North American ALMA Operations and the North American ALMA Science Center (NAASC) Staffing Plan

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1 ALMA in North America

1.1 Overview

The Atacama Large Millimeter Array (ALMA) is an international astronomy facility. ALMA is a partnership between Europe, Japan, and North America in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Southern Observatory (ESO), in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica in Taiwan, and in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC\(^1\)). ALMA construction and operations are led on behalf of Europe by ESO, on behalf of Japan by the National Astronomical Observatory of Japan (NAOJ) and on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI). The leaders of the project from each continent are called “The Executives” (NRAO in the case of North America, ESO in the case of Europe, and NAOJ in the case of Japan).

The Atacama Large Millimeter Array (ALMA) is a transformational instrument in its scientific concept, in its engineering design, and in its organization as a global scientific endeavor. ALMA will provide scientists with precise images of galaxies in formation, seen as they were twelve billion years ago; it will reveal the chemical composition of heretofore unknown stars and planets still in their formative process; and it will provide an accurate census of the size and motion of the icy fragments left over from the formation of our own solar system that are now orbiting beyond the planet Neptune. These science objectives, and many more, are made possible owing to the design concept of ALMA that combines the clarity of detail in images provided by the interferometric array together with the brightness sensitivity of a fully filled aperture. A complete description of the scientific objectives, scope and management of the international project is given in the ALMA Project Plan.

The primary governance for the ALMA Project is vested in the ALMA Board, which was established by the Bilateral ALMA Agreement between NSF and ESO. The ALMA Board was established by ESO and NSF, the Parties to the “Agreement concerning the joint Construction and Operation of the Atacama Large Millimeter Array (ALMA)” (hereinafter the “Bilateral Agreement”), as the supervisory and regulatory body for ALMA. It is the primary forum for interactions among, and for the decisions of, ESO and NSF+NRC concerning ALMA. The Board is advised by an international ALMA

\(^1\) NRC is a funding agency for ALMA through the NSF-NRC Memorandum of Understanding and NAPRA agreement.
Management Advisory Committee (AMAC) and an international ALMA Science Advisory Committee (ASAC).

The ALMA Operations Plan (AOP) describes the operations of the ALMA observatory, as agreed upon by the ALMA Board. The outline of ALMA Operations and the guiding principles of the AOP are contained in the ALMA Project Plan (Version II, 23 Sept. 2004). In this vision for ALMA operations, the Joint ALMA Observatory (JAO) is primarily a service organization for conducting the activities in Chile that are required for delivery of the scientific data products required by the ALMA user communities. In this plan, users never interact directly with any operations in Chile. Rather, users around the world interact with ALMA via an institution on their own continent, which supports their ALMA observations from the proposal stage through the delivery of the final fully reduced archive products. Specifically, Section 4 of the AOP states: “Scientific and technical interactions between the regional communities and ALMA will occur through the ALMA Regional Centers (ARC)s operated and managed by the Executives. The ARC{s shall provide core services determined by the ALMA Board. The value of these core services shall be considered part of the Executives contribution to the ALMA operations budget. Each ARC may also provide additional, enhanced services as deemed desirable by the managing Executive.”

This document describes the NRAO vision of the North American ALMA Science Center (NAASC). This center contains the North American ARC, designed to deliver all of the “core” ARC functions as described in the AOP, along with support activities for the maintenance, repair and development of NA produced hardware and software, and the enhanced services that are required in order to fully realize the transformational nature of ALMA and to maximize its scientific return for the North American community.

1.2 Organization of this Document

In the following sections, we present the NRAO staffing plan for the North American ALMA Science Center and the budget for the U.S. share of NA ALMA Operations. Before doing so, it is important to list the starting point. The NAASC differs from other major NRAO facilities in a very fundamental way: it is a fully international facility. As such, certain operational paradigms and structures are specified by the ALMA Operations Plan and must be adopted as the starting point for the NAASC. These assumptions are described in Section 3. We then present an overview of the NAASC and present its functional organization (Section 4). The subsequent sections discuss the work assignments for each organizational unit, and estimates the required staffing level and ramp-up. We break this into three major sections. The first (Section 5) discusses the NA ARC operations. This is almost exactly equivalent to the ARC as described in the AOP. The second (Section 6) describes the work organized within the NA ARC to maintain,
repair and develop software and hardware provided by NA to the ALMA project, specified in the AOP as being supported via contracts from the JAO. The third (Section 7) describes the enhanced services provided by the NAASC that go beyond those spelled out in the AOP.

The total NAASC staffing plan and ramp-up is presented in Section 8, with the resulting budget given in Section 9. Finally, in Appendix A we present a comparison of the NAASC with other U.S. astronomy science centers.

1.3 Disclaimer to version 0.5
This is a preliminary draft of the NAASC staffing plan. It is the result of a thorough reading of the AOP and AOB, a number of discussions with various personnel within the ALMA project, discussions with participants of the NRAO NAASC Organizational Meetings, and preliminary comments from staff at the NRC-HIA. The accelerated external review process has led to the early release of this document. As such it must be viewed as a work in progress. This document will be internally reviewed by technical and operational experts from all areas of NRAO and NRC-HIA. This review is currently scheduled for April 11 2006. The resulting changes will be incorporated into v0.6, which will be reviewed by the NRAO Directors Office and when accepted will become v1.0. This is a key NAASC activity for 2006.

2 Reference Material
2.1 Supporting Documents

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## 2.2 Acronyms used in this document

AIV  
ALMA  
AMAC  
ANASAC  
AOB  
AoD  
AOP  
ARC  
ASAC  
ATF  
AUI  
CfP  
CSV  
DB  
DM  
EPO  
ESO  
FTE  
GBT  
HIA  
HST  
JAO  
JWST  
LO  
MR&D  
NA  
NAASC  
NAOJ  
NAPRA  
NINS  
NRAO  
NRC  
NSF  
NTC
3 Background and Assumptions

The plan for the North American ALMA Science Center (NAASC) assumes and is based in large part on the ALMA Operations Plan (AOP) and the ALMA Operations Budget (AOB) prepared by the Joint ALMA Observatory. This follows directly from the fact that the North American ALMA Regional Center (NA ARC), described and budgeted in the AOP and AOB, is part of the NAASC. Specifically, Version A (ALMA-00.00.00-002-A-PLA) of the AOP and Draft J1/B (2005-03-17) of the AOB were used in drafting this document. This version of the AOP is “ Provisionally accepted” by the ALMA Board, and does not include the results of the rebaselined project or the expected contribution by the Japanese participation in operations. The AOB has neither been reviewed nor approved formally by the Executives or Board. The AOP is based on the ALMA Project Plan (APP), drafted by the JAO and the North American and European executives. In particular, the AOP is an interpretation of the effort required to implement the Project Plan. Where a conflict exists, the APP takes precedent.

The current document expands upon the scope of the AOP/AOB to include activities performed at the NAASC for the benefit of the U.S. astronomical community in order to fully leverage the transformational nature of the ALMA observatory. This includes activities such as advanced user support, educational programs, summer schools, workshops, constantly improving end-user products, a User Grants program, etc. These activities are in addition to the basic support provided by the NA ARC as described in the AOP, and are referred to herein as “beyond ARC” activities. For accounting and tracking purposes, we separate the required ARC activities (which are subject to approval of the ALMA Board) and the value-added “beyond ARC” activities (which are not subject to bilateral approval) both in the organizational chart and functional descriptions in this document. However, it should be obvious that while the activities and services are
separately described and accounted for, the staff that performs them need not be. In particular, we envision that an individual staff member may easily perform both ARC and beyond ARC functions, e.g. be responsible for help with the proposal submission tool as well as help organize a summer school.

The starting point for the staffing level for the NA ARC is that described in the AOP for the ARCs. However, it is important to recognize that the AOP itself is a preliminary document. It is probable that important details will change beyond the next year or so. For example, the inclusion of Japan and Taiwan into the project as a whole and the inclusion of Taiwan also into the North American side will alter the balance currently present in the Bilateral Agreement from which the AOP (and hence this document) is drawn. As such, this document will be revised as ALMA operations are refined, and as details of the greater NA partnership are worked out.

When reviewing the NAASC staffing plan, one must realize an important operational paradigm for the international ALMA observatory. This is that the initial ALMA array is assembled, integrated, tested, verified and commissioned as part of the international construction project. Eventually, these tasks are turned over to the Operations staff, which includes ARC astronomers. These plans are detailed in the Assembly, Integration and Verification: Overview and Work Plan (AIV plan; RD 04) and ALMA Commissioning and Science Verification Plan (CSV plan; RD 05). Specifically, the staffing plan included in this document does not include the manpower required to assemble, integrate, test and commission the telescope, except in a supporting role as detailed below. As detailed in the above two documents, this effort is provided initially by the AIV team\(^2\), who are trained by the development IPTs as the different telescope subsystems are delivered (FE, BE, Antenna, LO, M&S, etc.). The AIV team in turn trains both the ALMA Chilean operations staff\(^3\) as well as the CSV team.

As detailed in Section 9 of the CSV plan, the CSV team is composed of the Project Scientist, four members of the Science IPT, and four “external specialists” contributing 1 FTE in total. The AOP states that the “external specialists” may include staff from the ARCs, or may be experts from the scientific community. Additionally, the operations plan presented in this document requires ARC astronomers to provide 122 shifts of “Astronomer on Duty” support at the OSF in Chile. We envision that during the

\(^2\) As detailed in Section 6 of the AIV plan, the AIV staff includes four integration teams of eight engineers, programmers, and technicians, lead by a lead scientist and lead engineer. They are expected to start being hired or “matrixed” in 2006/7, will be stationed at the OSF, and are on site from well before the first telescope is delivered until the last one is delivered. See SD07 for the current Science IPT timeline.

\(^3\) As detailed in Section 9 of the CSV plan, the ALMA Operations staff in 2007 includes a science program manager, six duty astronomers, two ALMA fellows, and three systems astronomers. They divide their time between the OSF and Santiago on the turno system. They are supplemented by 1 FTE of duty astronomer support from each ARC.
commissioning phase, these ARC astronomers will primarily participate in commissioning activities during their time in Chile. And while the ARC astronomers may not play the major role in commissioning the array, they do play a major role in commissioning the software used by scientific users, through their roles as testers of the proposal submission, observing, pipeline, and offline software systems, starting in 2005 and continuing indefinitely.

This document does not include a detailed plan for Canadian involvement in the NA ARC. It is anticipated that some functions may be subcontracted to the National Research Council of Canada-Herzberg Institute of Astrophysics (NRC-HIA; e.g. a fraction of the maintenance, repair and development services), or the NRC might choose to support its share of the NA ARC, in part, by assigning personnel to NAASC staff positions. This would also help establish and maintain the close communications between the NRAO and NRC-HIA that are essential to a good partnership. These discussions are just beginning, and we expect to more fully flesh out a joint NRAO-NRC operations plan in the coming year. This may include Canadian participation in certain “beyond ARC” functions (such as summer schools and advanced user support), but for the current document we assume that the latter are solely for the benefit of the U.S. astronomical community.

Throughout this document we report the expected staffing level for each division both in terms of the expected number of staff members and the number of Full Time Equivalents (FTEs) required to support the described tasks. For the technical, administrative and management staff the two numbers are equivalent. For positions staffed by astronomers it should be understood that roughly 50% of the staff members time is reserved for scientific research, so that 1 staff astronomer = 0.5 FTE. The NAASC also includes 12 positions for postdoctoral fellows (half of which are stationed outside of the NAASC) and students. These positions are primarily for the education and/or training of the participants, which itself requires effort by the mentoring astronomer, so in the end we assume no net FTE contribution from these positions. While we hope this is not actually the case for the six NAASC ALMA Postdocs, it is clear that the NAASC should not depend critically on their contribution in order to meet the obligations to the community. Section 8 details the staffing levels both by the number of staff and the number of FTEs planned for the NAASC.

The budget section presents estimates of the North American share of the annual ALMA operations cost (including the NAASC), as well as the expected cost to the National Science Foundation. The participation levels are assumed to be 92.75% United States and 7.25% Canada of the total share of ALMA operations falling to North America, including the NA ARC, and the office of Chilean Affairs, but excluding additional activities performed within the NAASC that supplement the core NA ARC functions. As
mentioned above, the “beyond ARC” activities are assumed to be for the sole benefit of the U.S. community and as such are funded in total by the NSF.

The cost of ALMA Chilean Operations is taken directly from the AOB. This document will be fully reviewed by the ALMA board at some later date, so it does not seem prudent to deviate strongly from it at this point, at least for tasks to be performed in Chile. For services performed within the NA ARC we do not use the AOB calculations. Rather, these are calculated from a detailed WBS for the NAASC, which includes specific NRAO paygrades for the required staffing level and skill set planned for the NA ARC.

Participation by Japan in ALMA has not been taken into account. It is unclear whether or not some cost savings to Europe and North America will be realized when a full operations budget including Japan is developed.

4 The North American ALMA Science Center (NAASC)

4.1 Introduction to the NAASC

The NAASC serves as the portal to ALMA for the North American scientific community. It also supports the U.S. ALMA user community in the use of this unique and powerful facility. In the context of the NRAO, its closest parallel to the NAASC is a telescope-operating site like Green Bank or Socorro. The Science Centers of the NASA space telescopes (Hubble, Spitzer, Chandra) are better analogues. The NAASC will be the point of contact for North American ALMA users from proposal submission to calibrated data distribution and analysis. The core of the Center’s activity will be the development, maintenance and refinement of the ALMA data archive and of the pipeline and offline reduction software systems that surround it. Very importantly, the NAASC will foster community development to optimize the science use of ALMA, and guide its future evolution. To achieve these goals, the Center will conduct a program of ALMA Fellows and promote the establishment of grant support for data analysis by users on behalf of the NSF. It will be the focus for ALMA affairs in North America, sponsoring workshops, schools, and events that will stimulate the scientific activities appropriate to ALMA. ALMA development projects, both hardware and software, will be conducted by the NAASC. The NAASC will be responsible for ALMA within the NRAO program of education and public outreach.

4.2 Organization of the NAASC

The organization of the NAASC is presented in the following set of figures, which proceed from the highest level to a more detailed listing of tasks.
Figure 4-1 Relationship of the NAASC to ALMA and the NRAO. NRC is a funding agency for ALMA through the NSF-NRC Memorandum of Understanding and NAPRA agreement. Acronyms are described in Sec. 2.2.

Figure 4-1 shows the relationship of the NAASC to other NRAO efforts. The Head of the NAASC reports to the NRAO director. The head of the NA ARC is responsible for maintaining close contact with the Joint ALMA Observatory (JAO) in Chile, as indicated by the dotted line. In particular, the ARC Head is responsible to the JAO director for North America’s share of the ARC core operations support.

Figure 4-2 shows the organization of the NAASC in more detail. During ALMA construction, the Head of the NAASC reports to the NRAO ALMA Project Director, who reports to the NRAO director. At the conclusion of ALMA construction, these two positions could be merged into one. The ALMA North American Science Advisory Committee (ANASAC), which includes Canadian members, provides advice to the NRAO Director on NA ALMA Operations on behalf of the larger NA astronomical community.
Figure 4-2 The organization of the NAASC. The NA ARC is shown in yellow, work supported by maintenance, repair and development contracts from ALMA Chilean Operations is shown in light yellow, and beyond ARC activities are shown in green.

The North American ALMA Regional Center (NA ARC) is a subset of the NAASC. It consists of the NA ARC operations, shown in bright yellow. This division provides the ARC core functions as described in the AOP. Indeed, for day-to-day operations, the NA ARC is considered to be an integral part of overall ALMA operations. The ARC staff serves their regional communities, but also provide improved products for the entire ALMA observatory, such as improved pipeline heuristics or observing tools. The AOP calls for science staff from the ARCs to rotate through Chilean operations, providing the necessary close ties among the sites, and keeping the ARC staff familiar with the realities of Observatory operations.

The NA ARC also manages the Technical and Data Management divisions, which provide hardware and software maintenance, repair and development (MR&D) services to ALMA. As specified in the AOP, it is assumed that each ARC will maintain, repair and develop the hardware and software that they deliver to the project. This work is supported via sub-contracts from ALMA Chilean operations: one for NA hardware...
maintenance and repair (M&R), one for NA software M&R, and one for development. These combined services are indicated by the pale yellow boxes in Figure 4-1. The AOB provides an estimated budget for these contracts, but no detailed staffing requirements. In this document, we estimate the level of effort required to provide this support for NA deliverables.

Finally, the NAASC includes functions beyond those called for in the AOP. These are the enhanced services that are required in order to fully realize the transformational nature of ALMA and to maximize its scientific return for the North American community, such as student and postdoctoral programs, summer schools and workshops, advanced user support, a user grants program, and other services for the U.S. user community. These “Beyond ARC” activities are shown in green in Figure 4-2.

5 North American ALMA Regional Center (NA ARC)

The NA ARC is the main conduit between the NA astronomical community and the ALMA Observatory. Proposals and observing tools are accessed through the ARCs and with the assistance of the ARC’s staff. The ARC’s staff organizes regional Telescope Allocation Committees, and validates all scheduling blocks submitted by NA observers. They assist with observing quality assurance, and travel to the OSF to help with ALMA operations. The ARC hosts a complete copy of the ALMA archive, and assists NA users with data retrieval and post-observing data reduction.

The NA ARC consists of three main divisions, managed by the NA ARC Head Office. The three divisions are the Science Division, the Data Management Division, and the Technical Division. In this subsection, we describe the NA ARC head office, Science Division, and Archive Operations. These are the functions assigned to the ARCs in the AOP. The NA ARC also oversees MR&D activities funded via contracts from the JAO, but these are described separately (Section 6). The functions and staffing levels for each of these components is described below.

The NA ARC Operations conducts only those functions required of and funded by the ARC as described in the AOP. The principal tasks for the Science Division are divided into those required to support users prior to observations (Proposal Functions), and those required for basic support during and after observations (User Science Support). The Archive Operations division supports the use and maintenance of the NA version of the ALMA archive. While this division falls within the ARC, it is closely affiliated with and reports to the Data Management Division (Section 6.1).
5.1 NA ARC Head Office

As described in the AOP, the ARCs are considered to be an integral part of the overall ALMA operations. The NA ARC Head is responsible for directing the NA ALMA operations activities, including the ARC core functions and the software and hardware maintenance, repair and development activities. The ARC Head is responsible for maintaining close contact with the JAO and other ARC managers for operations related issues, as well as for the MR&D contracts, and to related ARC issues back to the head of the NAASC and NRAO director. The ARC Head must also interface with our Canadian colleagues in order to coordinate the Canadian participation in NA ALMA operations.

The head office of the NA ARC includes the ARC Head and an administrative assistant. The NA ARC Head is assumed to be a support scientist, so the staffing level of 2 for the NA ARC Head Office corresponds to 1.25 FTE. The acting NA ARC Head was appointed in 2005; the administrative assistant starts in 2006 at a level of 0.2 FTE, ramping up to 1 FTE by 2011.

5.2 Science Division Head Office

As detailed above, the ARC Head has many coordination responsibilities. For this reason, the day-to-day operations of the main scientific ARC functions are organized and overseen by the Head of the ARC Science Division, who serves as the Deputy Head of the NA ARC. This person is responsible for managing the personnel in the division, managing the software system testing schedules and assignments, setting priorities, rebalancing resources, and making sure the ARC staff have the resources and experience necessary to carry out their mission. She/he will also participate in the ARC support activities. This position will be filled by a staff astronomer (0.5 FTE), and is not included in the AOP staffing plan.

5.3 Proposal Functions

This divisional element is responsible for supporting observing proposals from the NA community, from the time of proposal submission (Phase I), to the construction and submission of observing scheduling blocks for accepted proposals (Phase II). This includes the following tasks:

- Provide user friendly documentation;
- Review and evaluate the Proposal Submission Tool (PST) and Observing Tool\(^4\) (OT) and provide feedback to developers;
- Design, implement and maintain additional tools for proposal construction;
- Issue call for proposals;
- Provide assistance to users with the PST;
- Organize review and ranking of NA proposals;
- Provide assistance to users in using the OT to generate observing scripts;
- Verify and correct observing scheduling blocks;
- Serve as interface between observer and Chilean Operations.

The NA ARC will need to spend considerable initial effort in providing user-friendly documentation for the proper use of ALMA. The project will deliver basic documentation, but it will require significant modification as experience is gained. We anticipate the need for documentation for the proper use of standard observing modes, the correlator capabilities, the Observing Tool science view vs. system view, scheduling block generation, what calibrations are needed, and the use of the calibrator database. We will also need to indicate clearly to users how observations get scheduled, when they can expect updates and otherwise clearly defined expectations for user observing programs. We anticipate that the Proposal Functions group will get considerable support from the programmers in the Advanced User Support for this function.

Four astronomers and two data analysts make up the staff to handle these proposal functions, principally, helping users in using the Proposal Submission Tool (PST) to prepare and submit proposals, managing the refereeing and ranking of proposals, ensuring that accepted proposals are properly characterized for Archiving and pipeline processing of observational data, assisting in the use of the Observing Tool (OT) for the construction of observing “scheduling blocks”, and in the verification of these scheduling blocks before submission to Chilean Operation for entry into the observing queue.

The staff requirement of four astronomers and two data analysts was constructed in two steps: First, one imagines that the tasks are continuous, rather than the reality, which has large peaks and valleys for most activities. Second, one checks that it will be possible to manage the reality by having the staff multi-task, moving from one task to another as required. This approach has been successful at the Spitzer Science Center. From the number of proposals expected and experience at the VLA/VLBA and VLT, we would need two astronomers (1 FTE) for assisting in the construction of proposals and for processing proposals, were the flow of proposals to be continuous rather than peaked at deadlines. Another astronomer (0.5 FTE) is required to provide assistance constructing observing scripts. A fourth astronomer (0.5 FTE) is needed to help maintain a calibrator.

\(^4\) The Proposal Submission Tool and Observing Tool are actually two different modes of a single Observing Tool software package.
and spectral line database and to construct additional software tools for proposal and observing support. From VLA/VLBA experience, two data analysts (2 FTE) are needed for observing script verification. The total staff of 6 is the same as called for in the AOP, although the skill mix is somewhat different. Specifically, the AOP calls for all six positions to be staffed by astronomers, whereas we assign the task of verifying scheduling blocks to data analysts, which works well at the VLA/VLBA. Our staffing level of 6 corresponds to 4 FTE rather than the 3 FTE of the AOP.

We require this division to start being staffed in 2006, in order to participate in test of the PST and OT, and to compile a high-frequency spectral line and phase calibrator database for use in the PST/OT. Effort on both of these tasks has already started in 2005 and will continue until (and likely after) the first Call for Proposals (CfP). The staffing level must increase sharply before the first CfP in order to generate sufficient documentation and community awareness of ALMA’s expected capabilities. The current timeline calls for the first CfP in early 2009. From 2009-2011 we anticipate relatively few proposals and scheduling blocks, but expect that these will require considerable effort to process and verify, requiring support by an experienced astronomer. By 2012 we envision that some observing modes of ALMA will be relatively straightforward, allowing data analysts to take over the verification process. We therefore ramp up to four astronomers by 2009, and add a data analyst in 2012 and 2013.

### 5.4 User Science Support

This divisional element is responsible for supporting users with the final observing products produced by ALMA. This includes the following tasks:

- Support ATF activities during construction;
- Participate in Science IPT activities during construction (including Commissioning and Science Verification);
- Review and evaluate the pipeline and off-line data reduction software;
- Review and improve cookbooks;
- Chile “Astronomer-on-Duty” (AoD);
- Quality assurance;
- Post-observation user support with off-line reduction via a Help Desk.

Four astronomers make up the staff to support user science, principally serving as the Astronomer on Duty at the ALMA Operations Support Facility (OSF) in Chile, providing quality assurance, and giving assistance with off-line data reduction.

The ARC staff is required to travel to Chile to perform “Astronomer on Duty” support at the Operations Support Facility (OSF). Following the AOP (cf. Footnote 28 and Sec.12),
there are two 12-hr AoD shifts per day, or 730 per year. In the current plan, Chilean Operations staff will support two-thirds of these, and the other third is split between the European and NA ARCs. This requires that the NA ARC support 122 AoD shifts per year. Following the calculations in the AOP\(^5\), this number of shifts requires 1 FTE of effort, or a staff of 2 astronomers (assuming this is their only functional duty). In reality, it will be desirable to spread these duties over all astronomers in the NAASC, so that they become familiar with all aspects of ALMA operations. During the commissioning phase, these ARC astronomers will primarily participate in commissioning activities during their time in Chile.

The AOP calls for two additional astronomers (1 FTE) to review and evaluate pipeline and off-line data reduction software, assist users with off-line data reduction (at the level of a Help Desk), and provide Level-3 quality assurance\(^6\) when required. Our experience at the VLA/VLBA is that this staffing level would provide a very minimal level of user support. We envision that the Science Division Head will contribute to these efforts. We plan to provide more complete user support (i.e., beyond the ARC core support) in the Advanced User Support subdivision of the Science Development Division.

This element needs to be staffed starting in 2006 in order to participate in tests of the offline system using the ALMA Test Facility (ATF) in Socorro, New Mexico. More staff will be added prior to the first CfP in order to participate in Commissioning and Science Verification activities so that the ARC staff will be sufficiently experienced to help users with the first observations. It will be fully staffed by the time the first data products are delivered to users (2010). While the number of projects and observing modes executed at this time will be low, we expect that each will require extensive involvement of the ARC staff.

5.5 Archive Operations

Each ARC will include a copy of the ALMA archive, containing a complete copy of all observational data and pipeline products published to the ALMA archive. The AOP states

\(^5\) These are covered in via the Chilean “turno” system, which provides eight 12hr shifts per trip to the OSF. In the turno system, staff is entitled to two compensation days for weekend work (2 more if working the night shift). The AOP calls for each trip by an ARC astronomer to the OSF to include two days at the JAO Santiago office (SCO) to prepare for the OSF shifts and interact with off-shift staff at the SCO (AOP Sec. 9.3.1). Each trip will also require 4 travel days, so every 8 AoD shifts cost an ARC astronomer \(8+2+4+2=16\) work days. The 122 AoD shifts therefore require 244 workdays. Since 1 FTE provides 223 work days (accounting for holidays and vacation), the ARC AoD requirements require \(~1\) FTE of effort.

\(^6\) The AOP describe QA3 as "Defect detection done by users but reported to local ARC data analysis support staff. These ARC staff then try to verify the problem. If verified, problem is reported to [JAO] for investigation and resolution." (AOP, Sec.7.11).
that ALMA is to be completely compatible with the Virtual Observatory (hereafter VO). This requires effort to establish and maintain the interface. We envision that the following activities are required for the ARC archive support:

- Maintain NA archive hardware and database;
- Support data transfer from main ALMA archive;
- Support archive software maintenance;
- User support for ALMA User Database;
- Provide user feedback for archive query tool, bug reports, etc.;
- Improve archive based on local and user feedback;
- Provide web documentation on what the archive holds, how often it is updated, when user projects are ready, how to query the archive, on VO interface;
- Provide archive VO expertise, especially for radio community.

These tasks are more detailed than called for in the AOP, which assumes that the archive consists primarily of data storage and retrieval hardware. The AOP calls for the archive to be maintained by a staff of five: a database manager and four archive technicians. In discussions with personnel from the NRAO division of data management and colleagues from the NRC-HIA with extensive experience with archives, we envision that the actual ARC archives will deviate somewhat from the AOP baseline. The archive will not be static, but will grow both in its data content, products, data access protocols, and information content and will need to keep up with VO standards. It will therefore require archive software developers, and not simply technicians. These developers will install updates to the archive and provide input to the project on recommended updates and improvements. They will respond to user queries that are outside the expertise of the archive technicians. They will also be tasked with interfacing with the VO.

Based on these considerations, we convert two of the Archive Technician positions described in the AOP into Archive developers. We retain the Database Manager and the other two Archive Technicians specified in the AOP, so that the staffing effort (5 FTE) remains the same. The archive technicians will load data into the archive, provide basic web documentation, and provide basic user feedback, forwarding more complicated user problems to the database manager or archive developers. The developers will install updates and patches to the archive and pipeline system, provide suggestions to the project for improving the archive based on local and user feedback, respond to more complicated user queries, and keep current with VO developments.

The ramp-up for this division is driven by the AOP plans to install a temporary data retrieval system at the ARCs in 2007, for use in the commissioning and science verification process. Therefore, we will bring one Archive Developer onto staff to install and maintain this system. The main Archive hardware will be purchased in 2008 in
preparation for early science observing, so the staffing ramps up from there, reaching full staffing by 2010.

We have not fully assessed the requirements to keep ALMA VO compatible. It is of special note that ALMA will likely define millimeter standards for the VO. The current plan includes no additional staff for VO, with the idea that the sum of all of the DB managers and archive developers across the project may be able to provide adequate expertise, but this should be reviewed.

5.6 NA ARC Operations Staffing Summary

A staff of 18 is required to support NA ARC operations: an ARC manager and administrative assistant (1.25 FTE); a head of the Science Division (0.5 FTE); 4 astronomers and 2 data analysts for Proposal Functions (4 FTE); 4 astronomers in User Science Support (2 FTE); and a staff of five to support the Archive (5 FTE). The total staff of 9 astronomers and 9 support staff (13.25 FTE) is very close to the staffing level specified in the AOP (11 astronomers and 6 support staff or 11.5 FTE), although somewhat different in its mix.

6 Contracts for Maintenance, Repair and Development

The AOP calls for each partner to maintain, repair, and develop the hardware and software that they deliver to the project. This work is supported via sub-contracts from ALMA Chilean operations: $1M/yr (US$2003) for NA hardware maintenance and repair (M&R), $1M/yr for NA software M&R, and $5M/yr for development (both hardware and software). The AOB specifies the above funding level, but provides no breakdown of the functions or staffing level required to support these activities. In this document, we use these contracts to support two major divisions, each of which report to the NA ARC manager: the Data Management division for software MR&D, and the Technical division for hardware MR&D.

6.1 Data Management Division

The largest unit of the NAASC is the Data Management Division, which is charged with the care and development ALMA software systems and data archive\(^7\). The success of

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\(^7\) While the NA Archive falls under the Science Division in the NAASC organization chart (Figure 4-2), it is managed by the Data Management division.
ALMA depends critically on its software systems, and the NAASC is responsible for supporting the software that interfaces most directly with ALMA users, namely, software to submit and review proposals, construct observing programs, receive and distribute pipeline produced reference images, operate a data archive, analyze images, and organize communications with users via email and the internet. The principle tasks assigned to Data Management are given in the following list:

- Maintain and improve software constructed by NA (scheduling, real-time system, pipeline, correlator, off-line);
- Develop software for new observing modes.

Although the list is short, the tasks are large. The dominant role of data management in the NAASC is similar to the role that computing plays in the science support centers of the NASA astronomy missions, ESO’s Very Large Telescope, and user support groups of the other telescopes of the NRAO (whose future evolution is to be patterned on the NAASC). The size of the data management task is indicated by the following: since its inception, the Hubble Space Telescope archive has grown to somewhat less than 20 Tbytes, whereas ALMA is expected to produce 180 Tbytes every year at current, perhaps low, estimates.

### 6.1.1 Data Management Division Head Office

The Data Management division needs a Division Head to organize the division, to set priorities, and to coordinate future development within the NA ARC. In addition, there is a need for a Software Coordinator, whose main obligation is to make sure that the NA ARC is plugged into software activities throughout the project. This coordinator would also serve as deputy division head. The main task of the coordinator would be to support the division head; to provide input derived from first hand experience at the ARC and from NA users into software projects being supported outside of the NA ARC (i.e., in Chile, Europe or Japan); to solicit and implement suggestions from outside NA into NA supported software efforts; and to coordinate software development between NA and the international partners. These positions are vital for the proper operation, coordination, and planning of the software efforts of the ALMA project.

### 6.1.2 Software Maintenance, Repair and Development

Each ARC is charged with the maintenance and repair of the software that it delivers to the project during the construction phase. For NA, this includes most of the scheduling, real-time system, correlator, pipeline, and off-line systems, with lesser contributions for some of the other systems (e.g. archive). In the AOP, this effort is funded from the
running costs of the Chilean Operations, and therefore included in the cost of Chilean Operations. It is necessary for us to account for this effort when planning the NA ARC, so in our calculations we associate the staff and associated capital costs of this effort with the NA ARC, reducing the cost of the NA share of Chilean Operations by the appropriate amount (see Section 9).

In addition to programming, it is anticipated that the Data Management division will also need to communicate with users and the NAASC scientists, in order to fully support observations and to get feedback on necessary or required improvements. A partial listing of the type of work anticipated for this effort is as follows:

- Support users and staff with PST/OT software;
- Provide user support for interpretation of pipeline processing scripts;
- Provide information on status of the pipeline processing;
- Simulation capabilities support (during and after observations).
- Offline reduction support - where to get the package, how to find information, helpdesk and bug-tracking support
- Help Proposal Support division in providing user-friendly documentation.

The staffing requirements for this effort are based on the widely recognized principle that the same number of software engineers are needed to maintain and improve a software system as it took to construct the system. Specifically, this is the experience of ESO with the VLT. We will therefore staff this division with 10 FTE for maintenance and repair and 7 for development. We note that the STScI has ~100 FTE in software development, and ~40 FTE for operations and the archive, serving both HST and the development work for JWST. The skill set of this group is as follows:

- Correlator: 3 FTE
- Common software: 1 FTE
- Monitor and Control: 4.5 FTE
- Integration and Testing: 1.5 FTE
- Systems Requirements: 1 FTE
- Scheduling: 1 FTE
- Pipeline: 1 FTE
- Offline: 2 FTE
- User Support: 2 FTE

The staffing timeline has been set by the need to capture qualified personnel as they move off of the construction project. The construction staff will clearly be the most qualified to work with the ALMA software in operations. It is envisioned that the skill set for construction will be perfectly matched to that needed in operations, and we need to be
able to retain the best software engineers and developers as they are released from the construction project.

6.1.3 Developmental Pipeline

We envision that the regional archive will not simply be a storage and retrieval unit, but also require the computing power to run a regional copy of the ALMA pipeline. In the AOP, it is envisioned that the pipeline will run in Chile at the completion of each scheduling block and again at the end of a project, and that these will result in products published to the archive, which are then propagated to the ARC archives. It will be challenging enough for this system to keep up with the standard pipeline processing for all new projects, and thus unlikely that it would be available to rerun user projects, for instance altering weighting parameters or combining data spread over several projects. While the offline system will allow users to reprocess their data on their home machines, it is likely that some (perhaps many) ALMA projects will be sufficiently large that users would require access to a copy of the pipeline for reprocessing their datasets. More importantly, a replica of the pipeline is required for proper pipeline development – obviously one would not want to put untested pipeline modifications directly onto the main ALMA pipeline in Chile. The NA ARC budget includes $300k (US$2006) in 2011 and an additional $80k/year in subsequent years for such a facility.

6.1.4 Data Management Division Staffing Summary

The data management unit will have a team of 19: a division head and deputy; 10 programmers to maintain and improve software constructed by NA; and 7 software developers to provide software for new ALMA capabilities. It requires capital to install and maintain a developmental pipeline.

6.2 Technical Division

Similar to the case for software MR&D, the AOP includes contracts to each of the ALMA Executives for the maintenance and repair of the hardware they provide, and a contract for development of new hardware. As with software MR&D, we associate this cost (both FTEs and money) with the NAASC rather than Chilean Operations in the staffing and budget sections.

There will be a Division Head to lead this division, managing these tasks, keeping abreast of developments across the project, and prioritizing work in NA.
6.2.1 Hardware Maintenance and Repair

Some engineering tasks, particularly for Front End and Back End, require specialized staff and test equipment which is present in North America but which would be expensive to replicate and maintain in Chile. These tasks will be subcontracted to the executors. In NA, this contract work will be managed and largely carried out by the NRAO Technology Center (NTC), located about 1 mile from the NAASC. The following maintenance tasks are expected, along with the required staffing support:

- Cold cartridges: replacing SIS mixers, LNAs, frequency multipliers; reassembly and re-test (1.5 FTE for each of band 3 and band 6, or 3 FTE total);
- Warm cartridge LO assemblies: replacing warm multiplier assemblies with MMICs, PLL components, power amplifiers; reassembly and re-test (2.5 FTE);
- Board-level troubleshooting and repair of all types: power distribution, monitor & control, etc. (2 FTE);
- All parts of the photonic LO system (3 FTE);
- All parts of the digital data transmission system (1 FTE).

The staffing requirements were derived based on the Mean Time Between Failures (MTBF) for the warm and cold cartridges\(^8\) and on extensive NTC experience. The management of these tasks requires 0.5 FTE, for a total staffing requirement of 12 FTE.

M&S required to support fabrication and test facilities, buy foundry services and components, etc. is around $0.6M per year (US$2006). Thus, the total support level of $1.1M per year current planned for ALMA operations is about a factor of two too low. In the current budget, the overage is taken out of the Development budget, which in turn leaves very little for development materials. If the MR&D staffing levels are deemed realistic, then this issue must be addressed as the AOP is reviewed.

6.2.2 Hardware Development

This task is estimated to be comparable to that of developing and building a cold cartridge and the Front End part of its local oscillator. There should be the equivalent level of effort for an indefinite period as technology improvements are made—sometimes analog work, sometimes digital work. The R&D staff required to support this effort is estimated based on the level of staff now employed by the ALMA construction project for Band 6 (WBS 1.04.165) and all the local oscillators (WBS 1.04.250-258):

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\(^8\) The MTBF estimate is 3.5 failures per year per band for each cold cartridge, and 16.6 failures per year for the warm cartridge assemblies, based on an initial outfitting of six receiver bands.
• Top level engineering: 1 FTE
• Support engineering: 2 FTE
• Software: 1 FTE
• Fabrication technicians: 3 FTE
• Test technicians: 3 FTE

In addition, the development staff will employ ~2 co-op students each year, providing young engineers the opportunity to get hands-on experience with mm/submm engineering tasks. These students are not expected to contribute any net FTEs of support, so the total staffing level for technical development is 10 FTE. The Head of the Technical Division will manage this task.

The M&S budget for this development is task-dependent; in the Band 6 example, the amount needed is about $3.7M (US$2006) per year for a period of about 6 years. After paying for the total hardware and software MR&D staffing support, the contracts budget only leaves $2.5M per year for M&S; as mentioned above, this needs to be addressed in the next version of the AOP.

### 6.2.3 Technical Division Staffing Summary

The total staffing required for these activities, based on experience during construction and in the NRAO Technology Center, is 25 employees: a Head, 12 FTE M&R, 10 FTE development, and two co-op students. The staffing ramp-up has been set by the need to capture qualified personnel as they move off of the construction project. The construction staff will clearly be the most qualified to work with the ALMA hardware in operations. It is envisioned that the skill set for construction will be perfectly matched to that needed in operations, and we need to be able to retain the best engineers and technicians as they are released from the construction project.

### 7 Beyond ARC Functions

The AOP recognizes that it is highly desirable for the regional centers to provide services and programs beyond the basic tasks provided by the ARCs. These activities expand the scope of the ARC to include activities performed at the NAASC for the benefit of the U.S. astronomical community in order to fully leverage the transformational nature of the ALMA observatory. ALMA will appeal to a much broader range of astronomer than traditional radio observatories, and these investigators expect more complete services and activities from a science center, such as advanced user support, educational programs, summer schools, workshops, constantly improving end-user products, a User Grants program, etc. It is these additional activities that make the NAASC a true Science Center.
These “beyond ARC” activities are denoted by green boxes in Figure 4-2 and described in this section.

Since these activities are beyond those described in the AOP/AOB, they are not subject to approval by the ALMA Board. Further, we anticipate that since these functions are to be funded in total by NSF, they will be entirely for the benefit of the U.S. community.

7.1 NAASC Director

The NAASC will have a director who is responsible for all of the science center activities, including the NA ARC, the Science Development Division, EPO, and Chilean Affairs. They will interact with the rest of NRAO and plan NA ALMA activities in the larger context of NRAO. The NAASC director will interact with NSF and other science centers and observatories, to help chart the evolution of the NAASC. The director will be a research astronomer, to be hired in mid-2006. Originally they will report to the NA ALMA Project Manager, but at the end of the construction phase these two positions could be merged.

7.2 Science Development Division

The Science Development Division encompasses most of the value-added activities provided by the NAASC in addition to the core ARC activities described in the AOP. These include:

- User data analysis grants program;
- Advanced User Support;
- Professional Development (student programs, schools and workshops);
- Maintain ALMA presence at meetings;
- Maintain a full-service NAASC web site;
- ALMA Fellows Program;
- ALMA EPO

The head of the Science Development division will manage the division and interact with the other divisions, particularly with the ARC Science Division. This person would interface most directly with the U.S. user community, assessing their desires and priorities for services performed at the NAASC and promoting the full use of ALMA, especially outside the traditional radio and millimeter community. This position will be filled by a staff astronomer, and will be in place for the first Call for Proposals in 2009.

7.2.1 User Grants Program
The User Grants Program is a program to support ALMA data analysis and publication by the U.S. user community, analogous to the NASA programs for HST, Spitzer, and Chandra. The requirements for such a program are not yet fully determined. The ALMA North American Science Advisory Committee (ANASAC) plans to conduct a survey of the community to advise NRAO in defining the necessary scope and guidelines for the program. We do know that such programs are critically important to NASA missions, and were strongly endorsed by the last Decadal Report for Astronomy and Astrophysics for new NSF funded facilities. We regard this program as essential to the success of ALMA in the U.S., noting that such support to European users is automatic by virtue of their funding mechanisms. The Observatory’s sole goal is to see that U.S. ALMA users have the support they need to achieve their scientific goals; NSF could run the User Grants Program directly. This program requires an administrative aid to support it.

Several independent elements arrive at the same rough estimate, assumed here, for program requirements: $10 million annually when ALMA is in full operation. This would provide ~$50,000 to each of ~200 programs of average size, ~12 hours of observing each. In reality, the individual programs would vary in size, need for funding, and amount of funding allocated. This estimate will be refined. The estimate presented here is based on previous discussions of the ANASAC, an independently derived estimate by the NRAO, and comparisons with comparable NASA missions, for example, the Spitzer Space Telescope.

The NAASC budget provides for the grant program to start along with Early Science operations in 2010, and fully ramp up by the beginning of full operations in 2012.

### 7.2.2 Advanced User Support

The Advanced User Support staff will provide many functions to enable NA ALMA users to fully explore and exploit the telescopes capabilities. These include: organizing observing and data reduction workshops; providing full post-observation user support (e.g. personal help with off-line data reduction; re-processing of large and/or complex datasets, help with non-standard data reduction); providing improved cookbooks, data analysis documents, and reduction tools; supporting special projects (e.g. public surveys and large programs); developing new approaches/algorithms for calibration and imaging, advanced simulation development to help users better plan their observations, develop improved pipeline heuristics, and improved observing techniques. A very modest staff of 2 astronomers and 4 programmers is required to support these activities.

This division is staffed already in 2006, with four developers working on off-line data processing system, providing a more friendly user command-line interface using python, and developing higher-order tasking functions (combining flagging, calibration, self-
calibration, and imaging). They are also working on critical tasks such as mosaicing, combining single-dish and interferometer data; phase calibration transfer and other ALMA-specific tasks. These developers will also help develop user-friendly documentation for the initial users of ALMA, as described in the Proposal Functions subsection (Section 5.3). These positions will continue throughout the project, performing the tasks described above. Two astronomers join the division in 2010, to provide additional user “handholding” and project support at the beginning of early science operations.

7.2.3 Professional Development

The Professional Development program requires two astronomers (1 FTE) to oversee the ALMA Fellows, Postdocs and student programs, plan and organize scientific workshops, conduct summer schools, schedule talks, and maintain an ALMA presence at scientific meetings. We have already started holding science workshops at the NAASC (“From z-Machines to ALMA: (sub)millimeter Spectroscopy of Galaxies”, January 13-14 2006), and we anticipate holding at least one per year from now on. The existing NA ARC staff currently supports this effort, but we anticipate the need for an astronomer to take over these duties as we near the call for proposals, so the first astronomer will be added in 2008. We anticipate holding the first schools after the first ALMA data are processed, so in around the summer of 2010, which is when we add the second astronomer.

7.2.4 ALMA Postdocs, Fellows and students

The ALMA Fellows Program is similar to the Jansky Fellows Program for the rest of the NRAO, the Hubble Fellows Program of the Space Telescope Science Institute, and similar programs at other world-class observatories. There will be 2 Fellows per year for three-year appointments starting with the ALMA Early Science phase (2010). In addition, there is an ALMA Postdoc program to help train future mm/submm astronomers. There will be 2 ALMA postdocs per year for three-year appointments starting in 2007. They will take part in all ARC and beyond ARC activities and accompany ARC staff to Chile, being fully exposed to the Observatory end-to-end operations. These positions are primarily for the education and/or training of the participants, which itself requires effort by the mentoring astronomer, so in the end we assume no net FTE contribution from these positions. While we hope this is not actually case, it is clear that the NAASC should not depend critically on their contribution in order to meet our obligations to the observatory of the community.
We also include support for two pre-doctoral students starting in 2011, to be stationed at the NAASC to take advantage of the collective expertise of this staff as they work towards their doctoral degrees.

### 7.3 Education and Public Outreach

As an international project of extraordinary scope and promise, ALMA is an opportunity to implement a vigorous education and public outreach program that delivers the scientific excitement and technological excellence of the Project to the entire astronomical community; to the world-wide general public; to students and teachers of all ages; and to the international media.

The ALMA EPO mission segments relevant to NAASC operations and staffing are: (a) international ALMA EPO, (b) Chilean ALMA EPO, and (c) NRAO ALMA EPO. Each of these is defined and described in the following paragraphs.

#### 7.3.1 International ALMA EPO

The international ALMA EPO program is jointly designed and funded by the Project’s major partners: the Joint ALMA Office (JAO), the National Radio Astronomy Observatory (NRAO), the European Southern Observatory (ESO), the National Observatory of Japan (NAOJ), and the Republic of Chile (RoC). It is managed by an Executive-neutral ALMA EPO Working Group that convenes at an annual face-to-face meeting to determine and fund a program of appropriate scope and resources. This Working Group also meets quarterly via video-conference to assess the progress and financial status of the annual International ALMA EPO Program Plan and make adjustments, as required.

The majority of the resources, including personnel, responsible for executing the International ALMA EPO Program Plan reside within the participating institutions: the NRAO, ESO, NAOJ, JAO, and the RoC. An Executive-neutral EPO Coordinator based in Chile, is required to coordinate the program on a day-to-day basis. This position is supervised by the ALMA International EPO Working Group. This EPO Coordinator’s office functions as the primary receiver and distributor for all ALMA EPO business. It acts as a clearing-house for ALMA scientific imagery, drawing upon the EPO and scientific staff of each of the executive for new materials. In this way there will be one place with the “latest and greatest” demonstration of ALMA’s unique capabilities, which will in turn provide a valuable resource to the executives for their own regional ALMA EPO efforts.
The International ALMA EPO program targets an international audience. Thus, this program includes the preparation of ALMA Project exhibits and ancillary materials (brochures, presentations, DVDs, etc.) for use and distribution at meetings of the international astronomical community, such as the International Astronomical Union (IAU) General Assembly. The international ALMA EPO program also provides similar resources for special ALMA scientific and technical sessions, VIP events, and press conferences at such international meetings. Outreach at ALMA scientific meetings targeting the international professional astronomical community is also included in this effort, e.g., “Science with ALMA: a New Era for Astrophysics”, a symposium being held in Spain in November 2006.

The following elements may be included in the International ALMA EPO program, in approximate priority order:

- An international ALMA web site;
- International press release coordination and distribution;
- Special event coordination;
- A virtual tour (on-line and DVD-based) of the ALMA facilities;
- ALMA site web cams;
- An international EPO postdoctoral program;
- A Hubble Heritage-like program for disseminating high-quality imagery;
- An international Research Experiences for Teachers (RET) program;
- An international Teacher Exchange program;
- An international summer student program;
- Traveling and electronic exhibits for science museums and planetariums;
- Periodic ALMA observing / research opportunities for amateur astronomers;
- Student internships in science journalism.

The international EPO effort will begin in 2006 with the convening of ALMA EPO Working Group and the hiring of an Chile-based EPO coordinator, and with contributions to the 2006 International Astronomical Union General Assembly and the November 2006 ALMA Science meeting in Madrid, Spain. The Working Group will determine the phasing and relative priority of the other efforts mentioned above, with costs share equally between the executives. The NAASC WBS includes a budget for the NSF’s share of these efforts, but since the supported personnel would be part of the JAO, the equivalent FTEs are not included in the NAASC staffing plan. An initial budget of $35K is required, increasing to $145K per year by FY 2013.
7.3.2 Chilean ALMA EPO

Since ALMA is built, operated, and maintained in Chile, an effective and significant EPO program within Chile is vital to ALMA’s long-term success and future international science projects. ALMA must be known and valued by the Chilean people, including teachers, students, media, and the government. The Chilean ALMA EPO program is also designed to increase the quantity and quality of the resources available to Chile’s professional astronomical community, thus benefiting the scientific exploitation of ALMA. An Executive-neutral program of Spanish-language ALMA education and outreach that is considerate of and responsive to the needs, interests, and culture of the Chilean people is an ALMA EPO priority.

This Chilean ALMA EPO program is coordinated and managed by the Executive-neutral EPO Coordinator office based in Chile (described in Section 7.3.1 above) with input and assistance from the International ALMA EPO Working Group.

The following program elements may be included in the Chilean ALMA EPO program:

- A Chilean ALMA web site;
- Press release coordination, translation, and distribution in Chile;
- Priority participation for Chilean teachers in the international RET and the Teacher Exchange programs;
- Traveling and electronic exhibits for Chilean science museums and planetariums
- An ALMA – Chile speaker’s bureau;
- An astronomer visitation / exchange program to foster research and professional development;
- An engineering visitation / exchange program to foster technology exchange and professional development;
- A science center at San Pedro and in Santiago;
- A grants program to facilitate collaboration with Chilean scientists and engineers.

This Chilean ALMA EPO program begins with the convening of ALMA EPO Working Group and the hiring of a Chile-based EPO coordinator, who determines the phasing and relative priority of tasks within this program. Costs are to be shared in a TBD manner between the executives and the Chilean CONICyT. An initial budget of $30K is required, increasing to $400K per year by FY 2013.
7.3.3 **NRAO ALMA EPO**

NRAO ALMA EPO is managed and conducted by the Observatory’s EPO Division for a North American target audience. These EPO activities are funded by the ALMA Operations budget, and are coordinated between the NRAO EPO and NAASC division heads. An overview of the proposed NRAO ALMA EPO plan follows.

**Astronomical Community**
- Design and staff ALMA exhibits at AAS meetings, ALMA science meetings in North America, and NAASC workshops;
- Assist NAASC with the organization, logistics, and staffing for Town Meetings, Special Sessions, NAASC workshops, international meetings, and the production of ancillary materials.

**World Wide Web**
- Create and manage ALMA EPO web content, including press releases, education materials, images and illustrations, animations, video, podcasts, presentations and slides, web cams.

**Education**
- Produce and distribute ALMA-related education products, including astronomy lecture web casts, and classroom-ready activities;
- Seek grant funding for and manage a Research Experiences for Teachers program and a Teacher Exchange program.

**News / Media**
- Write and distribute press releases;
- Organize special events, such as press conference and press receptions;
- Design, produce, and distribute ALMA media kits.

**Publications**
- Generate and annually update Observatory-wide brochures for the general public and the professional astronomical community;
- Distribute simulated and real ALMA images via an on-line Image Gallery, annual calendar, poster series, and periodic image DVD releases.

**Science Centers**
- Design and produce ALMA exhibits for the Green Bank Science Center, the VLA Visitor Center, and the NAASC;
- Incorporate ALMA into science center tour programs.
Science Museum Outreach

- Distribute ALMA press releases via ViewSpace “Radio Astronomy Update”;
- Produce and distribute (one per year) & annually update ViewSpace programs: (1) mm / sub-mm radio astronomy, (2) ALMA technology and engineering, (3) ALMA image tour, and (4) ALMA science discoveries.

Community Relations

- Provide for ALMA participation in an NRAO speakers’ bureau;
- Feature ALMA in community Open House events.

A budget of $25K is required for these efforts in FY 2006, $130K and 2 FTE in each of FY 2007 and 2008, increasing to 5 FTE and $315K per year by FY 2013.

7.4 Office of Chilean Affairs

AUI/NRAO requires the presence of a small office in Santiago, Chile, to handle its legal and business affairs, including representation of ALMA to the Republic of Chile for AUI, as well as support for the Joint ALMA Observatory operations staff. This support consists of implementing actions initiated by the JAO, such as, purchase orders, imports, pay orders, etc. This office already exists as part of ALMA construction, where it will remain until the completion of construction. It includes seven staff members: a scientist, business manager, secretary, and a staff of four in the fiscal/procurement office. Full details of this office are given in Appendix B.

8 WBS and Staffing Plan

Figure 8-1 presents the Work Breakdown Structure (WBS) for the North American ALMA Operations: the NAASC (WBS unit 71000; including the NA ARC 71100), the North American share of Chilean Operations (WBS unit 72000), the Contract work from the JAO for hardware and software MR&D (73000), the User Grants Program (74000), and Business & Facilities (75000). The later pays for facility costs for the NAASC, such as the building lease, AUI management fee, computer support, program and business office and HR services, and library access. It is calculated based on the number of staff in each division and the footprint of the NAASC offices.
Figure 8-1: Work Breakdown Structure (WBS) for the North American ALMA Operations, including North American share of Chilean Operations (72000), the NAASC (71000) and the NA ARC (71100).

The following tables present the NAASC staffing ramp up from 2006-2013, both in terms of the total number of employees (Table 8-1) and the number of FTEs (Table 8-2). The staffing levels have been justified in each subsection above. They are presented using the organization of Figure 4-2. The equivalent WBS units for each divisional unit are listed in the leftmost column. Subtotals of each of the major subdivisions making up the NAASC are given, and the staffing ramp-up is plotted for these subdivisions in Figure 8-2 (number of employees) and Figure 8-3 (number of FTEs).
Table 8-1  NAASC Staffing plan counting number of employees

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<tr>
<th>WBS Unit</th>
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### Table 8-2 NAASC Staffing plan in FTEs.

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Figure 8-2 NAASC staffing ramp-up in number of employees (cf. Table 8-1).

Figure 8-3 NAASC staffing ramp-up in FTEs (cf. Table 8-2).
The final NAASC includes a staff of 99 (74.85 FTE). This includes a staff of 18 (13.25 FTE) for NA ARC operations, 44 (42 FTE) in the ARC supported by grants from Chilean Operations for hardware and software maintenance, repair and development, and a staff of 29 (11.6 FTE) in the “Beyond ARC”, including 10 astronomers or scientific programmers for advanced community and user support, 14 postdocs and students, and 5 in EPO. Additionally, there is a staff of 7 in Chilean Affairs and an administrator for the User Grants program.

Overall in the NAASC there will be 15 astronomers, 28 computing staff, 23 engineering staff, 5 EPO staff, 6 resident postdoctoral fellows, 4 students (two co-ops and two pre-docs), 2 data analysts, 2 administrative assistants, and 1 manager. Also included in the staffing plan but not resident at the NAASC are 7 employees in the office of Chilean Affairs (based in Santiago) and 6 ALMA Fellows (based at U.S. universities).

The staffing plan was determined by the definition of the tasks to be performed by each unit, by past NRAO and ESO experience, by established industry principles, and by a desire to keep the total operating costs down. It represents the effort that we think we can do the job with, not the effort we would like to do the job with. Specifically, it is our opinion that the staffing level cannot be reduced without also reducing the tasks performed by or products produced by the NAASC. The vision for the ALMA observatory is that it will be the first ground based radio or mm/submm observatory to deliver fully reduced images, data cubes, and other products to users. The staffing level presented here is meant to provide for this capability. Conversely, any reduction in this level of support will jeopardize this unique vision of ALMA, and will put the NA user community at a disadvantage compared to our European counterparts.

As a sanity-check on our numbers, we compare the total level of support, in terms of FTEs, between the Space Telescope Science Institute (STScI), Spitzer Science Center (SSC), and NAASC. While direct comparisons with other science centers are complex, as each defines and organizes the tasks differently, we have grouped organizational elements which overall provide the same types of tasks or support. This comparison is presented in tabular form in Appendix A. Overall, the proposed staffing level of the NAASC is very modest. Anticipating that the NA share of ALMA programs will be of order 200 projects per year, or ~70% of the number of programs executed by Spitzer per year, then the NAASC staffing level should be ~70% that of the Spitzer Science Center, which is approximately the case (111 x 0.70 = 78 ~ 74.85).
9 Budget

These numbers do not reflect the new WBS structure. The total will stay approximately the same, but the distribution within the individual subdivisions will change. I hope to have new numbers to you, all progressed to US$2006, by April 11, and will present them at the review. –JEH

Table 9-1 presents the estimated total annual cost to the NSF for the North American share of ALMA operations in Chile and the NAASC. Two potential results of the re-baselining of the project are anticipated here: that spares and start-up equipment will be returned to the construction budget; these costs are not included here; and that the project will have a one-year delay. That is, the years 2006-13 are the years 2005-12 of the (unrevised) AOP delayed by one year, but with spares and start-up equipment deleted. All figures are in thousands of Y2003 US dollars. The difference between the fiscal year of the NRAO (for example, FY2005 starts on October 1 of 2004, etc.) and the fiscal year of ALMA, which is the calendar year, is ignored here. The cost to NSF is net of the contribution from Canada to the North American share of the AOP, assumed to be 7.25%.

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<td>JAO Development</td>
<td></td>
<td>186</td>
<td>232</td>
<td>278</td>
<td>1,531</td>
<td>3,063</td>
<td>4,640</td>
<td>4,640</td>
<td></td>
</tr>
<tr>
<td>NA ARC</td>
<td>447</td>
<td>513</td>
<td>989</td>
<td>2,146</td>
<td>2,799</td>
<td>3,213</td>
<td>3,302</td>
<td>3,624</td>
<td></td>
</tr>
<tr>
<td>Beyond ARC</td>
<td>768</td>
<td>982</td>
<td>1,514</td>
<td>2,044</td>
<td>2,575</td>
<td>2,773</td>
<td>3,008</td>
<td>3,297</td>
<td></td>
</tr>
<tr>
<td>User Grants</td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td>3,000</td>
<td>6,000</td>
<td>10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chile Office</td>
<td></td>
<td>50</td>
<td>212</td>
<td>374</td>
<td>535</td>
<td>697</td>
<td>741</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total NSF</td>
<td>1,863</td>
<td>4,990</td>
<td>10,582</td>
<td>15,949</td>
<td>21,544</td>
<td>27,003</td>
<td>32,605</td>
<td>37,260</td>
<td></td>
</tr>
</tbody>
</table>

Table 9-1. Cost to NSF for the U.S. share of the NAASC, in thousands of US$2003.

The entries in Table 9-1 are NSF's share of the following:

- JAO Ops: NSF's share of the budget line in the table on page 9 of the AOB, entitled "Chile" (i.e., Chilean staff and running costs), minus the amount of contracts (see JAO contracts below). This is the sent to the JAO for Chilean operations.
- Contingency: from the table on page 9 of the AOB.
• JAO Contracts: Contracts for hardware and software maintenance and repair. From AOB Table 3.4, those items under "Chilean Running Costs" noted as "Off-shore" (e.g., Remote Repair Support; Software Maintenance). This money is used to fund the hardware and software M&R efforts, as described in the text.

• JAO Development: Contracts for hardware and software development. From AOB table, pg.9, but an earlier ramp-up in order to support developmental work on SIS junctions at the University of Virginia Electronic Engineering department in 2007-2009.

• NA ARC: NRAO evaluation of the cost required to perform the ARC functions, not including the contracts for MR&D. From the “ARC” category of the NAASC WBS, v2.5-2012corr minus the amount of the contracts and including only NSF’s share.

• Beyond ARC: The cost of NAASC activities in addition to ARC functions. From the "SCIDEV" category of NAASC WBS v.2.5-2012corr, minus the User Grants program.

• Proposed User Grants program to support U.S. investigators use of ALMA.

• Chile Office: NAASC office of Chilean Affairs.

Software & Hardware Maintenance, Repair and Development (MR&D) are supported via $7M in contracts from ALMA Chilean Operations back to each ARC. $2.7M is used for new hardware, and the remaining $4.3M is used to support the required FTEs (42) for this effort.

Figure 9-1 Cost to NSF for NA share of ALMA Operations, based on Table 9-1.
Figure 9-2 Total cost to NSF of ALMA Operations in 2013, including Chilean operations, the NA ARC and NAASC.

Budget estimate for Chile operations was constructed bottom-up by international team with experience in operating large facilities – NRAO & ESO; Detailed Work Breakdown Structure is basis for budget estimate contained in ALMA Operations Plan (version J1), approved by the ALMA Board; the AOB Budget estimate compares well with earlier (2000), independent budget estimate prepared for ESO Council and NSF; NAASC operations plan is consistent with ALMA Board plan for Chile operations and the ALMA regional centers. Budget estimate based on a detailed Work Breakdown Structure that is based on NRAO experience in running radio arrays plus insights from a study of the Spitzer and Hubble science centers.

Appendix A – Science Center Staffing Comparison

This appendix presents a comparison based on the staffing levels of three prominent science centers: The Space Telescope Science Center (STScI) based in Baltimore, MD; the Spitzer Science Center (SSC) based in Pasadena, CA; and the Chandra X-ray Center (CXC), based in Cambridge, MA. This comparison was done in May 2005 based on Organizational charts available either from the science centers themselves (SSC, STScI) or from publicly available on-line presentations (CXC). The organizational charts available to us were generally based on staging levels circa 2000.
Table A-2 Science center staffing comparison

<table>
<thead>
<tr>
<th>HST Task</th>
<th>FTE</th>
<th>Chandra Task</th>
<th>FTE</th>
<th>Spitzer Task</th>
<th>FTE</th>
<th>NAASC Equivalent</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff Management (Director, Deputy Dir., Manager, Dep. Manager, Administrators)</td>
<td>14</td>
<td>2.1-4 Program Management (10.7-5.6 for procurement, facilities-5.1); 9.0 Grants Program (1.9)</td>
<td>~7</td>
<td>Staff Management (Director, Deputy Dir., Manager, Dep. Manager, System Scientist, Operations Scientist, Systems Engineer, Administration)</td>
<td>11.5</td>
<td>NAASC &amp; NA ARC Head office (2.25); Heads of DM, Technical, Science, Science Development Divisions (4); Users Grants Administrator (1)</td>
<td>7.25</td>
</tr>
<tr>
<td>Phase I/II Support (except documentation)</td>
<td>22</td>
<td>4.5 User Support (7.9)</td>
<td>7.9</td>
<td>Observation Planning &amp; Scheduling</td>
<td>5.5</td>
<td>Proposal Functions</td>
<td>4</td>
</tr>
<tr>
<td>Archive Operations</td>
<td>11</td>
<td>5.4 Archive Ops (6)</td>
<td>6</td>
<td>Science Data Management &amp; Database Administration</td>
<td>4.5</td>
<td>Archive Operations</td>
<td>5</td>
</tr>
<tr>
<td>Pipeline data reduction, Calibration, QA (47)</td>
<td>165.4</td>
<td>4.1 Devel. Ops &amp; Sci.Support (83); 4.3 Miss. Plan’g (8); 4.4 SciData Sys. (11); 5.1 Data Sys E&amp;I (3); 5.2 Hardware (8); 5.3 Software (22.3); 6.2 CXC Supprt (7)</td>
<td>67.6</td>
<td>Observer Support (14); Data Quality Analysis &amp; Pipeline Operations (7); Instrument Teams (32): IRS (10.5), IRAC (8.5), MIPS (13)</td>
<td>53</td>
<td>Science Support (2); Software M&amp;R (10); Software Development (7); Hardware M&amp;R (10); Advanced User Support (5); Professional Development (1)</td>
<td>35</td>
</tr>
<tr>
<td>EPO/Public Affairs</td>
<td>30</td>
<td>2.5 Outreach</td>
<td>14</td>
<td>EPO (3) &amp; Public Affairs (3) &amp; Media Relations, (3)</td>
<td>9</td>
<td>EPO</td>
<td>4.6</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>302.4</td>
<td>111.5</td>
<td>90.5</td>
<td>55.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacecraft Communication</td>
<td>?</td>
<td>7.0 Operations (66.7); 3.0 Sys. Eng. (3.5); 4.2 Calibration (15);</td>
<td>85.2</td>
<td>Uplink/Archive (4.5); Downlink (9.5); Integration &amp; Test (5.5)</td>
<td>19.5</td>
<td>(these equivalents happen in Chile)</td>
<td>0</td>
</tr>
<tr>
<td>NA</td>
<td>0</td>
<td>NA</td>
<td>0</td>
<td>NA</td>
<td>0</td>
<td>Hardware Development</td>
<td>9</td>
</tr>
<tr>
<td>Business, Systems Admin.</td>
<td>~120</td>
<td>Remainder of 2.0 Program Management (10.7-5.1-5.6); 5.5 Data Sys Ops (9)</td>
<td>14.6</td>
<td>Financial Staff (1); ISG Liaison/IPAC Shared Services (7)</td>
<td>8</td>
<td>Facilities and Management fee</td>
<td></td>
</tr>
<tr>
<td>Hubble Fellows (30)</td>
<td>0</td>
<td>8.0 Chandra Fellows (15)</td>
<td>0</td>
<td>Spitzer Fellows (15)</td>
<td>0</td>
<td>ALMA Fellows (6); Postdocs (6) &amp; Predocs (2)</td>
<td>0</td>
</tr>
<tr>
<td>NA</td>
<td>0</td>
<td>NA</td>
<td>0</td>
<td>NA</td>
<td>0</td>
<td>Chilean Affairs</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>~500</td>
<td>202.3</td>
<td>111</td>
<td>71.85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B – AUI/NRAO Chile Office

AUI/NRAO CHILE OFFICE:
ACTIVITIES AND RESPONSIBILITIES

1. Background

Neither ALMA nor the JAO exist in Chile (or elsewhere) as legal, independent organizations, nor do they legally own goods or property. The JAO provides the overall leadership and management to the Project, but ALMA activities in Chile, including its business interfaces for procurement, fiscal procedures, payroll, property management, are under the independent legal responsibility of the Executives of the Bilateral Agreement. What follows should be read bearing in mind that in Chile AUI/NRAO is liable to the Chilean Government for the NA component of ALMA.

AUI/NRAO negotiated and obtained full legal status in Chile under Law 15172, a status analogous to that of the other Executive, ESO. These negotiations and the resulting semi-diplomatic legal status enjoyed by AUI/NRAO in Chile have led to a number of legal commitments and responsibilities assumed by AUI/NRAO (some of them shared with ESO), which cannot be discharged by any other structure within ALMA in Chile. These are briefly described below:

   a. Land ownership and access, including property of the OSF land, and payment and monitoring of Concession rights for the AOS and its accesses.

   b. Environmental, including the monitoring of the EIS responsibilities.

   c. RFI Protection for the Site. The ALMA Quiet and Coordination Zone (the second such in the world) was granted to the individual Executives.

   d. Cooperative agreement with the U. of Chile. This agreement is the legal venue to have access to the benefits of Law15172 that grants AUI/NRAO virtual parity with ESO within Chile.

   e. Payment and selection process for the Fund for the support of Radio Astronomy in Chile via agreement with CONICYT (the Chilean NSF).

   f. Payment and monitoring of Fund for the social development of Region II, in particular of San Pedro, via agreement with the Government of Region II.

   g. AUI/NRAO (and/or ESO) provides goods and services in Chile to NAOJ as part of ALMA.

   h. Responsibilities for accreditation, monitoring and support of the NA international (expatriates) staff in Chile.

   i. Interface and coordination with the JAO and the other Executives.
j. Is responsible for the NA EPO in Chile both for the NA component and (collegially) for ALMA.

k. Business in Chile in support of ALMA. This fundamental aspect, together with AUI/NRAO’s newly acquired exclusive responsibility for ALMA Local Chilean Labor, are developed more fully below.

2. Business in Chile

a. Responsibilities for financial activities of the Chilean operations, assigned to AUI/NRAO including budget preparation and control, accounting, purchasing, and business planning and management; ensures compliance with AUI/NRAO policies and procedures under AUI/NRAO-NSF Cooperative Agreement, as well as consistency with local regulations.

b. Development and implementation of systems, processes and policies to establish and maintain records for the Chilean operations.

c. Liaison with administrative and technical personnel in the ALMA Project, including the other Executives, for activities performed in Chile.

I. Fiscal

d. Coordination, design, and implementation of internal financial reporting systems, financial controls, and management information systems in coordination with the automated financial reporting systems of AUI/NRAO in the US.

e. Manages cash, cash-related receipts, accounts receivable, credit and collection functions and payroll, ensuring timely processing and preparation and compliance with audits.

f. Tracks and maintains the property records of the Chilean operations.

II. Contracts & Procurement

g. Prepares and approves Invitations for Bid and evaluates and negotiates contracts for the purchase of services.

III. Safety

h. Develops or assists with the development and implementation of policies and procedures consistent with those of the ALMA organizations to ensure
efficient and safe operation of the Chilean Office and of ALMA at large. Remains ultimately responsible on this matter to the Government of Chile.

IV. Human Resources

It has been recently agreed between ESO and NSF that AUI/NRAO shall be the employer of local staff recruited to work for ALMA in Chile. The day to day management of the local staff (eventually some 140 people) will be under an ALMA HR Manager (a local AUI/NRAO employee), outside of the Chile office and under the ALMA Director, with the concurrence of the NRAO HR Manager when required. However the ultimate legal responsibility for labor, and all it entails, rests in Chile within the Chile office which is represented to the Chilean Government.

3. Representation and Science

Under the provisions of the AUI/NRAO legal (semi-diplomatic) status in Chile an official representation is required. The role of representative and resident scientist are joined together as a result of the overlapping of many of these duties.

The Representative/scientist in Chile has overall responsibility for the Chile Office. And represents AUI/NRAO to all Chilean authorities and institutions involving matters such as, but not limited to:

- AUI's right to conduct ALMA construction and operations activities as authorized by Law 15172 and associated decrees and agreements.
- The accreditation of all AUI international staff assigned to Chile regardless of whether such staff is assigned to the JAO, the Executive, or ALMA staff.
- The monitoring of compliance with laws and regulations related to labor, environment, health, safety, radio frequency interference protection, building codes and similar issues.
- The oversight, in coordination with the cognizant NRAO managers, of AUI/NRAO's executive functions such as procurement/contracts, accounting, human resources, and the import/export issues.
- The execution of AUI's interests in "Radio Astronomy Limitada", the jointly owned AUI/ESO Company created to receive the ALMA land concession and report on its use to the Government.
- The interface with the ALMA Director who is the primary point of contact in Chile for all issues related to the construction and operation of the ALMA Project with the exception of those that pertain directly to the Executives themselves.
The interface and coordination with other international observatories in Chile, including those of ALMA partners.

- Represents NRAO/AUI with the various scientific organizations and universities in Chile.

- Interfaces with all Universities and in particular with the U. of Chile with which NRAO has signed a cooperative agreement leading to access to Law 15172. The present representative is an adjoint Professor at U. Chile and supervises graduate thesis there.

- Responsible for all outreach activities in Chile on behalf of NRAO/AUI. Gives lectures in Spanish at all levels, makes NRAO science accessible to the Public in general.

- Represents NRAO/AUI on the CONICYT-Agreement Selection Committee and interfaces in that area with NAASC to foster NA scientific interests.

- Maintains official contacts with the IInd Region and the Commune of San Pedro, and monitors relations with the community.

- Could serve as an interface between NRAO/AUI or other NA scientists assigned to ALMA duty in Chile and their home institution.

In executing these responsibilities, the Representative is the AUI/NRAO's local interface with the JAO and any existing or future ALMA executives. In performing such interface responsibilities, the Representative shall insure that the JAO and Executives are appropriately involved in, and consulted on, matters that affect ALMA-wide interests.

4. Present and future Chile Office personnel

The present number of FTEs has evolved over the years from 1 person (1998-2002), to 2 persons (2002-2003), to its present complement of seven as indicated on the Budget, reflecting the natural evolution of needs and responsibilities indicated above. We expect the level of activities to increase during the next year due to the start of antenna assembly, integration and verification activities, peaking around 2009 and then to decrease to the present levels at the end of the construction-operations transition phase, and during full operations.

E, H. April 2006