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ALMA Project Book, Chapter 17

Construction, Integration, Interim Operations and Schedule

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Revision History
2000-Nov-28: First ALMA version

Requirements

- Establish a project and management structure for construction, commissioning, and interim operations of ALMA;
- Construct ALMA according to the tasks and schedule specified in the ALMA Project Work Breakdown Structure (WBS);
- Ensure that the instruments and software fabricated for ALMA are in compliance with the specifications established by the ALMA Project Book and detailed by the Joint Project Office;
- Test and accept subassemblies fabricated by the European and North American Executives. Provide for the integration of those subassemblies into ALMA project subsystems;
- Test, accept, integrate and commission completed project subassemblies at the array site in Chile;
- Provide for interim science operations as the mechanism to ensure that the delivered ALMA product is in keeping with the needs of the scientists who will use ALMA.

17.1 Overview of the Construction-Phase Project Organization and Management

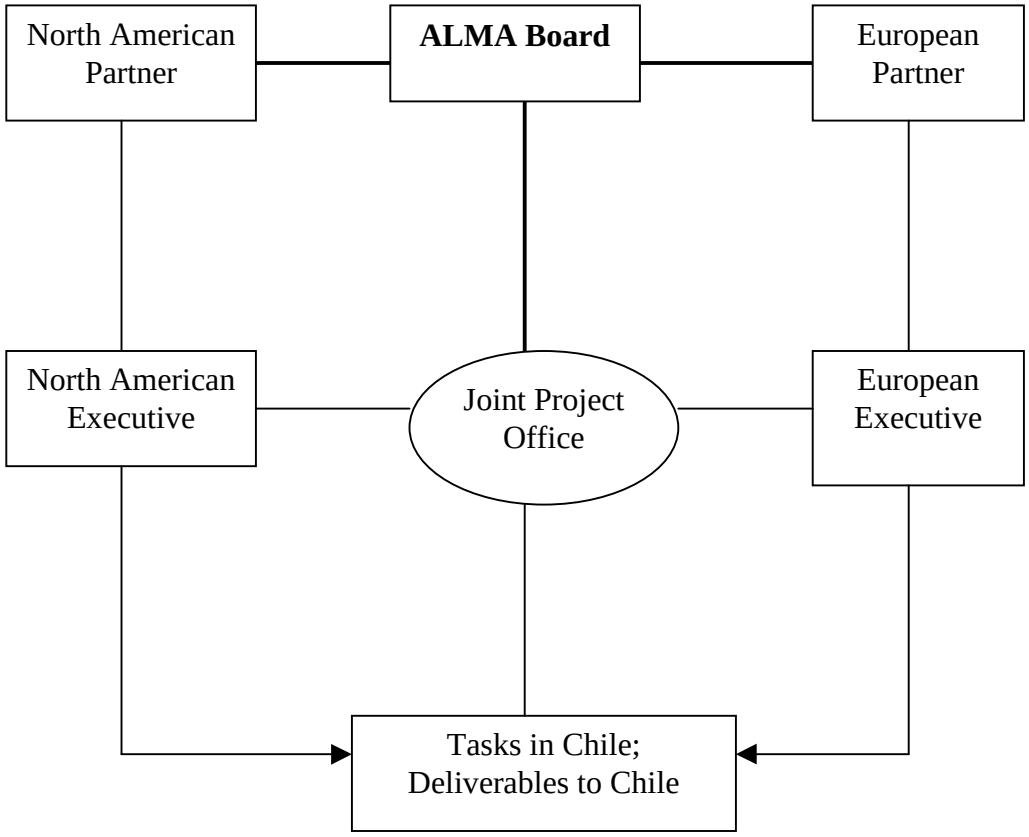
Organization of the management function for the ALMA Project is specified in the ALMA Management Plan. It treats ALMA as a *joint venture* of two Executive bodies that represent the North American and European ALMA partners respectively. It is the desire of both partners that no new legal entities be formed for ALMA; instead all the tasks associated with building, commissioning and operating ALMA will be the functional responsibility of the two Executives. For the European side of the partnership ESO is the Executive; for the North American side of the partnership AUI/NRAO is the Executive. The tasks associated with construction and operation of ALMA will be divided on an equitable basis between the two Executives and thereafter it will be the responsibility of each to perform those tasks, or rovide the deliverables, to the array in Chile.

The ALMA partnership is specified by the ALMA Agreement to be signed by the two partners. The governing board for the ALMA Project, established by the ALMA Agreement, is the ALMA Board whose membership is drawn in equal numbers from the two partners. The coordination of the tasks assigned to the two Executives is the

responsibility of the Joint Project Office. The role of the Joint Project Office is described in detail below. Here it is important to emphasize that the Joint Project Office is not a legal body—it cannot issue contracts, hire employees or establish a bank account. The staff of the Joint Project Office is drawn from the two Executives.

A concept-level organization structure for ALMA is illustrated below. The full organizational structure is described and illustrated in the ALMA Management Plan.

ALMA Construction-Phase Organization



17.2 Construction

The tasks leading to the fabrication of the hardware and software for ALMA are specified in the ALMA Project Work Breakdown Structure (WBS) elements 1.0 – 8.0. These level-1 WBS elements are:

1.0 Administration
2.0 Site Development
3.0 Antennas
4.0 Front Ends
5.0 Local Oscillator
6.0 Backend
7.0 Correlator
8.0 Computing

The responsibility for sub-elements of these level-1 tasks will be shared between the two Executives according to the task division specified in the ALMA Management Plan. A summary of the primary deliverables of each is given below.

Administration: This is a level of effort task that includes the project management at the two Executives and the management of the Joint Project Office. The deliverable here is an effectively managed project that meets its functional objectives, its schedule objectives, and its budgetary objectives.

Site Development: Development of the four sites needed for ALMA in Chile is summarized in Chapter 16 of this Project Book. It includes all the needed civil works (buildings, roads, utilities, antenna stations) on the array site; all the needed civil works at the Operations Support Facility including the equipment needed for integration and commissioning of the delivered hardware and software; the civil works needed to provide a communications link between the array site and the OSF; and the civil works needed to provide administrative and scientific offices in Santiago.

Antennas: The antenna task is specified in Chapter 4 of the Project Book. The antennas will be fabricated by the chosen antenna contractor, or contractors, and will be assembled by that contractor or contractors at the OSF. The responsibility of shipping the antennas to Chile, in pieces or subassemblies as the contractor elects, is the contractor's responsibility. Once erected, acceptance testing will be done at the OSF. Only when the antennas are accepted at the OSF will the ALMA Project take possession. Next, the antennas will be outfitted with ALMA-provided instrumentation (the front ends, cryogenics system, the monitor and control instrumentation, etc.) and the antenna radiometric performance will be verified. At this point they will be transported to the array site and placed on one of the site foundations. Commissioning tests will follow to confirm the mechanical, optical, and radiometric performance. Once the commissioning tests are complete the antenna will be given over to ALMA science operations.

Front-ends: The Front-end task is specified in Chapters 5 and 6 of the Project Book. Owing to the large number of subsystems involved in the Front-end assembly this task will require the greatest amount of coordination and management attention. The task division for the subsystems of the front-end assembly requires a large fraction of the work to be done by each of the Executives, and often done by means of work packages by participating organizations. The ALMA Project baseline plan is to integrate those front-end subassemblies in a hierarchical manner at progressively fewer institutes. This process culminates with the entire front-end assembly being integrated in one or two institutes. At these *front-end integration center(s)* the completed front-ends will be thoroughly tested for compliance with ALMA specifications. The tests will be documented and the front-end assembly will be shipped to the OSF in Chile. Here the important point is that the front-end is shipped from Europe or North America as a completed, functioning and tested unit ready to be installed on an antenna at the OSF.

Local Oscillator: The local oscillator task is specified in Chapter 7 of the ALMA Project Book. The fabrication, testing, and integration of the LO with the front-end assembly is a task entirely done by the Executives in North America and Europe. The LO deliverables are made to the institutes fabricating subsystems for the front-end assembly. These deliveries are shown clearly in the WBS. Once incorporated in the larger subsystems and assemblies the LO subassemblies lose their independent identity. The single exception to this is the central array LO reference which is distributed to each antenna station. The LO reference is fabricated, assembled, and tested in North America and Europe and delivered directly to the ALMA control building on the ALMA site.

Backend: The backend task is specified in Chapter 9 of the ALMA Project Book. The backend subsystem includes all those tasks associated with the down-conversion, digitization and transmission of the signals from the front-end at the antennas to the array control building. Here the instrumentation will be fabricated and tested in North America and Europe and then shipped to the array site in Chile. The final integration and tests must be done in Chile with the optical fiber IF communication system located on site. The site optical fiber is installed under WBS 2.0.

Correlator: The array correlator task is specified in Chapter 10 of the ALMA Project Book. The correlator is built in quadrants, the first quadrant of which will be delivered to the array site in 2004. The ALMA Project baseline is to locate the correlator in the array control building on the array site. The remaining three quadrants will be delivered at the rate of one quadrant every 16 months making the correlator complete and on site in 2007. Here again, the correlator quadrants are delivered to Chile as fully functioning, tested, and documented assemblies.

Computing: The computing task, WBS 8.0, is specified in Chapter 12 of the ALMA Project Book. The task will be accomplished by the common efforts of ALMA computing personnel assigned to this task by the two Executives. It is a joint effort that encompasses the real-time, monitor and control, imaging pipeline, and imaging analysis software that is an integral part of ALMA. At each stage in the construction project the software design and implementation will be reviewed for suitability by future scientist-users of ALMA.

17.3 System Integration

System Integration in Europe and North America: Role of the Test Interferometer: The guiding principle for ALMA construction is to build, assemble and test as much of the ALMA instrumentation as possible at participating ALMA institutes in North America and Europe. The rationale behind this principle is this: at established institutes there are experienced people and resources that can facilitate the ALMA construction tasks. It will minimize risk to the successful technical completion of the task; and it will minimize risk to the schedule because it allows the resource pool to be rapidly increased should the need arise. It is exactly this guiding principle, for example, that is behind the decision to assembly fully the front-end assembly in Europe and North America, and to ship it as complete and functioning units to Chile. But what is to be done with those subsystems

that need the ALMA infrastructure to verify their performance and to assure smooth integration into the system? One answer to this question is the test interferometer.

The test interferometer is an instrument to be assembled from the two ALMA prototype antennas at the ALMA test site adjacent to the VLA in New Mexico. The primary function of the test interferometer is to allow the ALMA staff to do precision tests on the two prototype antennas so that a choice can be made between the two designs. Initially the test interferometer is being built largely from special-purpose interferometer hardware for the antenna evaluation. However, once the antenna evaluation tests are complete, the test interferometer will be retrofit entirely with ALMA prototype instrumentation. This will include all aspects of the hardware except the front-end assembly. Early implementation of the ALMA prototype hardware and software on the test interferometer will permit a thorough system evaluation of those prototypes before production fabrication begins. These tests will assure compliance with instrument specifications as well as with system specifications. And it will do so in a controlled environment with a large resource base of people and test facilities to call upon to solve particularly difficult or subtle problems.

System Integration in Chile: Integration of the production hardware and software will begin in Chile in 2004. Prior to the arrival of the first array antenna, the system integration group will confirm compliance to specifications of the IF transmission system, the LO reference hardware, and the first quadrant of the correlator at the array control building on site. Once the first antenna arrives at the OSF, is accepted and outfitted, the systems integration team will confirm that the interface between the front-end and the antenna is as specified; they will confirm by performance measurements the interface between the software control system and the antenna mechanical servo; and they will verify by radiometric measurements the compliance of the complete antenna system with all performance specifications. At this point the antenna is transported to the ALMA site.

As the first antenna, and each successive antenna, is transported to the site the system integration team will verify all the interfaces with the electrical, data transmission and monitor and control system on site. They will again confirm by radiometric measurements the performance of the antenna and document all their results. At this point responsibility for the antenna is transferred to Array Operations for commissioning observations and interim science observations.

17.4 Interim Operations

There are several reasons to begin interim science operations with ALMA as soon as a few antennas have been accepted, outfitted, and installed on the array site. The following are among the important reasons:

- To use precision astronomical measurements to identify design or implementation deficiencies in the instrumentation or software that should be rectified so that those deficiencies are not replicated multiple times in the hardware still under construction;

- To characterize by careful measurements the affect of different atmospheric conditions on the astronomical imaging performance so as to lead to refinements in the array calibration system or to fine-tune the scheduling algorithms for the prevailing atmosphere;
- To build through experience a model for array operations that is in accord with the desires and expectations of the employees who will be responsible for operations;
- To train and develop a professional team of engineers, scientists, programmers and technicians that will become the ALMA operations staff;
- To expose scientist-users to the growing ALMA so as to receive from them informed advice on development priorities and to train them as the initial cadre of users to whom other prospective users can go for assistance and guidance.

The first few antennas will be on site and available for interim operations by early 2006. In order to make those antennas available for interim science operations it will be necessary to establish the rudiments of an operating observatory also in 2006. This will include:

- An observatory management structure;
- Array operators
- Support scientists, programmers and data analysts;
- Maintenance engineers, programmers and technicians;
- Maintenance support staff (kitchen, housekeeping, maintenance crafts, road maintenance and snow removal, etc.)

Estimates made by M. A. Gordon[1] suggest that an operations staff of 60 people, employees and personnel working under contract, will be needed for interim operations. Given the 5-year overlap between the beginning of interim operations and the end of construction—the period 2006-2010—a thorough operations plan, beginning with interim operations, will be developed in concert with the ALMA construction plan.

17.5 Schedule

The detailed ALMA Project schedule is given in the ALMA WBS. That WBS and schedule has not yet been informed by the funding schedules of the two partners; it awaits a final iteration including commitments by the two partners to provide funding on a particular schedule. In the absence of those commitments, the ALMA baseline schedule drawn from the WBS, at the highest level, is the following.

2002	January	ALMA Construction Project Start
2002	August	Test Interferometer Observations Start
2003	January	Site Civil Works Begin in Chile
2003	April	Prototype Antenna Decision
2003	April	Release Electronics Systems for Production
2003	August	Contract for Production Antennas
2004	October	First Production Antenna Arrives in Chile

[1] ALMA in Chile: A Plan for Operations and Site Construction, May 2000.

2006	January	Interim Operations Start
2010	July	Construction Complete
2010	September	Commissioning; Full Science Operations