Draft 22 February 2001: RLB

Proposal for ALMA Operations and Maintenance

1. Scope of the Proposal

Construction of the Atacama Large Millimeter Array is planned for the period 2002-2010. As antennas and their ancillary equipment are added to the array in Chile, ALMA will provide unique and expanding scientific opportunities that will be made available to astronomers during a period of interim operations that can begin as early as 2006. These interim operations will aid in the commissioning of the entire ALMA system, hardware and software, and facilitate the transition to full science operations shortly after 2010. The scope of this proposal is to focus exclusively on the full science operations phase, 2011 and later, and to provide a model for ALMA operations and maintenance from which operational costs may be derived. The model, and the cost estimates obtained from it, includes science operations, technical operations, array maintenance tasks, public education and outreach activities, safety, development of the next generation instrumentation and software, and the management tasks required to administer the effort.

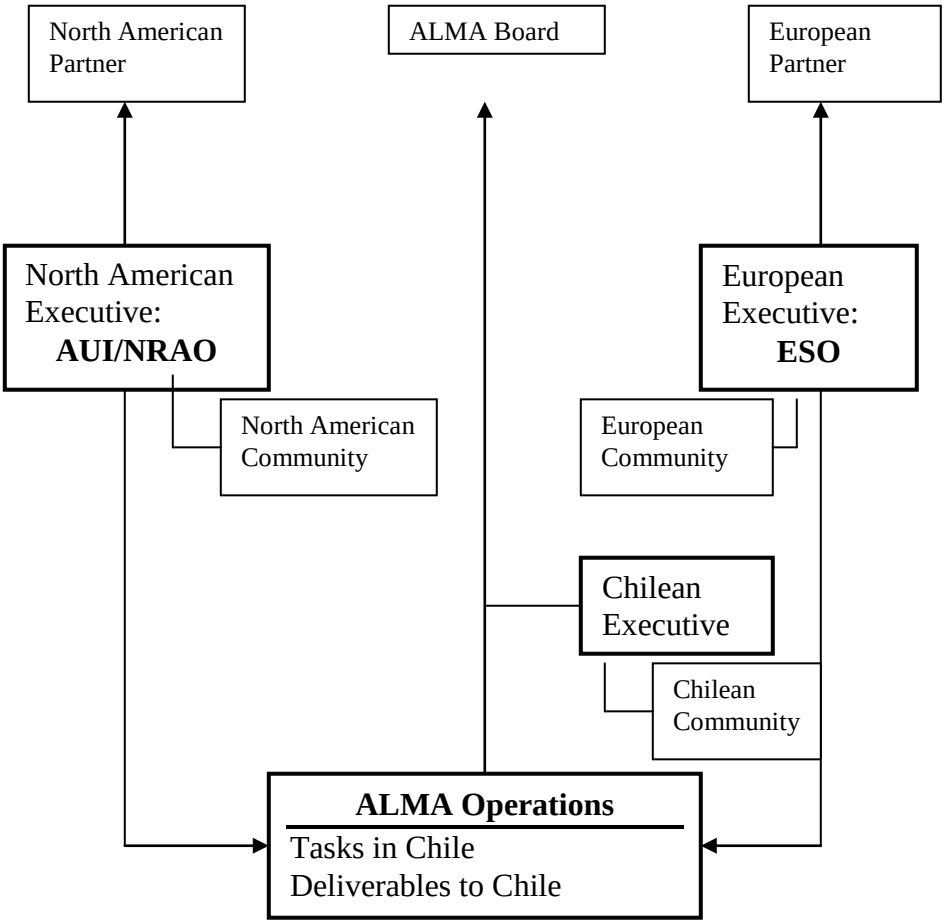
In the sections that follow we describe the operational model, discuss the organization of ALMA operations by location, tabulate the allocation of resources and finally cost those activities using a Work Breakdown Structure. A glossary of terms and acronyms is included as an annex to this proposal.

2. The Atacama Large Millimeter Array

ALMA is a joint scientific venture between Europe and North America with participation by the Republic of Chile. The ALMA operation will serve these three communities in a way that distributes the burdens and the benefits in a mutually agreeable way. The organizational structure for ALMA operations is derived from the organization of the project for the construction phase. It involves participation by the two Executives as described below, and coordination between the Executives that occurs through ALMA Operations as illustrated below. Note that the "Joint ALMA Office" that served to coordinate work in the construction phase of the project has been subsumed in the operations phase by "ALMA Operations"; this is the operating entity in Chile supported jointly by the two Executives as can be seen in the figure.

The function of the European and North American Executive is to handle the necessary ALMA scientific interactions with their respective communities and sponsoring agencies. This certainly includes accountability for funds spent and benefits realized, but it also includes receipt and review of ALMA scientific proposals, support for their respective science community of ALMA users, and support for access to the joint ALMA archive.

Figure 1. ALMA Organization for Operations



3. Model for ALMA Operations and Maintenance

(a) Tasks and Deliverables of ALMA Operations

In the ALMA operational model it is assumed that the astronomer-users will propose a program of observations to their respective Executive in Europe, North America or Chile. Once reviewed and accepted for observation, the astronomer will provide to the observatory an observing script that specifies the observational goals in *astronomical terms*. That is, the astronomer specifies the target object, frequency, spectral resolution (if applicable) and the desired on-source integration time, signal-to-noise desired, or uv-coverage needed. It is the task of ALMA Operations to deliver to the astronomer the following:

- real-time calibrated, pipeline-processed, image of the target object;
- calibrated uv-data set including tables of the calibrations that have been applied;
- tables of the monitor data, including prevailing meteorological conditions, atmospheric transparency measurements, and instrumental performance measures;
- data path to a copy of this same information that has been submitted to the ALMA archive and notification of the proprietary period that he/she has to that data (if any).

In order to supply these deliverables to the astronomer it is the task of ALMA Operations to carry out the following functions:

- Review the source script supplied by the astronomer and to select a sequence of calibration observations that will enable the astronomer to meet his/her goals;
- Review the source plus calibration observing script with the astronomer and modify as necessary (a task done by email);
- Determine whether the program script should be executed in *chapters*—a few hours around source meridian transit over several days in order to accumulate the integration time necessary—or whether the science can be achieved in a single source transit;
- Assign to the program script codes for the threshold criteria for atmospheric transparency and stability that need to be met before the program is run;
- Conduct pre-observations, as necessary, to select a nearby source for fast-switched phase calibration. Determine the position of that phase calibration source to the precision needed;
- Execute the program observations including pipeline processing of the data;
- Perform a data quality assessment to confirm that the pipeline-generated images are free of corruptions resulting from defective instrumentation;
- Transmit all astronomical and monitor data to the astronomer;

- Transmit the pipeline-processed images and the monitor data to the ALMA archive including with that data a date at which the proprietary period for the proposing astronomer ends.

(b) Guidelines for Array Operations

A few general principles established to maximize the safety and operating efficiency of the ALMA staff serve to inform the model for ALMA operations. Prominent among these are the following:

- ALMA is a *service observing* facility. The astronomer is not expected to be present when his/her observations are executed and this will usually be the case;
- The ALMA observing program will be done dynamically with a running optimization made to ensure that all programs in the queue are run when the prevailing meteorological conditions are suitable;
- The number of ALMA staff assigned to the Array Observing Site (AOS) at 5000 meters elevation must be kept to an absolute minimum;
- ALMA will operate as a full-time research facility for which the scientific demand will be very high;
- ALMA operations must insure that the instrumental "downtime" does not exceed the level achieved on major research telescopes elsewhere;
- It is the desire of the ALMA partners to minimize the size of the operating staff, and to maximize the effectiveness of that staff.

(c) An Implementation Plan for the ALMA Operations Guidelines

The guideline to minimize the ALMA staff assigned to the 5000m AOS has many ramifications that can be summarized by the statement that ALMA will be operated and maintained remotely. That is, the array operator and all personnel involved with astronomical observations and maintenance of array instrumentation will be located at ALMA facilities at lower elevation. This leaves on the AOS only those personnel needed to assure the security of the site, those responsible for module exchange—replacing failed instrument modules with functioning spares that are stored on the AOS—and those whose task it is to transport the antennas as needed for array reconfiguration. In order to achieve this goal the entire array must be designed and built to be modular in character, and wherever possible to be self-diagnosing. Each instrument must have provision for an adequate number of monitor points that are reported to the control computer in real time.

The guidelines to minimize the size of the operating staff, maximize the operating effectiveness of that staff, and to minimize the instrumental "downtime" all speak to the need to locate the operating staff close to the AOS but at lower altitude. Here the considerations are to provide a work environment that is at an elevation where the deleterious effects of a rarefied oxygen environment are minimized but

nevertheless a work environment that is sufficiently close to the AOS that instrumental problems can be investigated and solved quickly. The proposed solution to accomplish this objective is to locate the operations and maintenance staff at a facility as close to the AOS as possible, but at an elevation no higher than 3000m. We refer to this operations and maintenance facility as the *Operations Support Facility* (OSF). We will connect the OSF to the AOS by means of a road (public or private) for the transportation of the antennas, and a communications *highway* involving buried optical fibers over which the astronomical data and the instrument monitor data is carried in real-time, and at high bandwidth. These links will give the ALMA operations staff a virtual presence on the AOS that will be adequate to investigate problems quickly and begin the process of effecting a cure. All the professional staff assigned to the OSF will work *turno* shifts. A turno of 8 days on followed by 6 days off is common in Chile.

The final action in the plan to maximize the effectiveness of the staff is to locate in Santiago all those functions that are not directly related to the science operations and maintenance of the array. Santiago is the functional node for nearly all governmental relations, contracting, import/export administration in Chile. It also provides the living environment (schools, medical care, shopping, spouse employment) that ALMA professionals will demand just as is the case for their colleagues assigned to Paranal or La Silla do.

4. Functional Organization of ALMA by Location

(a) Overview

As mentioned above, ALMA operations will be done jointly by AUI/NRAO as the North American Executive and by ESO as the European Executive. These two agencies have responsibilities to their respective communities that they will handle separately in their respective countries; and they have responsibilities for the scientific operation of ALMA that they will handle jointly in Chile. There are four functions that are handled separately:

- Proposal submission and review;
- ALMA user support;
- Operation and support of the ALMA archive;
- Advanced Instrumentation and Software development program

The joint science operation of ALMA includes all the remaining responsibilities that will be centered in Chile around the joint entity called *ALMA Operations* in Figure 1 above.

Figures 2-4 below show an exploded organizational view of *ALMA Operations.*

Figure 2. ALMA Operational Structure in Chile

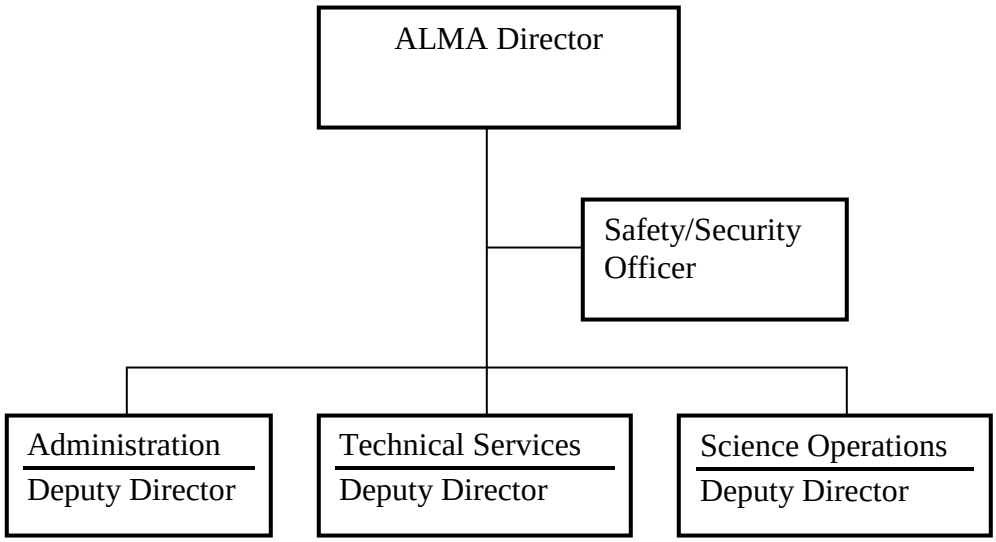


Figure 3. Organization of the ALMA Administrative Function

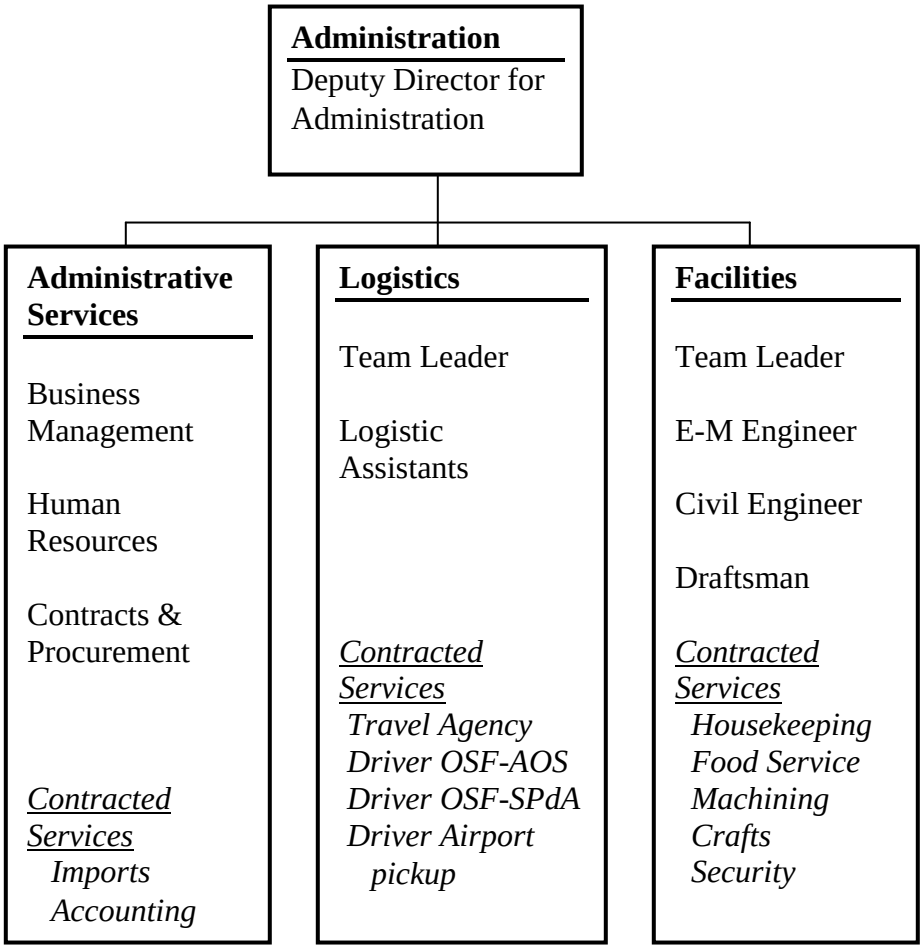


Figure 4. Organization of ALMA Array Operations Function

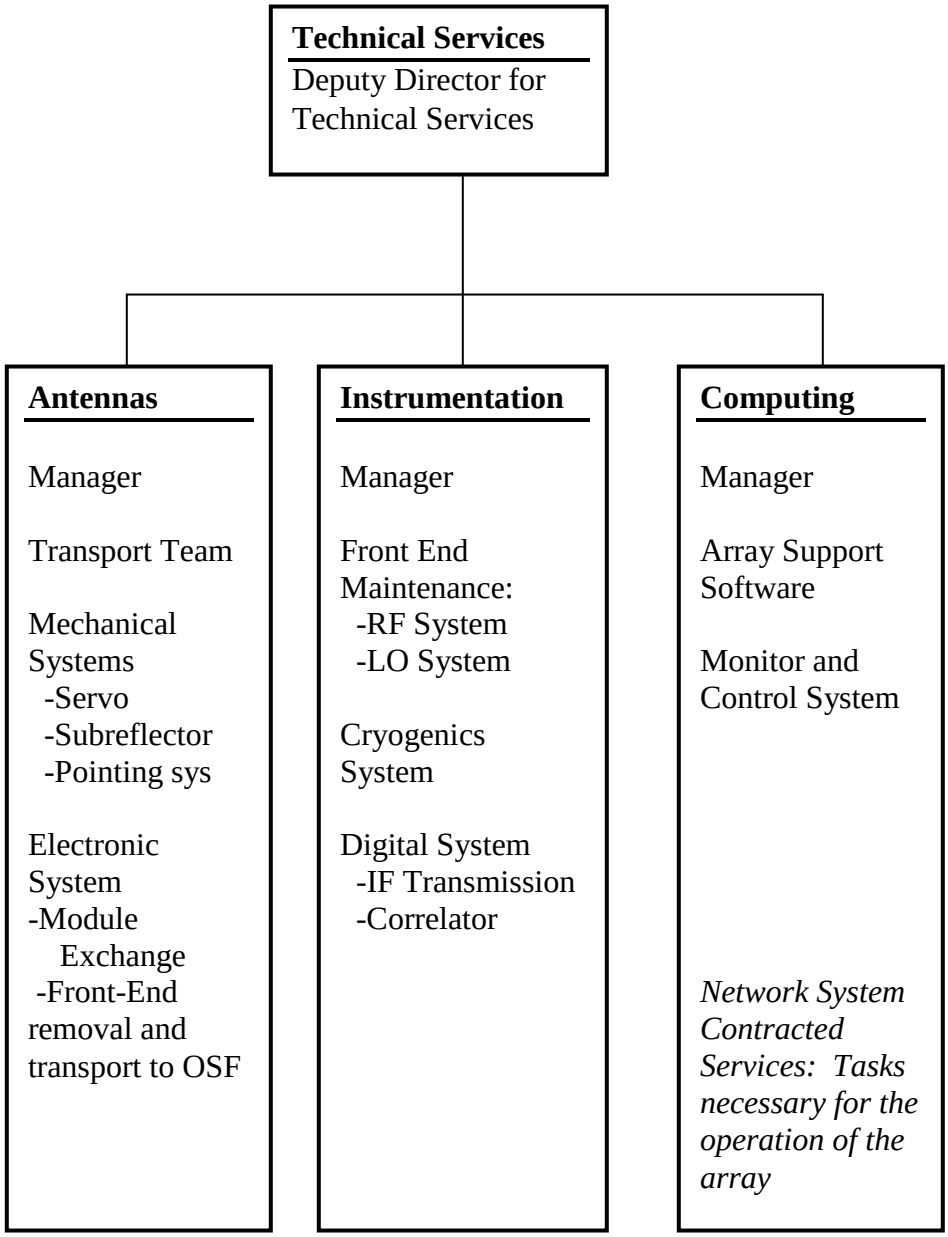
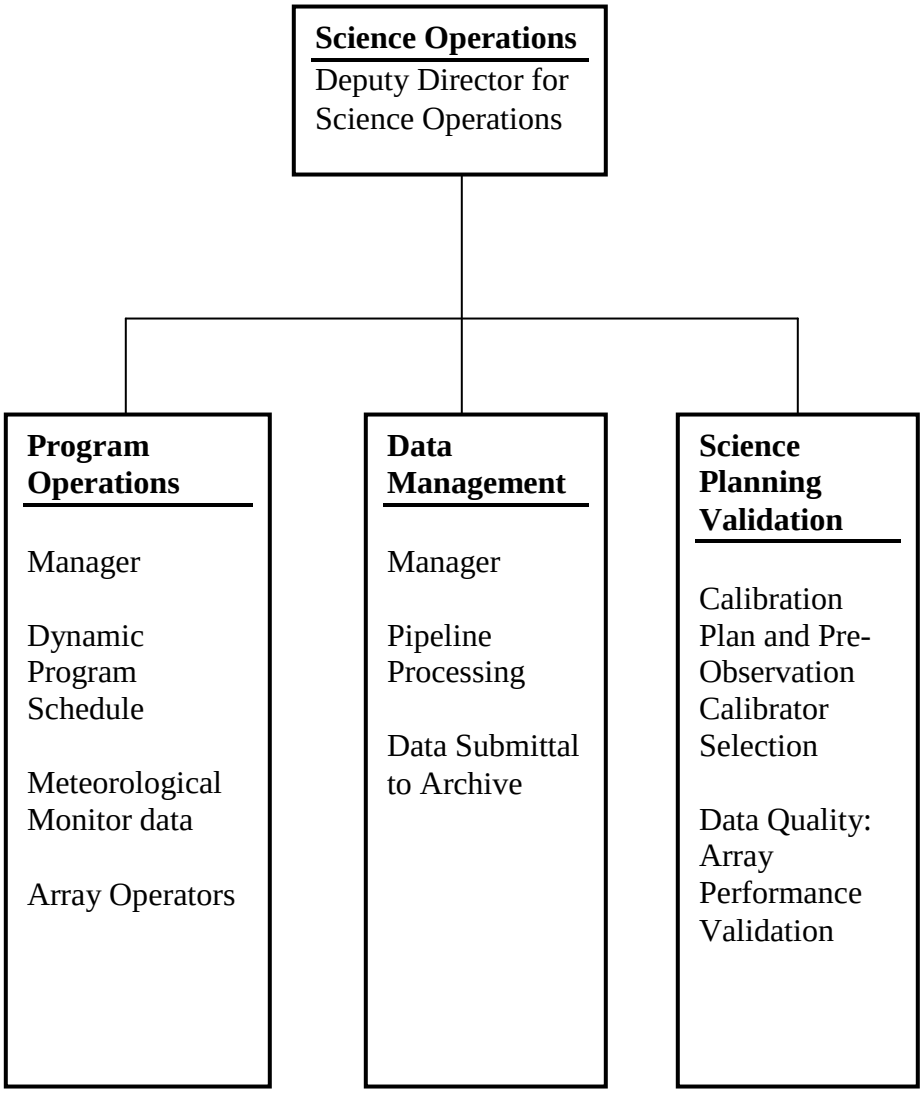


Figure 5. Organization of ALMA Science Operations Function

(b)



(b) Location of Operational Entities in Chile

Using the guidelines described above that (i) restrict the staff on the AOS to those individuals involved with antenna reconfiguration, routine antenna maintenance and routine instrument module replacement; (ii) limit the remaining operational staff to the OSF where they are needed for the conduct of the science program and for maintenance of the array hardware; and (iii) assign the remainder of the ALMA operations staff to the Santiago office, we can illustrate the functional distribution of ALMA activities in Chile as follows:

Activity	Location
Administration	
Business	Santiago
Logistics	Santiago
Facilities	OSF
Technical Services	
Antennas	AOS
Instrumentation	OSF and AOS
Computing	OSF
Science Operations	
Program Plan	OSF and Santiago
Data Management	OSF
Science Validation	Santiago

(c) Consequences of the Turno System

Professional employees whose work assignment is at the OSF will work turno shifts. It is likely that most will choose to live in Santiago but some may prefer to live elsewhere in Chile. The consequences of employees working one place and living another are the following:

- It is the responsibility of the observatory to transport these professionals from their residence to the OSF on their turno schedule;
- Residential housing will need to be provided at or near the OSF for the turno staff; this is part of the ALMA development plan;
- For astronomers working turno shifts, allowance will need to be made for them to pursue their personal research effectively. This requires time to be allocated for research in addition to time for functional duties, and the time off required by the turno shiftwork;
- The management of two or more employees *sharing* a job needs special attention.

None of these considerations is unique to ALMA. The other observatories in Chile that work turno shifts encounter, and solve, the same problems.

5. Work Breakdown Structure for Operations

6. **Glossary**

AOS	Array Operating Site, the location of the telescope array at 5000m elevation in the Altiplano of northern Chile.
Archive	An electronic database containing the images and data from all science observations made with ALMA.
Calibration	Measurements made of a known object (astronomical or physical) used to express the uv-data in absolute units of measure (signal strength and position on the sky).
Executive(s)	The legal entities representing the North American and European partners, respectively in the ALMA Project. The Executives may sign contacts, employ people and maintain bank accounts for ALMA.
Joint ALMA Office	The office established jointly by ESO, the European Executive, and AUI/NRAO the North American Executive, to coordinate the construction phase of the ALMA project. It is not a legal entity.
OSF	Operations Support Facility. The complex of offices, laboratories and residence facilities to be built near the AOS but at a lower elevation where the staff may work without suffering altitude effects.
Turno	A system of alternating time-on, time-off shift work common in Chile.
Uv-data	The fundamental measurement made by a pair of antennas acting as an interferometer. It is a complex number measuring the signal strength and phase corresponding to the separation between two antennas.