ALMA MANAGEMENT PLAN

Draft February 2002

The material in this document has not been approved by the ALMA Coordinating Committee.

1. OVERVIEW

1.1 Introduction

ALMA is a joint endeavor of several nations and many scientific institutes worldwide. The cost and burden of building and operating ALMA will be shared among the participants. This cooperation brings to the Project a broad base of experienced people and resources. Properly used, this breadth of experience has the potential to achieve outstanding performance and to reduce risk in many areas. For ALMA the challenge is to manage the combined resources in a way that empowers the participants and effectively coordinates their efforts. The management plan for the ALMA construction project described here is designed to meet this challenge.

Primary governance of the project is provided by the ALMA Board made up of an equal number of representatives of the European and North American partners, plus a Chilean representative. Organizationally, the ALMA construction project will be implemented through two Executive bodies – the European Southern Observatory (ESO) representing participating European organizations, and Associated Universities Inc./National Radio Astronomy Observatory (AUI/NRAO) representing the U.S. National Science Foundation (NSF) and participating North American organizations. ALMA is a bilateral partnership. The two partners will contribute equally to the project and receive equal benefit from it. Furthermore, responsibility for the task of constructing ALMA also will be shared equally by the partners and implemented by the two Executives using their existing institutions and infrastructure. Managing the project is consequently the effort of centrally coordinating work done through the Executives, but without direct, central control of funds or personnel allocations.

The management plan for ALMA, based on the proven concept of Integrated Product Teams (IPTs), assigns responsibility for each project task to one or the other of the Executive bodies. However, staff members from both Executives and from other participating institutions may participate in the effort of accomplishing each task. This concept equally empowers project staff from throughout the project and ensures a shared understanding of goals, progress, plans and information. A common Management IPT coordinates the work implemented through the Executives. Accountability throughout the project is assured by the necessity for both the Executive bodies, and the common Management IPT, to report to the ALMA Board. The IPT concept, tailored to the requirements of a bilateral partnership of equals, will successfully and effectively serve the needs of the global ALMA Project.

1.2 The Origins of the ALMA Project

Planning for the U.S. Millimeter Array (MMA) began at NRAO in 1982. A series of community science workshops sponsored by the NRAO were held in the decade of the 1980s that served to define the scientific requirements and technical specifications for the MMA. The result of these workshops became the basis for the MMA proposal submitted by AUI to the NSF for the design, construction and operation of the MMA.

The MMA Project proposed by AUI in 1990 was an array of 40 antennas, each of 8-meter diameter, equipped with receivers covering all the atmospheric windows at millimeter wavelengths, specifically to a highest frequency of 350 GHz. The MMA proposed then was optimized for precision imaging. This is achieved by having a sufficient number of interferometers (pairs of antennas) to fill the uv-plane quickly and completely.

Identifying a suitable site for the MMA was a major undertaking that occupied the decade from1985 to 1995. Remotely operated atmospheric testing equipment was built and operated at four potential MMA sites. The identification of a truly excellent and large site in the Chilean Altiplano proved ideal for the MMA and led to its recommendation to the NSF.

The exceptionally dry conditions on the Chilean site meant that the sensitivity of the MMA would not be limited by atmospheric emission and that the full scientific gain of quantum-limited receivers could be realized on that site. It also meant that the submillimeter atmospheric windows were also transparent from that site, unlike the case for the other potential sites studied for the MMA. Recognizing this, the scientific Millimeter Array Advisory Committee (MAC) recommended in 1995 that an observing capability in at least one of the submillimeter windows become part of the baseline MMA project. This recommendation was an addition to the scope of the array proposed by AUI, but it was recognized to be extremely desirable scientifically and it exploits fully the potential of the site. With this addition, the scope of the MMA Project was complete.

Since 1991 European astronomers have met to discuss concepts for a large millimeter-wavelength array for the southern hemisphere, the Large Southern Array (LSA). The LSA concept emphasized very high sensitivity achieved through large collecting area (10,000 m^2) at millimeter wavelengths. In addition, an array configuration as large as 10 km in extent was specified in order to achieve angular resolution of 0.1 arcseconds at millimeter wavelengths. The LSA also required a high quality site at an elevation above 3000 meters.

To refine the LSA concept, to explore possible sites, and to investigate the technology required; ESO, the Institute de Radio Astronomie Millimetrique (IRAM), the Onsala Space Observatory (OSO), and the Netherlands Foundation for Research in Astronomy (NFRA) agreed to pool their resources in a joint European study. A Memorandum of Understanding to this end was signed in April 1995 with the goal of producing a report within two years that could be discussed by the community and serve as the basis for further studies. Technical design and site studies followed, culminating in a report that was submitted to the sponsoring institutions in April 1997.

In 1997 representatives of the MMA and LSA project teams met and agreed on the desirability of merging these two projects into a single project of larger scope. The basic principle was that of a 50-50 partnership between Europe and the U.S., with joint overall direction. Three aspects were studied in detail – scientific, technical and management – and a feasibility study was published in April 1998. The merged project was to emphasize both the precision imaging requirement of the U.S. scientists with the

requirement of the European group for spectroscopic imaging of molecular gas in cosmologically-distant galaxies. An antenna diameter of 12 meters was adopted as the baseline specification for the combined U.S.-European project, provided that the design of that antenna would maintain its performance at submillimeter wavelengths. With this specification, and the agreement of their communities on the science goals for the merged array, it became feasible for the U.S. and Europe to proceed towards a joint project.

The framework for the formal European collaboration in a 3-year design and development phase (Phase 1) of this joint project was established in December 1998. An European Co-ordination Committee (ECC) was created to direct the European effort, with participation and funding from the European Southern Observatory (ESO), the Centre National de la Reserche Scientifique (CNRS), the Max-Planck-Gesellschaft (MPG), the Netherlands Foundation for Research in Astronomy (NFRA) and Nederlandse Onderzoekschool Voor Astronomie (NOVA), and the United Kingdom Particle Physics and Astronomy Research Council (PPARC). In early 2000~~,~~ the Swedish ~~Natural Science~~ Research Council (V~~NF~~R) ~~of Sweden~~, and the Instituto Geográfico Nacional (IGN) and the Ministerio~~Oficina~~ de Ciencia y Tecnología (M~~O~~CYT) of Spain were added to the European collaboration.

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Just updating to the latest names etc.
TheSpanish are sensitive to this.

In June 1999 the organizations forming the ECC and the NSF signed a formal Memorandum of Understanding (MoU) regarding collaboration on Phase 1 of the project, now called the Atacama Large Millimeter Array (ALMA). The U.S. side of the partnership is led by the NRAO, operated by AUI under a cooperative agreement with the NSF. Recently, Canada has formally joined the U.S. in the North American collaboration. The overall direction for the project is provided by an ALMA Co-ordination Committee (ACC), which oversees the activities of a joint ALMA Executive Committee (AEC) and several technical project teams, with assistance from international ALMA Scientific and Management Advisory Committees. The agreement expressed in the MoU is for the design and development phase (Phase 1), which ends December 31, 2001; however both sides also expressed their intention to complete and sign an agreement for ALMA construction and operation (Phase 2) so that the project can proceed without interruption from Phase 1 to Phase 2.

1.3 Project Development Phases

Phase 1: ALMA Design and Development Project. The goals and deliverables of the ALMA design and development project as specified in Article 6 of the MoU are two, namely:

- To define completely the work to be carried out in Phase 2 and its cost, and to negotiate the Agreement for its implementation. The definition is to include scientific and technical requirements, proposed technical and management approaches, a Work Breakdown Structure (WBS), and a cost estimate and schedule for Phase 2, as derived from this WBS.
- The project shall show in Phase 1 both the feasibility of the proposed technical approach to meet the requirements, and the reliability of the cost estimate and schedule, by performance measurements on prototype components, and subsystems, such as prototype antenna(s).

This work, including procurement of two prototype antennas, is underway both in Europe and in the U.S.

Phase 2: ALMA Construction Project. ALMA construction is proposed to begin in 2002 ~~upon completion of the design and development phase of the project~~. A complete WBS for the construction phase of the ALMA Project has been created jointly by the European and US ALMA Project teams. Appendix A is an abbreviated version of that WBS that also summarizes the project costs and schedule. The WBS is structured in terms of "ALMA Work Packages (AWP)", which are level-2 WBS tasks. Each AWP has sub-elements called "ALMA Work Elements (AWE)" which are the level-3 and below WBS tasks. The purpose of structuring the WBS into AWP and AWE is to facilitate a division of responsibility between the European and North American Executives. Responsibility is assigned at the Work Package level. The Work Elements that make up a work package may be provided by either Executive or they may be shared. A tabular summary of the work packages and work elements is given as Appendix B.

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The remote, overseas site for ALMA creates the need to organize the construction project around integration facilities in the U.S. and Europe and to ship to the site only completed, functioning, and tested hardware. For the ALMA construction project, the initial system integration and all of the testing and evaluation of the two prototype antennas will be done at the NRAO VLA site near Socorro, New Mexico, where office/laboratory facilities and crafts specialists are available. In Chile, the first two years of the construction project will emphasize development of the initial phase of the site civil works. This includes not only construction on the array site of the first roads, power generation and distribution system, and buildings, but it also includes the initial phase of construction of the Operations Support Facility (OSF) near the village of San Pedro de Atacama. Following completion of the evaluation of the prototype antennas at the VLA site in the second year of the ALMA construction project, the contract(s) will be let for the production suite of antennas. Once the first antennas arrive in Chile, the system integration task will relocate to Chile. One important part of the system integration is testing and commissioning of the newly arriving hardware. This will be done by involving the European, North American, and Chilean communities in the testing and commissioning of the array. This process will gradually and naturally evolve into interim scientific operations of ALMA.

Phase 2: ALMA Operations. For several years beginning in 2006, initial science operation of ALMA will overlap with the final years of construction. The overlap in time of these two phases has many benefits, among them the opportunity for the operations staff to work closely with the designers and builders of the ALMA instrumentation. This will facilitate the transfer of knowledge and provide a logical avenue for documentation to be created. The operations model for ALMA has yet to be established during Phase 1 and agreed by the ACC. The experience of the two Executives, ESO and AUI/NRAO, are complementary and provides the basis for an ALMA operations plan that is similar to the shared management approach to be used for the ALMA construction phase.

1.4 The ALMA Agreement concerning Phase 2

The construction, commissioning, and operation of ALMA will be governed by an international Agreement between two Parties, the NSF acting for the North American organizations involved, and ESO acting for the European organizations involved. The North American organizations are expected to be the NSF and the National Research Council of Canada (NRC). The European organizations are expected to be ESO acting for its member states (Belgium, Denmark, France, Germany, Italy, the Netherlands, Portugal, Sweden, Switzerland, and the United Kingdom) and the Instituto Geográfico Nacional (IGN) and the Ministerio de Ciencia y Technología (MCYT) of Spain. Drafts of this Agreement have been exchanged and negotiation of the final Agreement is underway. The principal features of the draft Agreement are:

Guiding Principles:

- *Parity* – the Parties will make equal value contributions. To the maximum extent possible work will be equally and equitably shared between the Parties;
- *Equity* – the Parties and the participating organizations and institutions will obtain intellectual and economic benefit from ALMA in proportion to the value of their contributions, and consistent with the timely and cost-effective execution of assigned tasks;
- *Merit* – key personnel will be selected through international search, solely on the basis of merit and qualification;
- *Utilization of Existing Institutions* – the Parties will only establish new institutions for ALMA if absolutely necessary. Personnel will be provided through secondment arrangements.

Implementation Principles:

- The Parties will establish an ALMA Board as the supervisory and regulatory body for the Project; the ALMA Board is not a legal entity;
- The Parties will each appoint an *Executive* empowered to act on behalf of the Party to carry out the tasks required to construct and operate ALMA; the Executives are legal entities. Funding for the Project will be provided by the Parties to their respective Executive;
- The ALMA Board will establish an International Project Office (IPO) to provide the central focus for the management and control of the Project. The Board will select the personnel for the IPO by international search;
- The ALMA Board will establish standing Management and Science Advisory Committees for the ALMA Project;
- The Executives will each establish a *Project Office* with a project Manager and the project management structure they regard as necessary to manage their assigned ALMA tasks;
- The Executives' project management, acting together, will establish the project Work Breakdown Structure (WBS) and divide the WBS tasks such that tasks of approximately equal value and equal risk are assigned to each Executive;

2. PHASE 2 PROJECT PLAN

The principal ingredients of the ALMA Phase 2 Project Plan are the Work Breakdown Structure (WBS) defining the Phase 2 tasks, a project schedule, and an allocation of resources to the tasks. These three items are integrated in a single software database.

2.1 Work Breakdown Structure

The WBS for the ALMA Project identifies the project tasks as well as the hierarchies and dependencies of the tasks. The WBS for the construction phase of the Project includes the following nine level-1 tasks:

1. Management
2. Site Development
3. Antenna Subsystem
4. Front-end Subsystem
5. Back-end Subsystem
6. Correlator
7. Computing Subsystem
8. System Engineering and Integration
9. Science

2.2 Assignment of ALMA Construction Tasks

The WBS for ALMA construction includes approximately 60 level-2 tasks or "ALMA Work Packages (AWP)". Each AWP is comprised of a number of level-3 tasks called "ALMA Work Elements (AWE)". There are approximately 180 costed ALMA Work Elements.

Task responsibility is assigned at the Work Package level. That assignment may either be to North America or Europe, with the shared tasks ~~(in all cases level-of-effort tasks)~~ being assigned to the appropriate Integrated Project Team (see Section 3 below). Costs are assigned at the Work Element level. In most cases~~A~~ given work element is ~~always~~ the task of one or another of the Executives (viz. Europe or North America); but many of the work packages consist of work elements ~~that are~~ carried out ~~independently~~ by both Executives.

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This is minor, but we do have non-level-of-effort work elements that are shared, e.g. Digital IF transmitters and receivers (2100).

The process by which the task costs are estimated and a contingency assigned is described in the document *ALMA Costing Methodology*. The basic concept is incorporated in the draft ALMA Agreement: Namely, each AWE will be assigned a value and the party responsible for a given set of tasks will receive benefits (e.g., observing time) proportional to the value of the tasks completed. The value of each task is the estimated cost plus contingency. The amount of contingency indicates the level of risk associated with the task. The goal is to arrive at a division of AWEs that balances the value and risk between the two sides while respecting the interests and capability of each side to perform particular tasks.

The resultant division of responsibilities that meets these criteria is shown in Appendix B. For each ALMA Work Element the recommended division of effort between the European and North American partners is shown as a percentage. Where the division for

a particular task is shown as shared, the separation into efforts that are the sole responsibility of the European or North American Executive occurs at a lower level of the WBS, i.e., at a subtask level not included in the presentation in Appendix B.

2.3 Phase 2 Construction Schedule

The ALMA Construction project schedule is included in the ALMA Construction WBS (Appendix A). A brief milestone summary of that schedule is the following.

Table 2.1 ALMA Construction Milestone Schedule

Date	Milestone or Deliverable
2Q 2002	Deliver VertexRSI Prototype Antenna to ATF; Tests Begin
2Q 2002	AUI & ESO Agree on Land Concession Terms and Request Concession
3Q 2002	AUI & ESO Form Chilean Society to Receive Concession
4Q 2002	Sign Agreement , AUI & ESO Chilean Society with Chile Government
1Q 2003	Site Access Permissions Secure; Begin Site A&E Studies
2Q 2003	Deliver A/C/E Prototype Antenna to ATF; Tests Begin
3Q 2003	Release RfP (CfT) for Production Antennas
4Q 2003	Begin Initial Phase of Site Construction
1Q 2004	Receive Production Antenna Proposal Responses; Evaluate
4Q 2004	Award Production Antenna Contract
3Q 2005	Finish Initial Phase of Site Construction
4Q 2005	Receive First Production Antenna in Chile (at OSF)
4Q 2005	Deliver First Quadrant of Correlator to Chile (Capability for 32 antennas at full bandwidth)
1Q 2006	Receive First Commissioning Front End in Chile (not full 4-band capability)
1Q 2006	Move/Install First Antenna on Chajnantor Array Site
4Q 2006	Start of Science Commissioning Observations (limited capabilities; observations for engineering purposes)
31 Dec 2006	Total of 7 Antennas in Chile
2Q 2007	Receive First Production Front End in Chile (all 4-band capability)
4Q 2007	Start of Interim Science Operations

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This obviously depends on the definition of "initial phase" to not include completion of all <5 km arrays.

	(Competitive proposals; limited capabilities and availability)
31 Dec 2007	Total of 18 Antennas in Chile
4Q 2008	Correlator Delivery to Chile Complete (all four quadrants; capability for 64 antennas at full bandwidth)
31 Dec 2008	Total of 30 Antennas in Chile
1Q 2009	Begin Final Phase of Site Construction (Completion of office/lab/living facilities; roads; 14 km configuration)
31 Dec 2009	Total of 42 Antennas in Chile
~~**4Q 2010**~~	~~Completion of Construction~~ ~~(All hardware and software delivered—not all integrated and/or tested)~~
31 Dec 2010	Total of 54 Antennas in Chile
~~3~~**2Q 2011**	All 64 Antennas in Chile (All hardware and software delivered—not all integrated and/or tested)
4Q 2011	Full Science Operations (All hardware and software integrated and tested. Full capabilities available to science user community)

Comment [RK4]: Page: 9
We don't have all of the antennas in Chile

Comment [RK5]: Page: 9
Concerned that we have been doing 1 antenna per month and suddenly we go up to 10 antennas in 6 months.

3. MANAGEMENT STRUCTURE

3.1 Overview of the ALMA Management Structure

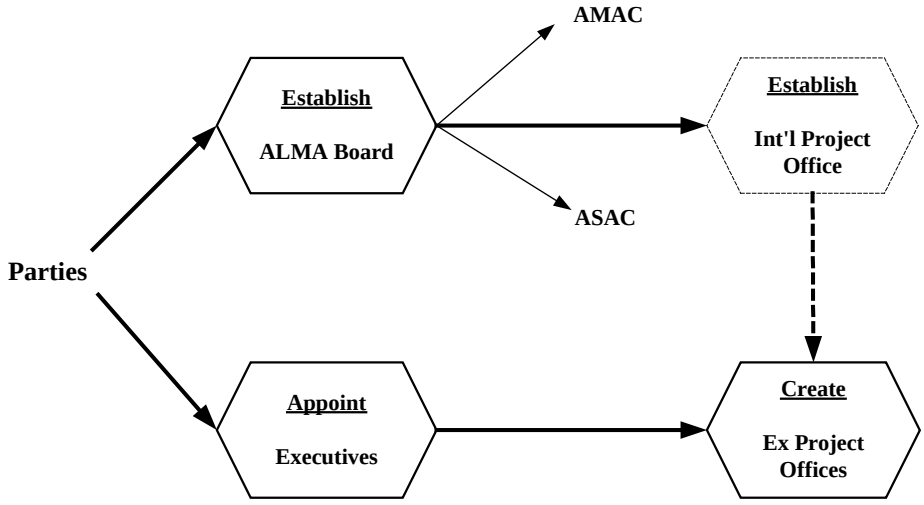
The management structure of the ALMA Project is chosen to assure that the goals of the project are met. In the case of ALMA, these goals extend beyond the usual project goals of control of performance, cost, and schedule. For a partnership of equals, the appropriate management structure must be consistent with the additional guiding principles of parity and equity as described in the draft ALMA Agreement. These principles set forth a project where work itself is carried out through two Executive bodies rather than in a single organizational entity. This separation of effort calls for a project organization in which work is managed and coordinated jointly while resources are allocated separately.

The entities that create the ALMA Project, in the terminology used above, are the *Parties*. The Parties are the entities that provide funding for the project. The Parties have two initial responsibilities: (1) to establish jointly, and by agreement, an oversight body for the Project, the *ALMA Board*; and (2) independently to appoint an *Executive Agency*, or *Executive*, to manage the project tasks and responsibilities that are agreed to become the purview of each Party. The ALMA Board is not a legal entity, but the Executives are legal entities (i.e., they can enter into contracts, employ staff, etc). In order to carry out

their ALMA functions each of the Executives will create an *ALMA Project Office* and secure for that office the staff and resources necessary for the performance of the ALMA tasks assigned to that Executive. The ALMA Board, on the other hand, has the responsibility to establish an International Project Office (IPO) that will manage the ALMA Project. The IPO will carry out its management function by specifying the scope, schedule and tasks of the Project and then coordinating the efforts of the Executives to provide the necessary deliverables.

Figure 1, on the next page, illustrates the development of this management structure. The development begins on the left with the Parties establishing the ALMA Board and appointing Executives. Subsequently, the Executives create their respective Project Offices. The ALMA Board establishes the International Project Office and appoints the ALMA Science Advisory Committee (ASAC) and the ALMA Management Advisory Committee (AMAC).

Figure 1: Development of the ALMA Project Management Structure



The management structure needed for the bilateral ALMA Project is one capable of assuring that the usual project goals of cost, performance and schedule compliance are achieved. But in addition, the *guiding principles* make it clear that it must also be one in which the work can be done by the Executive Agencies making use of the staff and resources of those Executives. The principle that no new institution is to be established as an organizational entity for ALMA means that the project must be organized so that the work is managed and coordinated jointly but resources are allocated separately. It is a significant challenge to create a management structure that satisfies all these requirements. The nature of the ALMA Project as the production of a set of tightly integrated instrumentation assemblies makes it impossible to separate the project into two

or three independent parts that can be simply controlled by two or three global interface documents; a tightly integrated management is necessary for a tightly integrated project.

As a solution to this problem, the management structure for the ALMA Project is based on the concept of Integrated Product Teams (IPTs). The essence of the IPT concept is the recognition that often the level-1 WBS tasks are shared between the two Executives; for this reason the leadership for those level-1 tasks are also shared. The IPT is that shared leadership. Each IPT consists of all those individuals who are assigned by one or another of the Executives with significant responsibility for subtasks within a given level-1 WBS task. The IPT staff will not be co-located; each individual works within the infrastructure of his or her Executive. The leadership of each IPT is provided by the Executives' respective task leaders. One of these persons will be identified as the IPT Leader and the other will serve as the IPT Deputy Leader. The intent is that these individuals will normally resolve by consensus any technical issues that arise within the IPT.

The IPT Leader and the Deputy are vested with the responsibility to assign, coordinate and monitor subtasks as specified by the ALMA WBS. In practice, this means that each of these individuals is responsible for completing the assigned subtasks within the existing infrastructure of, and using the resources provided by, their respective Executives.

The IPT management structure is a powerful method of organizing work carried out across geographic, institutional, and professional boundaries. It allows work packages assigned to different organizations utilizing different skill sets to be effectively coordinated. The IPT model is adopted to the ALMA Project to achieve the following goals:

- Provide a single point of integrative responsibility for each major work package. A single individual, the IPT Leader, is identified for each IPT. This Leader is responsible for assuring that the various work packages, when completed, will meet the project schedule and the performance specifications.
- Provide common, coordinated, management of the IPT and the work groups within the Executives. The IPT Leader and the Deputy are themselves the work managers for the Executives. Common management provides the link between the project coordination function and the means to accomplish the work within the Executives.
- Make decisions at the lowest level in the organization where sufficient knowledge is available. The organizational and technical complexity of the ALMA Project makes it impossible for all significant decisions to be deliberated project-wide. Instead, responsibility will be delegated to the IPTs and will carry with it authority to make decisions within that particular IPT. This has the benefit of empowering all those individuals who have responsibility for ALMA tasks and subtasks.

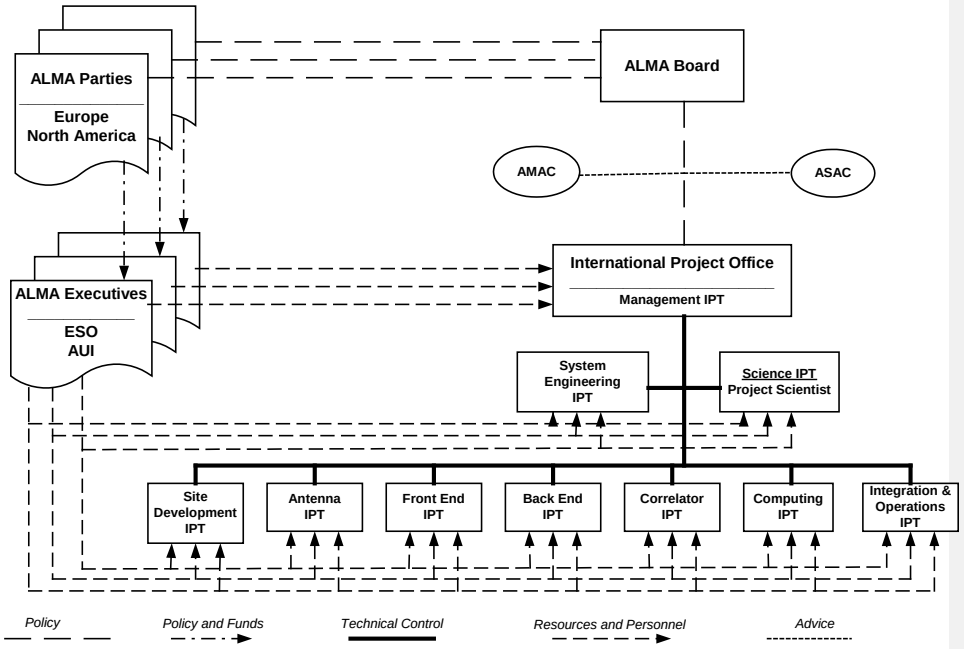
The Management IPT differs functionally from the other IPTs. The composition of the Management IPT is the Project Managers from the Executives, just as is the case for the other IPTs with their managers, with the addition of the ALMA Project Manager who is

on the staff of the IPO. Within the Management IPT the Project Managers from each of the Executives function as deputies to the ALMA Project Manager. The individual Project Managers from each of the Executives report to their respective Executive; the ALMA Project Manager, as part of the IPO staff, reports to the ALMA Board.

The ALMA Project Management implementation, structured around effort being the responsibility of the Executives but organized as IPTs, is illustrated in Figure 2. By focusing on the right side of this diagram, one can see that the ALMA Project has a traditional hierarchical management structure. In particular, the ALMA Board serves the function of a board of directors, the IPO functions as the project management, and the IPTs function as task managers. The unusual aspect of the management structure proposed for ALMA (shown in Figure 2) is the execution of tasks, or shares of tasks, at the Executives. Figure 2 is an illustration of ***management structure***; the functional structure proposed for the ALMA Project is shown schematically on Figure 3.

Functionally, Figure 3, the ALMA Management is structured along the lines of a general contractor with the IPO serving as that general contractor. Specifically, the IPO provides to the Executives a detailed definition of the ALMA system structured as a set of *work packages*. The Executives each agree to perform those work packages as *fixed price, sole-source, contracts*. The IPO then monitors those contracts and coordinates the interaction among the work package deliverables. However, it is not the intention that the IPO funds those contracts. Instead, the Executives receive their funding directly from their respective Parties and the Parties in turn receive project credit for the "value" of the contracts (i.e., the work packages) as agreed with the IPO.

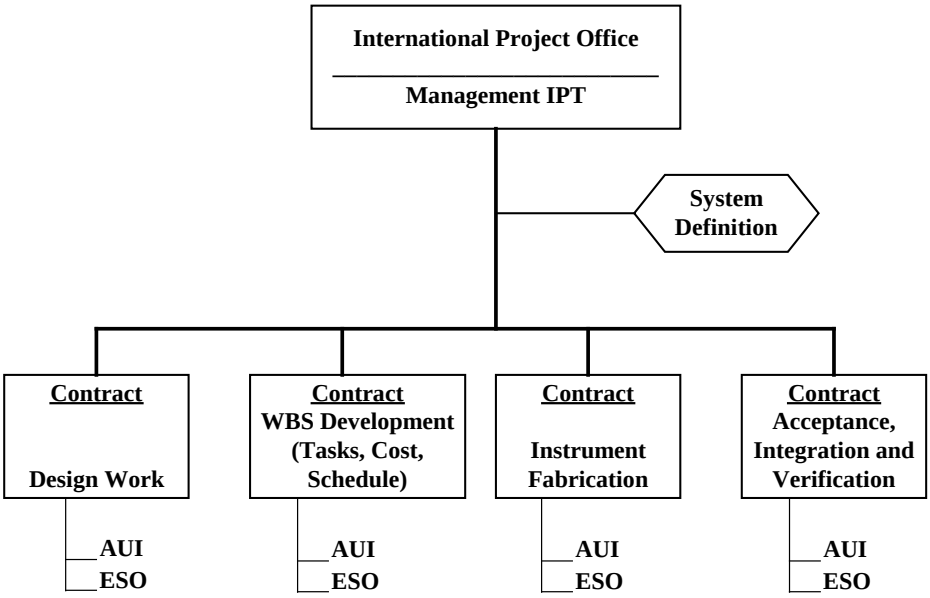
Figure 2: ALMA Project Management Construction Phase



~~**Figure 3-1.** The ALMA construction project management structure based on Integrated Product Teams~~

[Remove the Integraton & Operations IPT from diagram – it doesn't agree with the WBS.]

Figure 3: Functional Outline of ALMA Project Management



~~1.~~3.2 Role of the International Project Office

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Whether thought of functionally as the ALMA "General Contractor", or thought of structurally as the ALMA Central Management, the International Project Office is the focal point for implementation of the proposed ALMA Management Plan. Specifically, the IPO is responsible for (1) the Project scope, detailed specification of the ALMA system that satisfies that scope, and the Project schedule; (2) the Project budget and costs, and (3) it is the entity accountable to the ALMA Board (the "Parties") for successful execution of the Project.

~~3.2~~ Project Scope, System and Schedule: The IPO will:

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- Establish and maintain the scope of the project. This is done through a negotiation involving the user communities (as represented by the ASAC) and the ALMA Board. It is a tradeoff between prioritized science goals and costs.
- ~~Set~~ Establish the specifications for the ALMA system. Working in conjunction with the IPT Leaders and Deputies, the IPO establishes the top-level scientific requirements and corresponding technical specifications. Work packages will be developed to those specifications that will enable the IPO to negotiate with the Executives for completion of those work packages to a particular cost or "value". The IPO will serve as the ALMA "customer"; the Executives are "vendors".

- Establish and maintain the Project WBS and Schedule. This is the core of the management task for ALMA. It is the WBS and schedule that ties the efforts of the Executives together.
- Establish and control the configuration. This means enforcing strict adherence to the specifications and the WBS. Where the specifications or WBS must be changed, those changes have to be managed centrally. It is the IPO that controls the change process and manages the consequences of a change.
- Define, maintain and enforce Interface Control—indispensable for a project done by many institutions working cooperatively. ~~The IPO is the entity responsible for the ICDs.~~
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Costs: The IPO will:

- Provide an impartial, and consistent, accounting of the costs. This applies both to the cost of the baseline project and the cost of any additions or proposed alternatives. This prevents the Executives from being their own arbiter of costs.
- Negotiate an adjustment of "valued" cost estimates in the face of experience where necessary. This is to handle the case where, for some external reason, the cost of a particular task increases substantially above the value previously fixed for it (e.g., the chip makers form a cartel and dramatically raise prices). Such an event will have consequences for all Executives, not just the one with the task facing such an increase. An equitable adjustment will need to be negotiated.
- Serve as "scorekeeper" to assure that the valued contributions of each Executive remain on a par with those of the others. This is to handle the case where the action, or inaction, of one Executive causes a cost increase for the other. An example would be the failure of one Executive to deliver a subassembly to the other Executive on schedule causing the second Executive to idle some part of his workforce. ~~The IPO will assess and tabulate those consequences for future settlement.~~ . An equitable adjustment will need to be negotiated.
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Accountability**:** The IPO will:

- Establish and enforce acceptance criteria for delivered hardware and software from the two Executives.
- Be accountable to the ALMA Board for management of the Project.~~. This includes accountability for the actions of the Executives.~~
- Be accountable to the ALMA Board in achieving its scientific goals in accordance with the advice of the ASAC.

~~3.3~~ Composition of the IPO

The IPO will be composed of the following professional staff all of whom report exclusively to the ALMA Board:

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It may be semantics, but I think System Engineering is responsible for the ICDs

Comment [RK7]: Page: 15
The Executives have to be accountable for their respective Party for their actions.

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- Project Director
- Project Manager

In addition, the IPO will employ a project controller/scheduler(s) to be responsible for the WBS and the necessary reporting. Administrative staff will provide supporting functions. The staff of the IPO should be co-located.

With approval of the ALMA Board, each member of the IPO will be employed by one of the Executives.

3.4 North American ALMA Project Office

ALMA work packages assigned to North America will be the responsibility of the North American ALMA Project Office, which will be part of NRAO. The ALMA Project will be integrated into the NRAO organizational structure to maximize the benefit of shared resources and infrastructure with other observatory functions. The North American ALMA Project Manager will also serve as a NRAO Assistant Director and report to the NRAO Director. Working through the project IPT structure, the North American Project Manager will be assisted by ALMA Division Heads within NRAO, each of whom have the responsibility for tasks within a given level-1 WBS. The Division Heads will act either as the IPT lead or deputy in the corresponding IPTs. The North American Project Office will hold the pooled contingency for all of the North American work packages. Use of this contingency will be coordinated with the International Project Office as described in Section 4.3.

3.5 European ALMA Project Office

The work packages assigned to Europe will be carried out in existing institutions across Europe, including ESO. This activity will be funded through and co-ordinated by the European ALMA Project Office that will be part of ESO. The European ALMA Project Manager will lead the European Project Office that will be responsible for ensuring that the resources are made available to carry out the European work packages to performance and schedule. Each work package will be covered by a formal agreement between the institution concerned and ESO. The European Project Office will hold the pooled contingency for all of the European work packages. Use of this contingency will again be coordinated with the International Project Office. Working through the project IPT structure, the European Project Manager will be assisted by European Team Managers drawn from the participating institutions. The European Team Managers will have the responsibility for tasks within a given level-1 WBS and will act either as the IPT lead or deputy in the corresponding IPT.

3.6 ALMA Scientific Advisory Committee

The ALMA Board will establish an ALMA Science Advisory Committee (ASAC) that will provide regular scientific oversight and advice to the project through reporting to the ALMA Board and through direct interaction with the project organization. The ALMA

Board, in consultation with the Executives, will define the terms of reference of the ASAC and appoint its members. The makeup of the ASAC will be an equal number of members each from North America and Europe. The terms of reference will provide that the ASAC will select a chair, who will serve for a period not exceeding one year, from among its members. The chair will alternate between a member from North America and a member from Europe. Following the practice established in Phase 1, it is expected that the ASAC will have two face-to-face meetings per year and monthly teleconferences. At each meeting the ASAC will receive reports on the progress and activities from the project scientists and project management as well as any other matters of relevance to the scientific performance of the array. Written reports of the ASAC's discussions will be made to the ALMA Board by the chair of the ASAC following each face-to-face committee meeting.

3.7 ALMA Management Advisory Committee

The ALMA Board will also establish an ALMA Management Advisory Committee (AMAC) that will provide regular management, cost, and technical oversight and advice to the project through reporting to the ALMA Board and through direct interaction with the project management (see Section 4.7). The ALMA Board, in consultation with the Executives, will define the terms of reference of the AMAC and appoint its members. The makeup of the AMAC will be five members each from North America and Europe. The terms of reference will provide that the AMAC will select a chair, who will serve for a period not exceeding one year, from among its members. The chair will alternate between a member from North America and a member from Europe. It is expected that the AMAC will meet at least twice per year. At each meeting the AMAC will receive and review reports on the progress and activities from the project management, as well as a detailed statement on the past and planned use of financial and staff resources. Written reports of these reviews and assessments will be made to the ALMA Board by the chair of the AMAC following each committee meeting.

4. MANAGEMENT CONTROLS

As described in Section 3, management control in the ALMA Project flows through two paths. The joint project organization exercises technical control, starting from the Management IPT and continuing down through the level-1 IPTs to the work packages. Technical control means control over all technical aspects of the project, including performance, and control over schedule. The two Executives, through their respective project offices, allocate resources and control costs. As members of the Management IPT, the European and North American Project Managers also have a role in technical control of the project and conversely, enable the Management IPT to monitor the status of resource allocations and costs on each side.

4.1 Budget Process

The value of each work package in the WBS is the estimated cost plus a contingency that reflects the risks and uncertainty of the estimated cost. The budgeted value of each work package will be established as the estimated cost at the outset of Phase 2, exclusive of any contingency. A time-phased budget based on this value, broken down into the major

categories of expenditure (labor, materials, travel, contracts, etc.), will be established and documented for each work package. The Work Package Manager must request approval of any changes to this budget. Documented requests for budget changes will be directed to the Project Manager of the responsible Executive. The responsible Executive Project Manager can approve the budget change request, if it can be absorbed within the overall budget, including contingency, of the responsible Executive. The Management IPT must be informed of any budget change that is so approved. Any budget change that cannot be absorbed within the overall budget of the responsible Executive (i.e., implementation of the change would change the overall budget, including contingency, of the responsible Executive), must be brought to the Management IPT for approval. If the resulting change in the overall budget exceeds 1,000,000 U.S. dollars or Euros, and the responsible Executive wants to request a corresponding change in the value of its contribution, the change must be submitted to the ALMA Board for approval.

4.2 Cost Control

Primary responsibility for cost control rests with each Executive. Each Executive will use their established financial reporting and information system to track expenditures and provide this information to the central Management IPT. At the lowest level the Work Package Managers regularly monitor expenditures versus the budget (expenditure plan). Financial information comes either from the responsible Executive or the financial reporting and information system of the institution responsible for the work package, as appropriate. In addition, the Work Package Manager produces an estimated cost to complete the work at least twice per year. The Project Manager of the responsible Executive monitors regularly the cost performance of the aggregate of work packages for which s/he is responsible and reports the status to the Management IPT. The Management IPT in turn monitors the total project cost performance and reports it to the ALMA Board in semi-annual reports and meetings. However, responsibility for taking corrective action and/or requesting a budget change rests with the responsible Executive.

4.3 Contingency

On each side the aggregate contingency of all of the work packages for which each Executive is responsible will be pooled at the level of the Executive. The contingency will be held and controlled by the Project Managers of each Executive. When a Work Package Manager is convinced that it is impossible to complete the tasks in the work package for the budgeted cost, the Work Package Manager will request a budget change allocating contingency to increase the budget for the work package. The Project Manager of the responsible Executive will decide whether to approve or not approve allocation of contingency. If the Project Manager approves the budget change request and allocation of contingency, the Management IPT will be informed of the change. If a Work Package Manager is convinced that the tasks in the work package can be completed for less than the budgeted cost, the Work Package Manager will request a budget change that decreases the budget for the work package and allocates the savings to the contingency pool.

4.4 Business Procedures

Each Executive will use their established business and administrative procedures. These include personnel policies and procedures, contracting and contract management procedures, accounting and financial reporting procedures, travel policies and procedures, and shipping/import/export procedures. Because it is not a legal entity, the International Project Office will not need many of these procedures. Those business procedures that it does need can be adopted from either of the Executives, as the International Project Office chooses.

4.5 Schedule Control

Each Work Package Manager will develop and maintain a schedule of activities for their work package. Each IPT will build up a level-1 schedule of the activities for which it is responsible from the schedules for each of its work packages. The Management IPT will establish and maintain a project master schedule based on the level-1 IPT schedules. Schedule status will be reported up through the project organization – from work packages to IPTs to the Management IPT. The Project Managers for each Executive will get schedule status through the Management IPT.

4.6 Management Reporting

The Work Package Managers will receive monthly reports of the financial status of their work packages from the responsible Executive and provide a monthly report of technical, schedule, and financial status to the relevant IPT. The IPTs will conduct monthly reviews of the status of the work packages for which they are responsible and provide a report to the Management IPT. The Management IPT, through the Project Managers of the Executives, will provide quarterly status reports to the Executives. The Project Director will provide a semi-annual report of the project status to the ALMA Board.

4.7 Programmatic Reviews

The IPT monthly reviews referred to in Section 4.6 will be informal programmatic reviews at the working level. In addition, the Project Director will conduct a formal semi-annual programmatic review of the entire project. Each IPT, including the Management IPT, will present the technical, schedule, and financial status of the work packages for which they are responsible. The financial status will include the current estimated cost to complete. These reviews will be attended by members of the IPTs plus the ALMA Management Advisory Committee (AMAC). The AMAC will meet with the project management immediately following the programmatic review to discuss and advise the project on issues arising from the review. The semi-annual report from the Project Director to the ALMA Board will follow from the semi-annual Director's programmatic review. The AMAC will provide an independent report to the ALMA Board based on their observations at the programmatic review and the subsequent discussions with project management.

4.8 Configuration Control

As a Project with a projected budget greater than half a billion U.S. dollars conducted jointly by two Partners and many participating institutions, ALMA is a large, highly complex and geographically diverse project. A well-defined and organized process for controlling and communicating changes throughout the project is essential. Configuration control processes insure that changes proposed are accepted only after their impacts are well understood and that all parts of the project are aware of changes in a timely manner. A Project process involving a Configuration Control Board is used to control changes affecting scope, schedule and performance. Changes that result in "collateral costs", those costs incurred by one Executive arising from configuration changes requested by the other Executive, are controlled by a process requiring involvement of the ALMA Project Director and the ALMA Board.

4.8.1 The ALMA Configuration

The term "ALMA configuration" refers to all those documents that define the Project. Appendix ?.A is a list of the applicable documents. For the purpose of configuration control, the ALMA documents are divided into four groups:

i) Board level documents
ii) Project level documents
iii) IPT level documents
iv) Non-controlled documents.

4.8.2 Configuration Control

Configuration control acts on the documents that define the project. The process that is used depends on the type of document, above, that is to be controlled.

Configuration control is made up of four main elements:

i) A means of formally requesting a change;
ii) A process for analyzing the technical, performance and schedule impacts of the proposed change;
iii) A process for making a decision concerning the change;
iv) A process for communicating that decision.

The application of these elements to each of the four types of Project documents is as follows.

Board level documents include this Management Plan (and its Appendices), official cost and task division documents, the Top Level Science Requirements Document and international agreements passed by the ALMA Board. Baselining of, and changes to, Board level documents can be requested by Board members and require direct action by the ALMA Board; it is the responsibility of the ALMA Project Director to implement changes approved by the Board.

Project level documents include the Project Book, top level engineering requirements documents for each major subsystem and ICDs between subsystems that cross IPT or

WBS boundaries. Requests to change project level documents can be initiated by any of the work package or work element managers and require action by the Configuration Control Board (CCB).

IPT level documents include detailed drawings and documents intended to implement the contents of project level documents. Control of these documents is the purview of the IPT management. It is the responsibility of the IPT management to insure that these documents are consistent with all applicable Project level documents.

Non-controlled documents include the ALMA Memo Series and other documents that do not officially define the Project. Baseline and change authorization for these documents depends on the document type but all such processes are outside CCB control.
The ALMA Project Manager defines which documents are Project level documents and he/she determines when a version of each document is to be submitted to the CCB for baselining. Once baselined, all change requests must be presented to the CCB using the process outlined below.

4.8.3 Configuration Control Board

The configuration control board is responsible for managing changes to all project level documents. The CCB is chaired by the ALMA Project Manager~~. Until this individual is appointed, the Systems Engineering IPT Leader will serve as the Chairman.~~ The System Engineering IPT ~~Deputy~~ Leader will serve as the CCB Secretary.

The CCB shall consist of six permanent members:

- The Project Managers from both Executives;
- The Project Scientists from both Executives;
- The Project Engineers from both Executives.

Additional temporary CCB members may be added at the discretion of the CCB Chairman when he/she feels that a particular issue needs special consultation. In any case, as noted below, the CCB solicits input from all IPTs prior to considering a requested change. It is anticipated that most actions will be carried out by consensus of the CCB membership. If efforts to reach consensus fail, a vote of the members will be necessary. Such votes of the CCB can be carried out in any manner selected by the Chairman including, but not limited to: face to face meetings; audio or video teleconference; email or paper correspondence; or telephone polling.

The ALMA Director has the authority to rescind actions of the CCB by informing the ALMA Project Manager and the ALMA Board.

4.8.4 ~~Configuration~~ Change Requests

A ~~configuration~~ change request (CR) may be made by any of the work package or work element managers. Requests are made in writing using the CR template form available on the ALMA website. A sample copy of this form is included in the Appendix. All change requests are submitted to the Systems Engineering IPT Leader.

The CR form identifies the initiator and it includes a title, summary, description of the change being proposed, justification and known impacts in the areas of technical specification, science performance and schedule. Detailed information related to the proposed change can be included as attached documents or by reference to existing ALMA documents. The Systems Engineering IPT Leader will assign a CR tracking number, distribute the request to all IPTs and solicit responses as noted below. Cost impact is not an issue for the IPT Leaders to consider directly (but see section 7 below).

The systems engineering IPT will assist each IPT as it considers all potential impacts on their respective subsystems. Each IPT Leader is required to submit a response that emphasizes the impacts on his/her subsystem and a judgment as to whether the CR should be approved. Systems engineering will collate the responses and generate a summary for further consideration.

If in the course of consideration of a CR it is necessary to amend the CR itself, the original CR is closed with a disposition of "Withdrawn" and a new CR is initiated that references the previous one. CRs shall not be modified to prevent the possibility of confusion over the definition of a change.

A database of all CRs and their status or disposition will be maintained as part of the official project documentation.

4.8.5 Disposition of Change Requests

The Systems Engineering IPT Leader will initiate action on the CR depending on his/her assessment of whether the CR is a minor impact on the Project, or a major impact on the Project.

CR with a Minor Impact. The Systems Engineering IPT Leader may categorize the CR as a *Minor CR* if, in his/her opinion, the CR has an engineering impact only. That is, the proposed change to the configuration does not affect science performance, scope, or schedule. The decision process for Minor CRs is the responsibility of the Systems Engineering IPT. In arriving at a decision, the Systems Engineering IPT Leader shall consult with other members of the Project and may, at his/her discretion, seek formal advice or guidance from other IPTs.

Once a decision on the CR is made, the System Engineering IPT Leader will initiate the following actions:

i) *If the decision is to deny the CR, the CR will be archived, the IPT Leaders and CCB members will be informed, and no further action will occur.*

ii) *If the decision is to accept the CR, then the System Engineering IPT Leader will inform the two Executive Project Managers and seek their written assessment of the cost implications of the proposed change (see Section 7 below). He/she will assure that*

these assessments are forwarded to the ALMA Project Director for approval of the potential cost implications of the CR.

iii) Once approval of the ALMA Project Director is secured, the System Engineering IPT Leader will:

- *Implement the requested change;*
- *Archive the CR and its disposition.*
- *Inform the IPT Leaders and CCB members of the decision.*

iii) If the System Engineering IPT Leader cannot reach a decision on the CR the issue will be forwarded to the CCB for resolution.

CR with a Major Effect. The System Engineering IPT Leader may categorize the CR as a *Major CR* if, in his/her opinion, the CR will affect science performance, Project scope, or schedule. The decision process for Major CRs is the responsibility of the CCB. The CCB Chairman will circulate the CR to all Project IPT Leaders, asking those Leaders for comments. The comments may include advice from other members of the Project, or from outside advisors; each IPT Leader has the discretion to decide what advice is sought, and what comments he/she will write in response to the proposed CR. The CCB will not act until the CCB Chairman has received either a comment, or a written statement of "no comment" from each IPT Leader.

Once a decision on the CR is made by the CCB (formally the decision is made by the CCB Chairman), the CCB Chairman will initiate the following actions:

i) If the decision is to deny the CR, the CR will be archived, the IPT Leaders will be informed, and no further action will occur.

ii) If the decision is to accept the CR then the CCB Chairman will inform the two Executive Project Managers and seek their written assessment of the cost implications of the proposed change (see Section 7 below). He/she will assure that these assessments are forwarded to the ALMA Project Director for approval of the potential cost implications of the CR.
iii) Once approval of the ALMA Project Director is secured, the CCB Chairman will:

- *Iimplement the change requested by making the appropriate changes to the WBS;*
- *Archive the CR and its disposition;*
- *Provide a written report to the ALMA Project Director on the CR and its effect on the Project scope, schedule and performance.*

iv) If the CCB cannot reach a decision on the CR, the issue will be appealed to the ALMA Project Director for resolution.

4.8.6 Control of "Collateral Costs" Resulting from Requested Changes to the ALMA Configuration

The budgetary authority for all of the ALMA Work Elements that make up the scope of the ALMA Project is held either by the European Executive or by the North American Executive. When a request is made to change the ALMA configuration that change may have cost implications to one or both of the Executives. The process used to control these incremental costs is the following:

The two Executive Project Managers will be asked to provide a written assessment of the cost implications of each CR. This applies to both Minor CRs and Major CRs.

i) For CRs initiated by an ALMA staff member from Executive A that affect work elements that are wholly the responsibility of Executive A, the Project Manager from Executive A may simply inform the CCB Chairman (for Major CRs) or the System Engineering Leader (for Minor CRs) that he/she is prepared to accept the cost implications of the CR without providing a quantitative assessment of the cost implication. The Project Manager from Executive B, in this case, must provide either a statement that the CR has no cost impact on Executive B, or he/she must provide a quantitative assessment of the "collateral cost" impact of that CR. Costs incurred by one Executive resulting from CRs initiated by the other Executive we refer to as "collateral costs". In the event that one or both of the Executive Project Managers claim a collateral cost resulting from the CR, the statements of the two Executive Project Managers will be forwarded by the CCB Chairman (for Major CRs) or the System Engineering Leader (for Minor CRs) to the ALMA Project Manager for approval.

ii) For CRs that affect work elements that are the responsibility of both Executives, both Executive Project Managers must provide statements to the CCB Chairman (for Major CRs) or the Systems Engineering Leader (for Minor CRs) that include a quantitative assessment of the cost impact of that CR. The statements of the two Executive Project Managers will be forwarded by the CCB Chairman (for Major CRs) or the System Engineering Leader (for Minor CRs) to the ALMA Project Manager for approval.

iii) CRs that are initiated by an ALMA staff member from Executive A that affect work elements that are wholly the responsibility of Executive B are handled in the manner described in (ii) above.

The ALMA Project Manager shall review the cost impact statements submitted by the Executive Project Managers. If the Executive Project Managers agree that there is no cost impact, the ALMA Project Manager will authorize the Systems Engineering IPT Leader (for Minor CRs) or the CCB Chairman (for Major CRs) to implement the CR. If the statement from one or both of the Executive Project Managers includes a collateral cost impact, the ALMA Project Manager shall provide an impartial quantitative assessment of the extent to which such impact will be allowed as an adjustment to the value of the affected work package(s) for each Executive. The assessment of the

ALMA Project Manager will be delivered to the Executive Project Managers for comment.

- If the Executive Project Managers both agree with the ALMA Project Manager's assessment they shall indicate so in writing to the ALMA Director. In the case that the cost impact of the CR to one or both Executives exceeds 1,000,000 (U.S. dollars or Euros) the ALMA Director will then inform the ALMA Board of the agreed change to the value of the affected work element(s) and seek Board approval for the change in value. The Board may accept, reject or modify the change. Failure of the Board to act on the matter within 60 days from the date the Board Secretary receives the CR from the ALMA Director shall be regarded as approval~~. of the Project Director's assessment.~~ With Board approval, the Director will authorize the CCB Chairman or the Systems Engineering IPT Leader, as appropriate, to proceed. In the event the cost impact of the CR is less than 1,000,000 (U.S. dollars or Euros) the Project Director will inform the ALMA Board; Board approval is not required.
- If one or both of the Executive Project Managers disagree with the ALMA ~~Director's~~ Project Manager's assessment they shall indicate so in writing to the ALMA Director. The ALMA Director will review the comments and seek to obtain agreement.
- If no agreement is possible, the ALMA Director shall refer the issue to the ALMA Board for resolution providing the Board with a recommendation as to how the issue should be settled. That recommendation may include rejection of the CR itself. The decision of the Board is final; it is the responsibility of the Project Director to implement that decision.

Comment [RK8]: Page: 25
I think $100,000 (0.04% of contribution) is too low a threshold.

5. SAFETY AND HEALTH

The ALMA construction activities will take place at existing organizations (e.g., NRAO, ESO, including Chilean operations, and other European and North American institutions) with established safety and health policies and regulations that comply with applicable national or international requirements. The ALMA Project will abide by these established policies and will only create new rules and regulations if no applicable rules and regulations exist. The persons responsible for safety and health management at the participating organizations will report the results of any relevant safety and health audits or reviews to the ALMA Director. Members of the ALMA project staff will serve on safety and health committees at their respective locations.

The ALMA site at 5000-meter altitude in Chile presents unique safety and health challenges. The ALMA Project will abide by all applicable safety and health rules and regulations imposed by Chile. Until the applicable Chilean rules and regulations have been defined in the course of the negotiations to obtain the necessary permissions for construction and operation of ALMA, "Safety Rules for NRAO Personnel on the ALMA 5000-m Site", attached as Appendix C, will be applied.

Appendix: Applicable Documents

(List—to be completed)

Appendix A

ALMA Work Breakdown Structure

Draft Revision February 2002

The material in this document has not been approved by the ALMA Coordinating Committee.

Appendix B

ALMA DIVISION OF EFFORT:
WORK PACKAGES AND WORK ELEMENTS

Draft Revision February 2002

The material in this document has not been approved by the ALMA Coordinating Committee.

Appendix C

Safety Rules on the ALMA 5000m Site

Draft February 2002

The material in this document has not been approved by the ALMA Coordinating Committee.