence that chemical and isotopic gradients in galactic disks have on the formation of spiral structure;
- Determine the dynamics of dust-obscured protostellar accretion disks, the rate of accretion and infall from the nascent molecular clouds, the mass distribution over the disk, and the structure of molecular outflows;
- Detect the photospheres of stars in every part of the Hertzsprung-Russell diagram, and resolve the photospheres and chromospheres of giant and supergiant stars within a few hundred parsecs;
- Image the gas kinematics in protoplanetary disks around young sun-like stars with a resolution of a few astronomical units out to a distance of 150 pc (roughly the distance to the star forming clouds in Ophiuchus or Corona Australis), enabling the study of their physical, chemical and magnetic field structures and detection of the tidal gaps created by planets undergoing formation in the disks;
- Reveal the crucial isotopic and chemical gradients within circumstellar shells that reflect the chronology of invisible stellar nuclear processing;

- Obtain unobscured, sub-arcsecond images of cometary nuclei, hundreds of asteroids, Centaurs, and Kuiper-belt objects in the solar system along with images of the planets and their satellites;
- Image solar active regions and investigate the physics of particle acceleration on the surface of the sun.

1. 2 Developments of the Last Years

During the last few years the ALMA organization, management and construction has been established and substantial progress has been made. The birth of ALMA dates back to the end of the last century. Large millimeter/submillimeter array radio telescopes were studied by astronomers in Europe, North America and Japan. Three different possible observatories had been proposed. After a thorough investigation, it became obvious that all of these ambitious projects could hardly be realized by a single community. Consequently, an agreement was signed in the year 2002 by the North American community, represented through the NSF, and the European community, represented through ESO, to construct ALMA.

Following years of detailed design studies and prototype research, it became evident that this project could not be realized within the original project timescale and within the available funds foreseen at the time of signing the agreement between the partners in North America and Europe. Therefore the management and scientists involved in ALMA were charged to develop a new configuration of the project within acceptable cost, while still maintaining the prime scientific objectives. In this respect, the year 2005 was certainly a year of critical importance to the ALMA Project – the year in which the baseline project was redefined.

One consequence of "rebaselining" was the reduction of the number of 12 meter diameter antennas from 64 to 50. However, the successful prototyping of key components of the receivers over the last years was an important element in allowing a reduction of the number of antennas without significantly compromising significantly the performance of the original baseline, bi-lateral, project. During this period, in-depth studies were made to define the "rebaselined" ALMA project. Independent advisory (e.g. ALMA Scientific Advisory Committee) and review (ALMA Cost Review Panel) committees, focusing on the technical performance as well as on the cost of the project, confirmed the scientific importance of the modified ALMA project, based on the new affordable costs. By the end of 2005 the rebaselined project and the new budget was approved by the ESO Council. The North

American partners received approval from their Funding Agency, the National Science Foundation (NSF), of the United States by the middle of 2006.

In parallel, Japanese scientists, through the NAOJ, have continued to work out details to define and formulate their participation in the ALMA project. The European and North American partners in ALMA spent a considerable amount of time with their Japanese partners in identifying the Japanese participation and reviewed various subsystems, in particular, correlator, receivers and antennas. Details on the partnerships were defined and an official, trilateral agreement between ESO, the NSF, and the National Institute for Natural Sciences (NINS, Japan) was signed in summer 2006. In addition to the equipment which NAOJ will provide for the bi-lateral ALMA configuration (50 antennas), NAOJ will provide four antennas of 12 meters diameter, twelve antennas of 7 meters diameter, as well as two (and following successful R&D studies, a third) additional receiver bands for all 66 antennas of ALMA. Approval of funds required for the Japanese participation in ALMA is expected soon. With the inclusion of the Japanese partners ALMA becomes a truly global astronomy facility, involving scientists from four different continents. Then "the sun never sets on ALMA".

In parallel to the ongoing construction, a baseline ALMA Operations Plan has been reviewed and accepted. The plan foresees the start of operations in the year 2006, followed by a ramp up phase, including Early Science starting in the year 2010. The Joint ALMA Observatory shall reach full operation by 2012. Modifications to the baseline Operations Plan and the associated budgets are ongoing.

2. THE ALMA MANAGEMENT

2. 1 The ALMA Board

The ALMA Board has the overall responsibility for the Joint ALMA Observatory. The ALMA Board is the supervisory and regulatory body for ALMA. It is the primary forum for interactions and for decisions of the partners concerning ALMA. The ALMA Board, as well as the ALMA Project, is not a legal entity.

NSF and ESO have each appointed four members to the ALMA Board. NINS has appointed three members to the Board. One member appointed by each Executive represents this

Executive. The Executives have designated one of their appointees to speak on their behalf. Board members serve for a three years (renewable) term. In addition, North America and Europe each appoint an Assessor.

The Board designates one of its members as a Chairperson. The Chairperson shall rotate every two years between a Board member appointed by NSF and a Board member appointed by ESO. The Board also designates one of its members as Vice Chairperson serving for two years. The Vice Chairperson is appointed by the Executive that did not appoint the Chairperson. Neither the Chairperson nor the Vice Chairperson may be an employee of either Executive.

Other persons may be invited by the Board through the Chairperson to attend meetings. Normally these include:

the ALMA Director, the ALMA Project Manager, the ALMA Project Scientist, and the ALMA Project Engineer;
the three Regional Project Managers (from Europe, North America and East Asia);
the Chairs of ALMA Scientific Advisory Committee and ALMA Management Advisory Committee;
the Secretary to the Board.

The Board shall meet not less than two times per year. Telephone conferences are held about every four to six weeks in between face to face meetings.

The Board shall:

1. ensure that Construction, Commissioning, Early Operations, and Operations are carried out jointly by the Executives in accordance with the terms and provisions of the Bilateral Agreement.
2. exercise budgetary oversight and policy control over ALMA.
3. determine the dates of completion of Construction and of Commissioning, the date of the start of Early Operations, and any reapportionment of Value between Construction and Commissioning and Early Operations where those periods may overlap;
4. approve the Budget for the following year and endorse a Long Range Plan;
5. approve the award of contracts, the use of contingency, and insure that the contributions from the parties are equitable and fair;

6. report at least once per year in writing to ESO and NSF on the status of ALMA, including the financial situation, progress on Construction and Commissioning, and projected timescales, estimated cost to completion, and the status of Early Operations and Operations;
7. approve the appointment of Joint ALMA Office Key Personnel;
8. annually review the job performance of all Key Personnel in consultation with the Director and the Executives;
9. approve, upon recommendation of the Executives, extensions to the appointment of all Key Personnel;
10. determine the policy and manner in which Early Operations and Operations will be carried out;
11. determine the policy and procedures for the allocation of Observing Time, for data rights and the proprietary period.

2. 2 Various ALMA Committees

The ALMA Board and the Executives have appointed several committees.

These are bodies, dealing, for example, with a broad spectrum of issues, e.g. of scientific, technical, personnel, financial, management, organizational and political nature. These committees have regular communication and interactions, either by telephone conferences or face to face meetings, in most cases in monthly intervals (with the exception of the AMAC, see below). The various ALMA committees deal in some cases with overall aspects of ALMA, in other cases also with regional aspects related to the specific circumstances of the respective Executives.

At present the ALMA Board has appointed

- the ALMA Budget Committee,
- the ALMA Personnel Committee,
- the ALMA Management Advisory Committee (AMAC),
- the ALMA Annual External Review Committee, and
- the ALMA Scientific Advisory Committee (ASAC).

In addition, the Executives have appointed

- the ALMA North American Scientific Advisory Committee (ANASAC),

- the ALMA European Advisory Committee (ESAC), and
- the ALMA Japanese Scientific Advisory Committee (JSAC).

The committees, in general, receive charges from the ALMA Board. They study and discuss specific aspects of the project and make recommendations to the ALMA Board. The ALMA Board then decides on the relevant issues and charges the Project Management with the implementation of their decisions.

2. 3 The Joint ALMA Office

In the year 2004 the ALMA Board established the Joint ALMA Office (JAO) which is located in Santiago de Chile. The Executives provide the necessary funding, infrastructure and personnel support to operate the JAO. The JAO is headed by the ALMA Director and is comprised of the Key Personnel, employed by the Executives, plus such other staff as are required to carry out the functions of the JAO.

The organizational structure of the JAO (Figure 1) was reviewed and approved by the ALMA Board. The Key Personnel of the JAO include: the ALMA Director, the ALMA Project Manager, the ALMA Project Engineer and the ALMA Project Scientist, who are all selected and appointed by the ALMA Board.

The JAO is, through the Director, responsible for the overall leadership and management of joint construction, commissioning, and operations. The JAO defines, maintains, and applies specifications and acceptance criteria for deliverables. It synchronizes activities of the Executives in Europe, North America and Japan, as well as on the ALMA site near San Pedro de Atacama. One of the most important responsibilities of the JAO is the management and organization of the Assembly, Integration, Verification and Commissioning (AIVC) of the telescopes in Chile.

The JAO also, in close collaboration with the Executives, estimates the cost to completion and for operations of the ALMA Observatory. Every year, the JAO proposes the annual construction and operations budgets for the following calendar year for approval to the ALMA Board. Monthly reports are provided by the JAO to the ALMA Board on the progress of the project, including detailed financial information and projections.

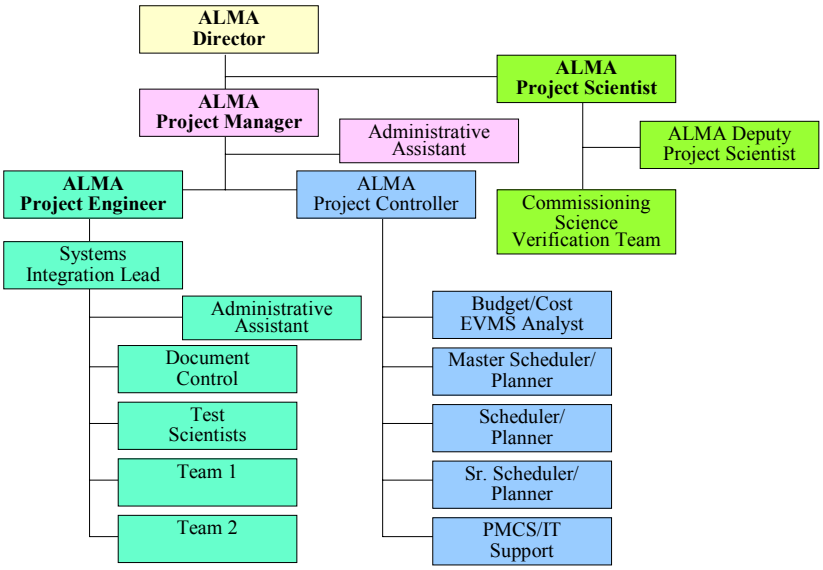

Figure 1: Organization of the Joint ALMA Office

The ALMA Director must notify the ALMA Board of the intention of an Executive to place any contract valued above 1 million Euros or 1 million US dollars. The approval of the ALMA Director is required for the placing of any contracts above 500,000 Euros or 500,000 US dollars. The placing of any contract above 10 million Euros or 10 million US dollars requires the recommendation of the ALMA Director and the concurrence of the ALMA Board. The Director's approval is required for the use of contingency in excess of 500,000 Euros or 500,000 US dollars by the Executives. Board approval is required for the use of contingency in excess of 1 million Euros or 1 million US dollars.

The Director shall allocate Observing Time during Early Operations and Operations in accordance with policies and procedures determined by the ALMA Board.

2. 4 The European ALMA Project Office

The European ALMA activities are managed by the European ALMA Project Office (see Figure 2), located at ESO in Garching. The ESO Director for ALMA provides a path for information flow between the ESO-ALMA Division and the ESO Director General, for relations with the ALMA Director, and is at present secretary of the ALMA Board. The day to day activities of the Project Office is led by the European ALMA Project Manager, and the Head of the ALMA Division at ESO. They are supported by the European ALMA Project Scientist, the ALMA Regional Centre (ARC) Manager, a Management Team, and several Integrated Product Team (IPT) Leaders. The IPT Leaders direct their team of engineers and scientists for the various subsystems of the ALMA Project. Figure 2 also indicates that several ESO staff from other ESO divisions has been delegated to the ESO ALMA Division. By April 2008 a total of 57 persons was directly involved in ALMA.

Figure 2: Organization of the European ALMA Project Office

Similar Project Offices have been set up at NRAO in Charlottesville (USA) for North American, and NAOJ in Mitaka (Japan) for East Asian construction activities for ALMA. These three Project Offices collaborate closely with each other, not only at the level of the Regional Project Managers, but also the Management Teams and IPT Leaders.

In addition, the ALMA Project Manager, stationed in Santiago de Chile, and his team at the JAO coordinate overall aspects of the project. Telephone and video conferences, involving all partners affected, are held not only on a regular basis, but also ad-hoc should any need arise.

3. THE ALMA CONSTRUCTION

3.1 Principle

Initially the ALMA Project was an arrangement only between NSF and ESO. Both partners defined the project in a Bi-lateral Agreement, signed in the year 2002 and updated in 2007. Both Parties agreed to each make equal contributions to the ALMA Project. Furthermore it was agreed, to the maximum extent practicable, that work shall be fairly and equitably shared between NSF's designated Executive (AUI and NRAO) and ESO.

The Bi-lateral Agreement states that the Parties, including their organizations and institutes, shall obtain intellectual and economic benefit from ALMA in all its phases in proportion to the Value of their contributions and consistent with the execution of assigned tasks on time and within budget. This is an essential measure for the allocation of observing time.

Furthermore it was agreed that, wherever practicable, the ALMA Project will utilize existing institutions, their infrastructure, expertise and qualified staff. Where necessary, personnel will be supplied by secondment from existing institutions. To the maximum extent possible, there shall be no exchange of funds between the Parties.

The components provided to ALMA are subject to common specifications and acceptance criteria. Defining, maintaining, and implementing ALMA specifications and acceptance criteria is the responsibility of the Joint ALMA Office.

The East Asian partners, through NINS and NAOJ, joined the ALMA Project only after the signature of the original Bi-lateral agreement. Their participation and their benefit in the

project have been defined by additional agreements following the same principles as used in the Bi-lateral Agreement between NSF and ESO.

3.2 Constructing a Completely New Observatory – a Great Challenge

The design, definition and construction of a brand new observatory in the Atacama dessert, the driest place on Earth, and at 5000 meters altitude is undoubtedly an organizational and logistical challenge. The location chosen for the ALMA Observatory is indisputably excellent for scientific reasons – and at the same time rather difficult because of its remoteness and harsh environmental conditions. The ALMA site at the Altiplano of Chajnantor is perfect for submillimeter/millimetre astronomical observations – high and dry – no better place to go!

At the same time, services which are common in our every day life are simply not easily provided at the locations of the ALMA Observatory. Neither electricity nor water is easily supplied. Also, the sites of the Observatory and the antenna array are so remote, that the road access had to be specially constructed by the ALMA Project.

Considering these boundary conditions, it is obvious that the ALMA Project had to take account of a wide spectrum of activities related to the construction of the Observatory. Delicate, high precision instruments – at the State of the Art - needed to be developed and refined to achieve the demanding technical performance, and at the same time the project had to organize civil engineering and take that basic supplies are available.

The Executives already have experience in this kind of managerial and logistical challenges. Nevertheless, the challenges are of unprecedented nature and magnitude.

3.3 Sharing of Construction Activities

The Executives have agreed to deliver well defined goods and services as their contribution to the construction of the ALMA Observatory. Table 1 gives a high level overview of the major deliverables of the three ALMA partners.

IPT / Subproject	Europe	North America	East Asia
Site Development	ALMA Road to AOS	Roads at AOS	Financial Contribution to All Infrastructure Costs
	OSF Technical Facilities	AOS Technical Facilities	
	Residence at OSF	General Infrastructure	
	ALMA Building in Santiago		
	ALMA Power Supply		
	192 Antenna Foundations at AOS		
Antennas	25 Antennas – 12 meter Diameter	25 Antennas – 12 meter Diameter	4 Antennas – 12 meter Diameter
	Two Antenna Transporters	Front End Service and Handling Vehicles	12 Antennas – 7 meter Diameter
Front End	Band 7 Receivers	Band 3 Receivers	Band 4 Receivers
	Band 9 Receivers	Band 6 Receivers	Band 8 Receivers
	Cryostats	Support Structures	Band 10 Receivers
	Water Vapour Radiometers	Monitor and Control System	
	Calibration System	Power Supplies	
	Integration Centre (Setup & Operation)	Integration Centre (Setup & Operation)	Integration Centre (Setup & Operation)
Back End	Photomixers	Optical Transmitters and Local Oscillators	
	Digitizers and Digitizer Clocks	Digital Formatters and Digital De-Formatters	
	Multiplexers	Back End Integration	
Correlator	Tunable Filter Boards	Correlator for 64 Antennas	Correlator for 16 Antennas

Table 1: Major Goods and Services to be delivered by the three ALMA Executives

4. ALMA OPERATIONS

It is planned that ALMA construction will seamlessly transition into the operations phase. It is expected that full scientific operations will begin in the last quarter of 2012. The ALMA management has agreed that Early Science will begin as soon as 16 antennas, fully equipped with receivers, are available for observations. This should occur in 2011.

The ALMA Director has submitted an ALMA Operations Plan to the ALMA Board, which was approved in October 2007. This plan describes the regular operations of the ALMA Observatory and also includes perspectives for upgrades and future developments of the observatory.

The ALMA Operations Plan also describes the relations with local scientific users, to be dealt with through the ALMA Regional Centres (ARCs). The ALMA project is establishing three regional centres. The European ARC will be at ESO in Garching, the North American ARC will be at NRAO in Charlottesville, and the East Asian ARC will be provided by NAOJ in Mitaka. In addition to the European ARC in Garching several additional ARC nodes will be established in ESO member states. These ARCs are the interface to local ALMA users, to provide astronomers for duty shifts in Chile and to maintain a local archive.

The major tasks of the ARCs are:

- Phase I and II proposal preparation,
- Final data quality assurance and support,
- Archiving software for ALMA,
- Astronomer On Duty shifts in Chile,
- Feedback from users to the ALMA Observatory,
- Operation of an e-mail helpdesk.

The Executives have agreed to have a single Observing Program Committee for ALMA. This will be organized and operated by JAO in cooperation with the Executives. Proposals are to be sent to the JAO; however, the regional ARCs will assess the technical feasibility of proposals.

5. CONCLUSIONS

High precision, large arrays of antennas operating in the millimetre/submillimeter have been discussed since more than 15 years. Many concepts have been developed and were discussed within the astronomical community. At the end, the synergy of these proposals has led to the realization of the ALMA Project – beyond regional, economical or political considerations.

This is a trend in basic research, already adopted in other domains of fundamental research, which will ensure that projects of the significance and magnitude of ALMA can be realized within budgetary limitations and reasonable schedules.

The ALMA Project requires uniting world-class expertise in a single radio-astronomy observatory. The scientific challenges are so demanding, that all resources need to be pulled together to successfully achieve the ambitious goals of ALMA. The potential transformational discovery power of ALMA is unprecedented. This is certainly a significant and essential consideration for the Parties to take part in the project. Even if only being a partner within an intercontinental consortium, the scientific perspectives are so attractive that astronomers from four continents want ALMA to be realized with full scientific potential, and this as soon as possible.

The multi-national and multi-cultural aspects are, at this scale, a new constellation in ground based astronomy. Working together in this international project; seamlessly combining different systems, cultures, procedures and administrations is certainly not an easy task. However, the challenges, visions and scientific ambitious of all partners involved are so encouraging and motivating to overcome these possible obstacles.

The scientific perspectives of ALMA are spectacular and the technical requirements are extremely demanding. Because of the technical complexity and the financial investments a project like ALMA can only be realized by an international consortium which focuses on the scientific objectives. Such a challenging scientific project can only be successful if all partners take and respect joint leadership and responsibility.