Atacama
Large
Millimeter
Array

ALMA Operations Plan

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Prepared By:		
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Change Record

Version	Date	Affected Section(s)	Change Request #	Reason/Initiation/Remarks
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A	2004-02-18	ALL	Draft G2	Release: G1 + Sec 8 - 14
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A	2004-06-13	ALL	Draft H1	Comments from NA/EUR Executives Comments from Mini-ALMA Week Preliminary report from ASAC (May 2004) Various other reviewers of Draft G3

A	2004-06-15	ALL	Draft H2	Various comments from Ops Working Group

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1 Executive Summary

This is the ALMA Operations Plan.

Fundamentally, this plan has been derived from the ALMA Project Plan, Version 1 (2003-Feb-10) – in particular, Chapter 6 – based on input from and discussion with the JAO ALMA Operations Working Group (OG). Whenever possible, however, proposed revisions to Version 1 have been taken into consideration.

As of this release, this plan is still a work-in-progress. Concepts and/or issues that need further development written in *italics*. Concepts and/or issues that have budgetary impact are marked as *boxed italics*.

This plan has not been reviewed or accepted by the JAO, ALMA Executives, or ALMA Board. Therefore, all information presented herein are subject to change.

2 Introduction

In this section, the fundamental goals of ALMA Operations are summarized. It is likely to be massaged heavily depending on Executive & Board-level discussions.

The prime goal of the ALMA operations teams is to facilitate the most efficient possible use of the Joint ALMA Observatory, consistent with operating safely at a high altitude (5000m) site and with as small as possible impact on the unique environment in and around the ALMA sites in northern Chile. To this end, operations modes will be developed and implemented that allow the antennas, instruments, and data flow to work together in a fully coordinated fashion and to adapt quickly to the prevailing atmospheric conditions. Operations shall be designed to minimize the global overhead for target selection, antenna pointing, target acquisition, instrument set-up, data acquisition & storage, and quick-look quality control.

ALMA operations include activities at the Array Operations Site (AOS) and Operations Support Facility (OSF) near San Pedro de Atacama, the Central Office (SCO) in Santiago de Chile, and the ALMA Regional Center (ARC) in each ALMA region. Additional technical support, particularly in the areas of software development & maintenance such as major module repair (e.g. receiver cartridges), is provided by the ALMA Executives.

To optimize the match between varying atmospheric conditions and science observations, the Joint ALMA Observatory will be operated almost exclusively in service observing mode, in which observatory staff execute observations based on pre-determined execution sequences provided remotely by the ALMA scientific and technical user community. Observations will be executed via a dynamic scheduling process designed to ensure a high degree of completion for the highest ranked science proposals as well as to maximize the overall scientific return. To this end, the goal will be to execute the observation with highest scientific rank that matches the current atmospheric conditions and array configuration. All other things being equal, programs closer to completion shall be given priority. Observing time shall be allocated in hours and shall be over-subscribed to ensure a continuous supply of observations to execute.

Observation preparation will follow a Phase 1/Phase 2 process. During Phase 1, observation proposals will be created using software tools provided by the Joint ALMA Observatory and submitted for scientific & technical review. Approved Phase 1 proposals will be admitted to Phase 2 where all observations will be specified as Scheduling Blocks (SBs) using software tools provided by the Joint ALMA Observatory.

ALMA operations shall ensure that appropriate calibration data are acquired for all ALMA science data. A calibration plan shall be implemented. The calibration plan shall provide information about the nature of calibration data, frequency of calibration acquisition, accuracy goals of calibration, and application of calibration data for processing science data. As necessary, users will be encouraged or required to specify science program specific calibration observations. The Joint ALMA Observatory shall implement a data quality assurance process to ensure that observations are performed under the user-specified atmospheric conditions and system configuration, that system performance fell within published expected range during the observations, and that the calibrations meet the published accuracy requirements.

By the time the Full Science Operations stage is reached, the fundamental data product of the Joint ALMA Observatory shall be calibrated, deconvolved images. In addition, astronomers shall receive the appropriate calibration data necessary to re-process the data. Raw data shall be made available to astronomers through the ALMA archive. An on-line data pipeline processing system shall be implemented to process science & calibration data, to support the Joint ALMA Observatory quality assurance program, and to produce the final images. The Joint ALMA Observatory shall provide the off-line software necessary to re-process ALMA data, if this is needed for particular datasets.

The backbone of ALMA operations will be the ALMA archive, a distributed system with nodes at the OSF, SCO, and ARCs. The OSF/SCO nodes will be tightly bound by a high-bandwidth Internet link and specified to handle an average data rate of 6 Mbytes/sec with sustained periods with data rates of 60 Mbytes/sec. If high data rates are maintained for days, creating a large data transfer backlog, it will be possible to transfer data via digital media (e.g. hard disks). The ARC nodes will contain complete copies of the OSF/SCO nodes but synchronization will not occur in real-time.

ALMA observations shall be systematically archived along with calibration data, processed images, and those engineering and environmental data required for subsequent engineering & scientific analysis. Such data will be distributed to the Principal Investigators promptly. All archive data shall be accessible to the world-wide community after the expiration of a proprietary period of 12 months [TBC] from the delivery to the PI. The Joint ALMA Observatory Director may grant extensions to this period upon justified request.

In summary, the Joint ALMA Observatory must provide:

- Effective preventive & corrective maintenance
- System performance monitoring and trending for timely detection of problems
- Astronomer friendly interfaces, tools, and documentation for observation planning and execution
- Reproducible and quantitative ALMA data products
- Standard calibrations for standard modes
- Data processing tools to assess quickly data quality and extract accurate, quantitative results
- A science archive that allows data trend analysis as well as data re-use

To achieve these demanding goals, the Joint ALMA Observatory must implement the following processes:

- Phase 1 proposal generation: Call for Proposals; proposal submission, review, & scheduling; user support & notification
- Phase 2 program generation: user support, Schedule Block creation, submission, & validation
- Observation execution: system calibration, site conditions monitoring, quick-look quality assurance, dynamic scheduling, SB execution

- Maintenance: preventive & corrective maintenance, performance trending, fault correction, array re-configuration
- Archive & pipeline operations: archive~~creation &~~ maintenance (science & engineering data), detailed quality assurance, data product generation & delivery
- Science Research Archive: Web-based, Virtual Observatory compliant interface to public data, project-independent search and retrieve tools

2.1 High-level Assumptions

This operations plan was developed under the following assumptions:

- Level-1 Requirements shall be derived from the Board-approved Project Plan (Version 1, 2003-02-10).
- Japan will join the Project, adding the ALMA Compact Array (ACA) with seven (7) receiver bands as well as three (3) more receiver bands on the main array, resulting in a total of seven (7) receiver bands on 80 antennas.
- Routine preventive & corrective maintenance activities (including repair of some modules) will occur in Chile. However, specialized maintenance will occur at repair facilities maintained by the Executives.
- Minimal development will occur in Chile.
- This plan, and thus the associated resource requirements, will evolve with time as experience is gained with the real system.

2.2 ALMA Operations Group

This plan was created by the Operations Group, which was appointed by the Joint ALMA Office. This group was first formed in May 2003 and led by Stéphane Guilloteau and Dick Sramek. In August 2003, Darrel Emerson became the group leader. Group members as of ~~February~~June 2004 were:

Name	Organization	IPT
Darrel Emerson	NRAO	
David Silva	ESO	
~~Tetsuo Hasegawa~~	~~NAOJ~~	~~ACA~~

Clint Janes	NRAO	Back-end
Ryohei Kawabe	NAOJ	ACA
Max Kraus	ESO	Antenna
Robert Lucas	IRAM	Computing (SSR)
Jeff Mangum	NRAO	Antenna Evaluation Group
~~Sachiko Okumura~~	~~NAOJ~~	~~ACA~~
Koh-Ichiro Morita	NAOJ	ACA
Simon Radford	NRAO	Site
Joseph Schwarz	ESO	Computing
Richard Simon	NRAO	JAO
Dick Sramek	NRAO	System Engineering
Gie-Han Tan	ESO	Front-end
John Webber	NRAO	Correlator
Al Wootten	NRAO	Science

2.3 ALMA Board Approved Reference Documents

The following documents have been approved and released by the ALMA Board. In the event of conflict between the current document and a Board-level document, the latter always has precedence.

Reference	Document Number	Date	Title
BD01	XXX	XX	Bi-lateral Agreement
BD02	ALMA-90-00.00.00-01-B-SPE	2004-Jan-13	ALMA Scientific Requirements Specifications and Requirements
BD03		2003-02-10	Project Plan

~~2.4~~

2.4 Other Reference Documents

The following documents are referenced in this document. In the event of an inconsistency between the current document and one of these reference documents, the current document has precedence.[1]

Reference	Document Number	Issue	Date	Title
RD01			2000-05-30	ALMA in Chile: A Plan for Operations and Site Construction (M.A. Gordon)
RD02			2001-02-07	Post-Construction Operations, Project Book, Chap. 18 (Gordon, Brown)
RD03			2001-03-30	ESO ALMA Phase 2 Proposal, Vol 6, Operations Proposal
RD04			2001-05-04	ALMA Memo 367: ALMA Operations Model, the SSR Committee View
RD05	ALMA-SW-0011	4.3	2002-10-23	ALMA Software Science Requirements and Use Cases
RD06				ASAC Science Operations Recommendations
RD07				ALMA Science Design Reference Mission
RD08				ALMA Calibration Plan
RD09				ALMA Safety Document(s)

[1] At ~~this time (Feb 2004),~~the time of this draft, this document is still under development and inconsistencies may still exist between it and the documents in Section 2.4. As necessary, these inconsistencies will be discussed and reconciled, either by updating this document (if change not inconsistent with Board-approved documents) or by requesting change to affected document in Section 2.4. Once this present document is approved and released, it will have precedence over the documents in Section 2.4.

RD10				ACA Project Description: Part 1
RD11	ALMA-80.11.00.00-001.A-GEN		2003-11-03	ALMA Product Assurance Requirements

2.5 Abbreviations and Acronyms

ACA ALMA Compact Array
ADO ALMA Directors Office
ALF Administration, Logistics, and Facility (Management)
ALMA Atacama Large Millimeter Array
AIV Assembly, Integration, and Verification
AoD Astronomer-on-Duty
AOS Array Operations Site
ARC ALMA Regional Center
AMAC ALMA Management Advisory Committee
ASAC ALMA Science Advisory Committee
ATF Antenna Test Facility
AUI Associated Universities, Inc.
BE Back-end
BER Bit Error Rate
BGA Ball Grid Arrays
CM Corrective Maintenance
CMMS Computer Maintenance Management System
CSV Commissioning & Science Verification
DD Deputy Director
DDT Director’s Discretionary Time
DSO Department of Science Operations
DTS Department of Technical Services
ESO European Southern Observatory
FE Front-end
FTE Full-Time Equivalent
FPGA Field Programmable Gate Arrays
HVAC High-volume Air Conditioning
HW Hardware
ISM International Staff Member
ISO International Standards Organization
IT Information Technology
IPT Integrated Product Team
JAO Joint ALMA Office
LRU Line Replaceable Unit
LSM Local Staff Member
LTQ Long-Term Queue

LTS Long-Term Schedule
MDT Mean Down-Time
MIS Management Information System
MTBF Mean Time Between Failures
MTBM Mean Time Between Maintenance
MTS Medium-Term Schedule
MTTC Mean Time To Complete
MTTR Mean Time To Repair
MTTRS Mean Time To Return (to) Service
MTTS Mean Time To Service
NRC National Research Council of Canada
NRAO National Radio Astronomy Observatory
NSF National Science Foundation
OSF Operations Support Facility
PEL Program Execution Likelihood
PDM Program & Data Management
PM Preventive Maintenance
PRC Program Review Committee
RAID Redundant Array of Independent Disks
RSC Regional Support Center
SB Scheduling Block
SI Systems Integration
SCO Santiago Central Office
SPV System Performance & Verification
SSR Science Software Requirements
STS Short-Term Schedule
SV Science Verification
SW Software
TBC To Be Confirmed
TBD To Be Determined
UPS Uninterruptible Power Supply
VLA Very Large Array
VLT Very Large Telescope
VO Virtual Observatory

2.6 Glossary

TO BE COMPLETED

2.7 Verb Convention

Shall is used whenever a statement expresses a convention that is binding. The verbs *should* and *may* express non-mandatory provisions. *Will* is used to express a declaration of purpose on the part of the design activity.

2.8 Acknowledgements

Many people have contributed to ALMA operations planning over many years – we stand on the shoulders of giants, we thank you all. In particular, we acknowledge the early work of Bob Brown, Mark Gordon, Eduardo Hardy, and Daniel Hofstadt. We also acknowledge the operations section of the ESO Phase 2 proposal, written by Richard Kurz, Peter Shaver, and Ewine van Dishoeck. Stéphane Guilloteau made important contributions in several areas before leaving the Project. Guidance on various science operations issues was provided by reports created by the ALMA Science Advisory Committee (ASAC) and the Science Software Requirements (SSR) working group. As necessary, we have shamelessly adopted operations concepts from VLT planning documents written by Dietrich Baade, Jacques Breysacher, Jim Crocker, Roberto Gilmozzi, Bruno Leibundgut, Alvio Renzini, and Peter Quinn. Brian Glendenning and Debra Shephard also provided significant conceptual contributions. Finally, thanks to the external reviewers of Draft F: Willem Baan (Westerbork), Paul Ho (SMA), Roberto Neri (IRAM), Peggy Perley (NRAO), David Woody (OVRO), and Melvyn Wright (BIMA). Thanks also to the following people for providing detailed comments on Draft G3: Jody Bolyard, Fernando Comeron, Jim Hesser, Harvey Liszt, Gautier Mathys, Jason Spyromilio, Roberto Tamai. Finally, thanks to the May 2004 ASAC for a careful reading and good discussion.

3 Narratives

3.1 A Typical Day in 2012

This section is a narrative description of a typical ALMA day across the world when the system is completely operational.

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3.2 A Typical Day in 2007

This section is a narrative description of a typical ALMA day across the world during early operations.

TO BE COMPLETED

4 Joint ALMA Observatory Management Structure

At ~~this writing (December 2003),~~the time of this draft, the Executives and ALMA Board ~~are~~were still discussing the concepts presented in this section. Therefore, some or all of this section is subject to change. In addition, this section shall be revised when the Japanese formally join the Project.

ALMA is a joint scientific venture between Europe and North America (hereafter, the Regions) with participation by the Republic of Chile. ALMA operations will serve these communities in a way that distributes the burdens and benefits in a mutually agreeable way. The organizational structure for ALMA operations of the bilateral observatory is derived from the organization of the project for the construction phase and is shown in Figure 4-1.

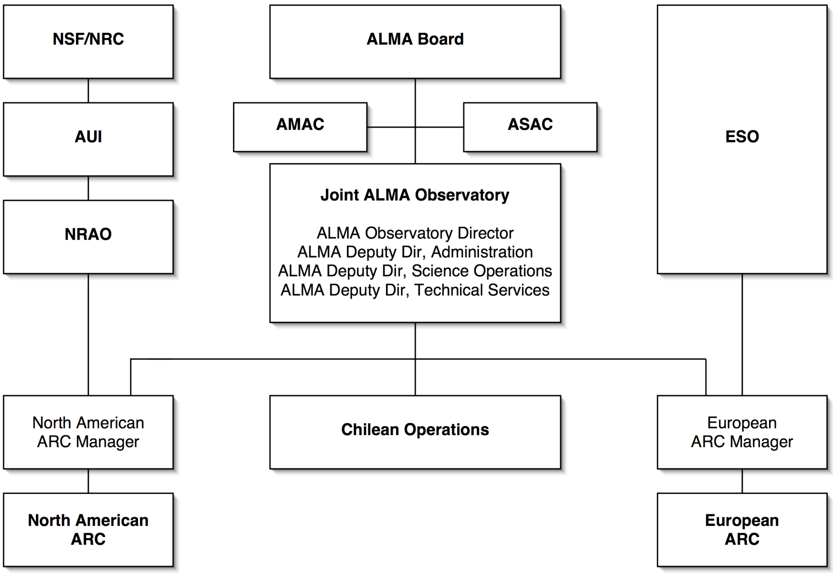

Figure 4-1. ALMA Organization for Operations

The Joint ALMA Observatory is staffed and funded by the Executives, and overseen by the ALMA Board, composed of representatives of the Parties (i.e. the funding agencies: NSF/NRC and ESO), the Executives (i.e. the designated administrative organizations: AUI/NRAO and ESO), and the user communities. The primary function of the Joint ALMA Observatory is the operations and maintenance of the array at the Array Operations Site (AOS) and the Operations Support Facility (OSF) near San Pedro de Atacama in Chile. The Joint ALMA Observatory shall also maintain the Santiago Central Office (SCO) to facilitate administrative and operational tasks better done there than at the OSF, as well as to provide offices for the ALMA scientific staff during work periods scheduled for personal scientific research. The Joint ALMA Observatory top-level organization view is shown in Figure 4-1.

The Joint ALMA Observatory Director's Office (ADO) is the focal point for operations management of the Joint ALMA Observatory. The ADO will be composed of the following primary personnel:

- Joint ALMA Observatory Director
- Deputy Director – Department of Administration, Logistics, and Facility Management
- Deputy Director – Department of Science Operations
- Deputy Director – Department of Technical Services

The Joint ALMA Observatory Director leads the Joint ALMA Observatory and reports to the ALMA Board. The Joint ALMA Observatory Director shall have the responsibilities and authorities as stated in the Bilateral ALMA Agreement. The ALMA Board appoints the Joint ALMA Observatory Director and the three Deputy Directors.

The ADO hires the additional staff necessary for ADO activities. All ADO staff will be co-located~~in Santiago de Chile~~ at ~~the Central Office (SCO),~~te SCO except for tasks better executed at the Operations Support Facility near San Pedro de Atacama, as deemed necessary by the ADO. With approval of the ALMA Board, each member of the ADO will be employed by one of the Executives.

Joint ALMA Observatory employees fall into three categories. International Staff Members (ISMs) are employees of the individual Executives assigned to ALMA and working under the contractual terms and conditions established by the relevant Executive. Local Staff Members (LSMs) are hired in Chile by an organization established by the Executives and work under the contractual terms and conditions established by that organization.[2] Contract Staff Members (CSMs) are provided by local service providers under contract to one of the Executives. CSMs work under the contractual terms and conditions established by the provider, as amended by the service contract between the relevant Executive and the provider. All Joint ALMA Observatory employees in Chile are managed by, and report to, the Joint ALMA Observatory Director, either directly or indirectly.

Scientific & technical interactions between the regional communities and ALMA will occur through ALMA Regional Centers (ARCs) operated and managed by the Executives. The ARCs shall provide core services determined by the ALMA Board. The value of these core services shall be considered contributions by the Executives to the ALMA operations budget. Each ARC may also provide additional, enhanced services as deemed desirable by the managing Executive. The value of these enhanced services shall not be considered contributions by the Executives to the ALMA operations budget. The location and internal organization of each ARC is the responsibility of its managing Executive.

Each ARC shall have a Manager. Like all ARC employees, the ARC Manager is hired by and reports to the regional Executive. The ARC Manager is responsible for providing Board-approved operational deliverables to the Joint ALMA Observatory and the regional ALMA user community, in accordance

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[2] This statement is consistent with available versions of the Project Plan, Chapter 6. However, the Executives and JAO ~~have~~are apparently discussing a different arrangement, i.e. that all LSMs will be hired by one of the Executives directly. This issue is obviously TBD.

with the detailed requirements and schedule established by the ADO. The ARC Managers are also responsible for providing Board-approved technical deliverables produced in their regions to the Joint ALMA Observatory.

Analogous to the ALMA Management IPT for Construction, the Joint ALMA Observatory shall have a Management Team that consists of the three Deputy Directors, the ARC Managers, the Safety Manager (Section 5.1) and the Human Resources Manager (Section 11.2) (see Figure 8-1). The Management Team is led by and reports to the Joint ALMA Observatory Director.

In conjunction with the Joint ALMA Observatory Management Team, the Joint ALMA Observatory Director is responsible for:

- establishing end-to-end operational priorities and schedules, subject to the review and approval of the ALMA Board;
- ensuring that sufficient operational interfaces are implemented and maintained between the Chilean operations group(s) and the ALMA Regional Centers (see below)

The Joint ALMA Observatory Director is solely responsible for resolving operational conflicts between the Chile-based operations group(s) and the ARCs. As necessary, the Joint ALMA Observatory Director shall take such conflicts to the Executive and/or Board level for discussion and resolution.

The organization of the ADO and its relationship to the ARC Managers provide the necessary centralized decision-making and direction required to manage a distributed operations structure. On the other hand, the risks in ALMA operations are borne by the Executives. It is recognized that there may be instances when the Executives cannot accept the legal, financial, or political risk associated with a proposed ADO decision. In these cases, of necessity, the ADO will need to seek an acceptable alternative. But the Executives agree not to impose their prerogatives unnecessarily, exercising their right to alter ADO decisions only in cases where the risks are judged to be large.

The career development decisions for ALMA Regional Center personnel reside with the Executives. It is important that the ADO participate in the processes that lead to these decisions for ARC Managers. That is, annual performance reviews, salary reviews, and promotion recommendations for these ALMA managers ~~are~~will receive ADO comments and input.

The ARC Managers perform a critical role in maintaining the linkage between the ALMA Director's Office and their respective Executives. In addition to reporting for operational purposes to the Joint ALMA Observatory Director as provided above, the ARC Managers are responsible for managing the execution of the operational tasks under their control and for reporting cost, scope and schedule information to their respective Executives in sufficient detail to permit the Executives to exercise their managerial and legal responsibilities consistent with the subsections below.

Development of new instrumentation for ALMA, both hardware and software, is carried out by the Executives, in possible collaboration with other institutes they may choose. New projects to be funded by ALMA Operations are developed by the Joint ALMA Observatory Director with suggested prioritization, in consultation with the Executives. Development projects and their prioritization require approval by the ALMA Board. Such development projects are conducted in a manner identical to the conduct of the ALMA construction project. The Executive having task responsibility will assign a project manager who will report to the Executive regarding matters of cost and will report to the Joint ALMA Observatory Director regarding technical scope and schedule.

The roles of the ALMA Science Advisory Committee (ASAC) and ALMA Management Advisory Committee (AMAC) as defined in Section 3 of the Project Plan shall continue during ALMA operations.

The ASAC will provide regular scientific oversight and advice to the Joint ALMA Observatory, reporting through the ALMA Board. The ALMA Board, in consultation with the Joint ALMA Observatory Director, will define the terms of reference of the ASAC and appoint its members. Written reports of ASAC discussions will be given to the ALMA Board by the ASAC chair following each committee meeting.

The AMAC will provide regular management, cost, and technical oversight and advice to the project through reporting to the ALMA Board. The ALMA Board, in consultation with the Joint ALMA Observatory Director, will define the terms of reference of the AMAC and appoint its members. Written reports of reviews and assessments will be given to the ALMA Board by the AMAC chair following each committee meeting.

5 Operations Development Concepts & Milestones

The ALMA Board has established two Level-1 milestones for operations: Early Science Operations in 2007 Q3 and Full Science Operations in 2012 Q1. In this section, general operations development guidelines and assumptions are provided, after high-level discussions of safety, operations management, and Construction/Operations interfaces are presented. It concludes with a list of quarterly milestones for the period 2004 – 2011. More detailed planning is the responsibility of the Joint ALMA Observatory Director's Office.

In total, this section supports a fundamental conclusion: development of ALMA operations structures, processes, and staff recruitment must start in 2004 to be ready to provide the support demanded by the Construction project and to be ready to start Early Science Operations in 2007.

Budget Impact: this implies that ALMA Operations monies must start flowing in 2004.

5.1 Safety

The Joint ALMA Observatory will be one of the most technologically complex astronomical complexes in the world, operating at the highest altitude ever for a facility of this magnitude. It is imperative that a comprehensive safety management system following international standards be implemented through all parts of ALMA Construction and Operations. A Safety Manager shall be appointed as soon as possible to monitor, enforce, and extend ALMA safety procedures. The Safety Manager shall be independent of any specific part of the ALMA Project and Observatory. The Safety Manager will report directly to the Joint ALMA Observatory Director.

In particular, the Safety Manager must be cognizant of safety issues related to activity at altitudes spanning 2500 – 5000m above sea level. Subject to the approval of the Joint ALMA Observatory Director, the safety officer shall implement AOS safety policies, including requirements & procedures related to the level and kind of activity allowed both at day and at night. It shall be a high-level goal to minimize the number of staff at the AOS at any time. In general, night-time travel to and activity at the AOS shall be discouraged, except in the cases of critical system failure that could result in major harm to ALMA personnel or facilities. Various close monitoring practices should be implemented, such as check-in/check-out with on-duty array operator, no one working alone at AOS for extended periods, monitoring of activity by supervisors at OSF or from oxygenated environments at the AOS, and team leaders for all AOS activities. Procedures will be developed for regular medical certification before authorization for AOS ~~work.~~

work. It shall be general practice to develop checklist-based processes for all operational activity at the AOS. These checklist shall incorporate safety procedures (e.g. check-in/check-out with on-duty array operator).

The Safety Manager ~~will~~shall be responsible ~~for~~ for:

- organizing the OSF/AOS fire brigade, foreseen to be a sub-set of OSF-based staff trained in the use of the fire brigade equipment. After initial training, regular drills to develop & maintain proficiency will be ~~necessary.~~ necessary;

- ~~The Safety Manager will be responsible for~~ monitoring the performance of contracted medical and/or paramedical ~~services.~~services;
- ~~The Safety Manager will also be responsible for~~ developing and implementing security procedures at all ALMA sites in Chile. In particular, the Safety Manager will develop and implement an AOS 24-hour site security plan, which may or may not include the presence of security personnel round-the-clock at the ~~AOS.~~AOS;
- developing an operations safety manual, as early as possible before the start of operational activity, and in coordination with safety practices already set in place by the Construction project. Specific issues to address include but are not limited to: employee safety training and certification requirements, accident/injury reporting procedures, safety inspection procedures, access control and limitations to all ALMA facilities, etc. The legal liabilities and responsibilities of the Executives must be taken into consideration. The NRAO and ESO safety officers should be involved in development of the operational safety manual.

Budget Impact: potential costs of 24-hour security at the AOS, including video surveillance equipment and security personnel at the OSF and/or the AOS, are ***not*** *included in current operations budget projections.*

One key safety assumption must be highlighted: **no one shall work at the AOS alone or unsupervised.** All personnel traveling to and from the AOS must contact the on-duty array operator to check-in when leaving the OSF and check-out when arriving at the OSF. The array operator will maintain regular contact (hourly, TBC) with all personnel working at the ~~AOS.~~

AOS. Inside facilities at the AOS, the oxygen concentration of the air will be enriched to provide a safer as well as more comfortable and productive working environment.

5.2 Environmental Impact

Joint ALMA Observatory operations shall be compliant with all Chilean environmental regulations, as well as international standards (e.g. ISO 14000 family) as they apply to the OSF and AOS sites. Consistent with the spirit of this requirement, the Joint ALMA Observatory will remain mindful of the unique and high environmental and historical value, as well as sheer natural beauty, of the OSF and AOS sites. Efforts will be taken to minimize the physical impact of Joint ALMA Observatory in its environs by, e.g. keeping the footprint of facilities as small as possible consistent with safe and efficient operations, driving on graded roads only, walking on graded paths for everyday activity, choosing the most environmentally friendly power generation process whenever possible, exercising proper care with waste disposal, etc.

The Joint ALMA Observatory shall also take measures to minimize the emission of all electromagnetic radiation that might interfere with either itself or possible future astronomical facilities near the OSF/AOS site.

5.3 Operations Management

Minimizing operations costs, especially in the areas of staffing levels, requires maximizing operations efficiency. Process automation at the sub-system level is only part of the solution. Maximizing operations efficiency requires a top-down management process to manage, track, & report all high-level operations processes, including:

- science program status tracking & reporting (e.g. a program lifecycle)
- science/calibration data quality assurance tracking & reporting
- data product and data package production & delivery tracking
- technical data stream monitoring & reporting
- inventory control
- integrated problem reporting & tracking[3]
- repair history tracking
- maintenance planning

Implementation of these processes will be based on the paradigm of capturing operations process information and then processing this information into task specific reports. Depending on the context, reports could be either plain text suitable for further processing or graphical representations of data. Consideration should be given to international quality management standards, such as the ISO 9000 family.

Complete specification of the necessary toolset(s) to support operations management is beyond the scope of the current document. However, certain general characteristics are mandatory. Tools should be workflow driven, managed using high-level GUIs and/or Web interfaces, and (as much as possible) should be an integrated system, not just a toolbox. Data process management data must be accessible without resorting to major software development, so that unforeseen reports can be generated expediently. Preference should be given to conservative, proven solutions that allow the use of simple tools (e.g. SQL scripts) or off-the-shelf commercial products (e.g. Crystal Reports).

However, a set of management tools is not enough – there must also be well-understood lines of authority and responsibility. Each process should be owned by a limited number of individuals, not distributed across many people or within a large committee. Operational interfaces should be minimized as well as the required number of information/data transfers/acknowledgements (handshakes) across each interface. Individuals shall not be held responsible for deliverables unless they also have authority to take immediate corrective action when problems arise.

5.4 Construction/Operations Interfaces

Systems Integration (SI) is a Construction activity ~~under control of the Systems Engineering IPT whose head is responsible for all SI activity.~~led by the JAO Project Engineer. The primary responsibility of SI is to assemble and integrate the major ALMA sub-systems into a working system and establish its initial technical performance. SI will continue until all antennas are accepted from the

[3] If possible, there should be one integrated problem reporting & change request management system across the entire Observatory, including the ARCs.

contractor, outfitted, and integrated into the array. It includes single antenna activities (e.g. fitting out of antenna) as well as system-wide activities (e.g. IT network check-out, correlator start-up). From the perspective of Operations, important secondary SI activities include:

- validation (or development) of all maintenance procedures, particularly start-up and shut-down procedures under normal and emergency (i.e. power failure) situations
- establishment of site tools and spare parts list(s) (location and quantity of each)
- establishment of (interim?) tracking system for maintenance activities and problem reporting

SI activity will start in 2005 and continue until the end of 2011. By necessity, it will run in parallel to Early Science Operations (see below). The SI team will be largely self-contained, but will draw on certain Operations funded resources and infrastructure (e.g. antenna transporter crew, OSF lab space maintained by Operations, etc.). Care should be taken to assure that SI and Operations staff, facilities, and equipment duplication is minimized. Some duplication is unavoidable, meaning that when SI is completed, some support hardware may be superfluous and not all SI staff can transition to Operations in 2012. More detailed plans can be found in the *ALMA Integration Plan* document (in preparation).

Commissioning & Scientific Verification (CSV) is a Construction activity~~under the control of the Science IPT and~~ led by the ~~ALMA~~JAO Project Scientist. After each significant SI milestone is achieved (e.g. after each antenna is integrated into the array), the CSV team executes a number of antenna-specific and system-wide tasks to test & tune the system to the required technical and scientific performance. Tasks include, but are not limited to: final on-sky holography, baseline establishment, pointing model tuning, and testing of a pre-determined range of operations modes (e.g. continuum imaging at 100 GHz). The CSV team is also responsible for testing & tuning of the end-to-end data management system, including (but not limited to): Phase 1 proposal creation & submission, Phase 2 proposal & submission, SB execution, raw data capture & archiving, pipeline processing, quality control, and data delivery. When the CSV team finds problems with newly integrated hardware or software, it is the responsibility of the SI team to diagnose and (if possible) correct the problem, with assistance from the various Construction IPTs as needed.[4] *In essence, the CSV team is accepting all ALMA system components, hardware and software, on behalf of ALMA operations.*

For testing and training purposes, it is highly desirable that the initial ARC scientific staff members be hired early enough to participate in CSV activities, especially in the area of end-to-end data management system.

CSV has two primary products. The first product is a set of operational procedures and check-lists for operating the Observatory in its various observing modes as a science facility using the entire end-to-end data management system and appropriate calibration data. These procedures may often be preliminary and require later refinement. The other CSV product is a report describing the as-built performance of the commissioned system with supporting scientific datasets demonstrating that performance for each commissioned and released mode. After review and approval of the Joint ALMA Observatory Director, the datasets shall be released to the ALMA community via the ALMA archive

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[4] IPTs must include the possibility of such support in their detailed planning.

system. In practice, both products (procedures and datasets) are built up and released incrementally as CSV progresses.

Analogous to SI activity, CSV activity starts in 2006 and continues until the end of 2011. Operations staff (e.g. array operators) support CSV activity as necessary. Many (but not all) CSV staff transition to operations as time progresses (as discussed in the Operations Development section below). An overview of CSV activity can be found in the *ALMA Integration Plan*. More detailed plans, including a CSV task and verification matrix, can be found in the *ALMA Commissioning & Scientific Verification Plan* document (in preparation).[5]

Once SI and CSV tasks are completed, operating and maintaining the system is the responsibility of Operations. One critical milestone is the delivery of the ~~three antenna~~three-antenna interferometer. Before this milestone, Operations provides support to SI and CSV but has no responsibility for the system. After this point, Operations has operational and technical responsibility for a facility that expands with time.

5.5 Operations Development Assumptions

5.5.1 Key Concept: Early Staff Recruitment

The key concept of ALMA operations development is the early recruitment of the operations staff and the integration of these people into the SI and CSV activities. Thus, core operations staff (i.e. astronomers, engineers, technicians, computing/IT support, and operators) can be involved in the verification and/or creation of the operations and maintenance procedures delivered by the SI and CSV teams. Such integration has the additional advantage of fostering team building by minimizing an "us vs. them" attitude between Construction and Operations teams. Early recruitment also allows the earliest hires to be trained at ~~Project centers~~component fabrication sites outside of Chile, ~~if appropriate.~~as appropriate, during component fabrication and before component delivery.

Operations personnel training is based on the procedures developed by the SI and CSV teams. Training starts with brief tutorial introductions of general concepts and specific sub-systems in a classroom-like setting followed by a review of documentation and hands-on execution of the relevant procedures. It shall include a general introduction to ALMA safety procedures, especially any such procedures related directly to the sub-system(s) under discussion. Training is complete when the trainer certifies that the trainee can execute the procedure unassisted.

On the other hand, care must be taken to ensure that operations staff members are not over-stressed, especially during 2006 and 2007 when there will be significant CSV and science operations preparation

[5] The CSV team could include external scientists in several ways. First, a joint Science IPT/ASAC group could propose demonstration science observations. Data from these science observations would have no proprietary period. Second, external scientists could participate in the processing of CSV data to provide feedback to the CSV team. Third, external scientists could temporarily participate in CSV activities in Chile. Minimal time of commitment: 3 – 6 months. Using too many external people should be avoided, however, since ALMA needs to focus on training future operations staff members, not just future users. ALMA should issue a Request for Letters of Interest in CSV Participation as far in advance as possible (perhaps one year) to allow external participants to arrange, e.g. sabbatical leaves.

tasks running in parallel. During this period, ALMA must endeavor to staff the combined SI/Operations and CSV/Operations teams at the proper level. In concept, this is akin to over-staffing the SI and CSV teams in 2005 and 2006 with people who will become the startup Operations staff. By 2012, all SI and CSV staff have transitioned to Operations or left the Project.

Budget Impact: determination of correct staffing levels to support SI and CSV requires further study.

5.5.2 Sistemo de Turno

Due to the remote nature of the OSF, it is assumed that most OSF staff will work on rotating shifts. In Chile, this is known as the ~~*Sistema*~~*Sistemo de Turno*. In Chile, the turno system is used by all international observatories and most mining operations. It complies with Chilean labor laws. It works well for many office positions and for interchangeable personnel (e.g. telescope operators, maintenance people) who must be available seven days a week, 24 hours a day. This system is not appropriate for highest level management people who need to be continually available. It is also inappropriate for employees responsible for creating new systems or equipment.

Turno work arrangements include a range of possible schedules. ESO uses two schedules: known as ~~5x2 and 8x6. The 5x2~~5+2 and 8+6. The 5+2 schedule is appropriate for office staff. Remote site work begins at 1500 on Monday, consists of 9.5-hour days Tuesday through Thursday, and ends at 1300 on Friday. Santiago-based work follows a normal 8-hour per day cycle, Monday – Friday. The ~~8x6~~8+6 schedule is more appropriate for skills needed every day. It provides ~~approximately 80 work hours~~72.5 work-hours over a two-week period. It ~~begins at 1500 on day 1, consists of 9.5 hours~~covers 6 hours on day 1 starting at 1330 hours, consists of 10 work-hours each on days 2 through 7, and ends at ~~1300~~1530 on day 8.~~Sunday is compensated at 1.75 x the basic rate.~~ Replacement personnel overlap on days 1 and 8.

Budget Impact: ESO experience shows that 2.4 employees are needed for each ~~8x6~~8+6 position to ensure overlap and continuity. For management positions, only two (2) employees used, since 365 day coverage is not strictly required.

It is assumed here that ALMA will follow the ~~5x2 and 8x6~~5+2 and 8+6 rotations similar to ESO, except for staff astronomers who will have turno shifts tailored to allow work at OSF and SCO as well as research time (see further discussion in Department of Science Operations section). For each turno employee, ALMA shall provide room, board and transportation to and from pre-established pickup points in Calama and Santiago. Ideally, each turno-employee would have the same room and the same bed each visit. In this way, that employee could leave personal effects in the room and could decorate the room to suit his or her preferences.

Budget impact: longer rotations such as ~~11x9 or 14x14~~11+9 or 14+14 should be considered because they would reduce the number of required staff, the number of change-over days per year, and the number of intra-Chile flights per year. These reductions lower operations costs but risk making employment conditions less attractive and thereby risk making staff recruitment more difficult.

5.5.3 Critical Operations Development Assumptions

The following critical operations assumptions have been made in this plan:

- **No regularly scheduled Visitor Mode:** Visitor Mode is defined as observing runs where Principal Investigators (or designees) are physically present in the OSF control room, with complete control of the observing sequence for a fixed period of time. During normal science operations, there shall be **no** ALMA Visitor Mode runs except under truly exceptional cases reviewed and approved by the Joint ALMA Observatory Director.

- **Observation execution via Schedule Blocks strongly encouraged:** as soon as possible, all observations (scientific and technical) shall be executed using Schedule Blocks, to facilitate end-to-end data management commissioning and uniform data quality. Tools will be available to allow the direct selection and execution of individual SBs stored in the archive.

- **Array operations from AOS strictly discouraged:** as soon as the AOS-OSF fiber link is established, array operations from the AOS technical building shall be strictly discouraged unless absolutely necessary. *Establishing the AOS-OSF fiber link early should have high priority for the Construction project.*

- **Restricted access to OSF and AOS computers & network from external sites**: for safety and security reasons, remote access from external sites shall be restricted for certain ALMA computer systems at the OSF and AOS. The exact list is TBD but in general shall include any system from which a user could directly or indirectly issue commands to the on-line main array and ACA systems, particularly major mechanical or science operations systems. Remote access shall be granted only under exceptional circumstances and for a specific task and limited time only. Remote access shall be granted only upon the review and approval of the Joint ALMA Observatory Director and/or the Deputy Director for Science Operations or Deputy Director for Technical Services. Note that some systems will have less restricted access to allow, e.g., remote access to the engineering data stream to facilitate remote diagnostic engineering.

- **Limited science time at start:** Early Science operations will be initially limited to 15 (TBC) contiguous days per 30 days, with the goal of reaching 25 days per 30 days by 2010. Early Science operations may be limited initially to 16 hours per day, with the goal of reaching 24 hours per day by 2009. The former restriction allows for major continuing SI and CSV activity while the latter allows for staff & process ramp-up. *The June 2004 ASAC report has recommended that Early Science operations blocks be even more limited, i.e. they should be days long, not weeks.*

- **Limited array re-configurations at start:** before 2009 (date TBC), major array re-configurations will not occur continuously, i.e. every four days – they will occur at irregular intervals determined by technical need and scientific demand. During this period, an array configuration schedule will be published at regular intervals (viz. VLA or IRAM). After some TBD date, a more continuous re-configuration scheme will be phased in, with the eventual goal of moving four antennas every four days by 2012.

- **Limited use of sub-arrays at start:** before 2009 (date TBC), the use of sub-arrays for simultaneous science and technical activities may be limited. In general, the array will be block-scheduled – certain periods will be all science operations and other periods will be all technical activity. The eventual requirement is to operate the main array as up to four sub-arrays to facilitate, e.g., efficient calibration and re-configuration management.

- **Procedure development:** it is assumed that the SI team is responsible for the development or verification of all technical procedures (primarily in the areas of setup and maintenance) while the CSV team is responsible for the development or verification of all operational procedures.
- **Staff development:** it is assumed that the SI and CSV teams will host and train the initial operations staff contingent. From the Operations perspective, the SI and CSV teams host the core Early Science operations teams.
- ~~**Software procedures:**~~**Operations management and staff ramp-up:** a high-level goal of ALMA is to automate all data management processes. It can be expected, however, that such automation will be phased in over time as procedures are refined, implemented, and validated. This is particularly true for the following critical areas: definition of standard observing modes, Phase 2 validation, dynamic scheduling heuristics, pipeline heuristics, and science data quality assurance. *Thus, it is assumed that the ALMA science operations staff does not scale with the number of antennas – rather, it has a quick ramp-up and reaches the full-up level by 2008 (TBC).*
- **Direct user interaction:** there shall be **no** direct interaction between scientific end-users and the on-duty staff at the OSF during normal science operations except under extraordinary circumstances. In general, only ARC staff will interact directly with OSF staff during science operations. A higher level of interaction may be both necessary and appropriate during SI and CSV.
- **Indirect user interaction:** in the spirit of ASAC recommendations,[6] a minimal eavesdropping capability will be implemented with the goal of delivering execution and quality assurance information via a Web interface to PIs as soon as possible after each SB execution. Resources permitting, this capability will be implemented by the start of Early Science Operations. Support for breakpoints, as recommended by the ASAC[7], shall be a goal for Full Operations, but not Early Science Operations. Until mature operations are achieved, more sophisticated eavesdropping options involving science pipeline output and various forms of real-time interaction with active operations shall not be further considered or implemented.
- **ACA operations:** the ACA will operate independently of the main array. Main array and ACA observations may be coordinated in time on an as-needed basis. It is further assumed that only one Astronomer-on-Duty (see below) and one array operator can together handle both the main array and ACA operations unassisted during periods of normal operations. *During Early Science Operations, it may be necessary to have more than one (1) AoD and array operator per shift. This is TBD.*

[6] See October 2001 ASAC report (Appendix C).

[7] ASAC, ibid.

- **Scheduled system-wide down-time for preventive maintenance:** In steady-state operations after 2011, it is expected that one 10-hour daytime shift per week will be scheduled for such system-wide preventive maintenance activities. In addition, a double shift once per month (i.e. from 0800 on Day 1 to 1800 on Day 2, including night-time) will be scheduled. These shifts will be coordinated with the array reconfiguration schedule to minimize total system downtime. Required maintenance may involve hardware or software components. If no preventive maintenance activity is necessary, these shifts will be returned to science operations. At the discretion of the Joint ALMA Observatory Director, additional down-time shall be scheduled for major system-level maintenance or upgrades.
- **Science-quality images not delivered immediately:** the science pipeline will need 12 – 24 months of commissioning after Early Science operations begin. Therefore, science quality images will not be available at the start of Early Science operations. During these early months, ALMA shall deliver the raw data, data processing software, and a cookbook for data processing and imaging, as well as ARC-based data processing user support via a remote helpdesk model.
- **Staged central Archive deployment:** the Archive is the backbone of the ALMA data flow system. It is assumed that basic Archive data capture and storage capabilities will be available at the start of CSV activity on the three-antenna interferometer. Exact capabilities are TBD. The central archive facility will remain at the OSF until approximately 18 – 24 months after the start of Early Science Operations. During this period, most (perhaps all) archive operations and data management activities will occur at the OSF. After these first 18 – 24 months, the central Archive will migrate to the SCO as will many archive operations and data management activities.
- ~~**Archive/Pipeline staging:**~~**Staged central Pipeline deployment:** at the start of Early Science Operations, the central ~~archive/~~pipeline system shall be located at the OSF and ~~most (perhaps all) data management activities will occur there. Within 24 months, a new central node will be implemented at the Santiago Central Office and many data management activities will relocate to there.~~
- will still need fine-tuning and commissioning to adapt it to the "as built" ALMA system (see above). After commissioning is completed, pipeline operations will migrate from the OSF to the SCO in coordination with the migration of the central archive to the OSF (see above).
- **Delayed delivery of ARC archive/pipeline systems:** it may not be possible to deliver commissioned and operational archive/pipeline systems to the ARCs until ~~18 –~~the SCO systems are operational, i.e. until circa 24 – 30 months after the start of Early Science operations. In the interim, archive/pipeline related user services shall be provided from the central archive in Chile. It may still be possible to provide data delivery via the ARCs (TBD) and data product and analysis support shall be provided by ARC staff.
- **Only two proposal submission cycles in first 24 months:** the initial proposal submission cycle shall start roughly 10 months before the start of Early Science operations. Given new and complex proposal submission system running in parallel to ramp-up of complex observatory systems, there shall be only two (2) additional proposal submission cycles in the

first 24 months of Early Science Operations. After that, the Observatory goal should be 2 or 3 cycles per year (TBC).

5.6 Operations Development Stages

There are four distinct stages of operational development, each with its own tasks and deliverables. At each stage, the balance between Construction and Operations evolves until Operations activities finally dominate. Each is discussed in turn below.

5.6.1 Early Pre-Operations Stage

Definition: period prior to the availability of a three-antenna interferometer ~~(2006 Q2)~~. By the end of this period, the members of the SI team are on site continuously. The CSV team, however, is still based outside of Chile, coming to Chile only as necessary.

Operations activities include, but are not limited to:

- Establish ALMA Director's Office at Santiago Central Office in coordination with JAO
- Recruit high-level management staff for Chile
- Establish human resources group(s) in Chile
- Initiate Chile staff recruitment & training, coordinated with Construction IPTs
- Participate in Commissioning & Scientific Verification development
- Initial arrival & acceptance of Construction deliverables (e.g. transporter, OSF facilities, etc.)
- Start ALMA Regional Center development & staff recruitment (responsibility of Executives)
- Start SI and CSV support
- Transport integrated antennas to AOS as requested
- Accept ~~three antenna~~three-antenna interferometer
- If possible, begin commissioning of proposal submission and review management tools

Most of these tasks involve staff recruitment and therefore have relatively long lead times – they must therefore be initiated as early as possible~~, i.e. 2004~~. By the end of this period, the initial complement of operations staff and infrastructure must be in place and ready to support SI and CSV activities.

It assumed that the SI and CSV teams will specify their operations support requirements in their respective plans.

5.6.2 Late Pre-Operations Stage

Definition: period from availability of three-antenna interferometer~~(2006 Q2)~~ to start of Early Operations ~~(2007 Q3)~~. During this period: (1) SI activity continues; (2) CSV team moves to Chile to start continuous activity on a multi-year basis; (3) core ARC science support activity begins; and (4) preparations for the start of Early Operations are completed.

Operations activities include but are not limited to:

- Continue staff recruitment & training in coordination with Construction IPTs
- Continue support of SI and CSV activity
- Start core ALMA Regional Center activities (responsibility of Executives)
- Prepare for Early Science operations, i.e. release first Call for Proposals, support Phase 1 and Phase 2 proposal preparation, release initial Web pages, etc. (joint ARC/Chile activity)
- Commission operationally critical software tools, particularly Observing Tool and archive system at OSF
- Commission proposal submission and review management tools
- Commission observation preparation (Phase 2) management tools

It is assumed that international personnel on temporary (several months – several years) assignment in Chile will execute many of these pre-operations tasks. However, it is essential that the long-term Chile-based operations staff in equivalent positions be hired as early as possible to learn the system as it is being assembled and commissioned. Of course, many of the people on temporary assignment may elect to accept long-term positions in Chile.

One of the final pre-operations tasks is **dry runs,** i.e. complete tests of the end-to-end operations and data management systems. This task should be done by the staff responsible for Early Operations with as little as possible assistance from the SI or CSV teams. This is a chance for the Operations team to verify the system and their training, as well as detect and resolve any last minute problems. This dry run activity should be coordinated and managed by the Deputy Director for Science Operations

To prepare for Early Operations, the following fiducial task sequence is foreseen:

Relative Date (months)	Nominal Date	Actor	Task
T-10	2006 Dec1	JAO	Start Call for Proposals preparation
T-8	2007 Feb 1	ARC	Call for Proposals 01 (CfP01) released: some modes guaranteed to work at T=0 some modes are possible but not guaranteed for T=0
T-6	2007 Apr 1	ARC	Observing proposal submission deadline
T-4	2007 Jun 1	ARC	Regional program review work complete
T-3	2007 Jul 1	ARC/JAO	International program review work complete, LTQ ready, Phase 2 begins
T-1	2007 Sep 1	ARC	Phase 2 complete, all SBs certified correct by ARCs

T = 0	2007 Oct 1	JAO	Early Science Operations start
T+2	2007 Dec 1	ARC	Data delivery & data analysis support begins

The initial proposal review cycle is 10 months long. If more than one proposal submission deadline is scheduled per year, this implies overlapping activity that may not be sustainable in the early years. Hopefully, ALMA can reduce this cycle to six (6) months or less. It is assumed above that in the first 24 months, ALMA will issue only two (2) Call for Proposals.

5.6.3 Early Operations Stage

Subject to Board approval, and following the recommendations of the ASAC[8], Early Operations shall begin when the following conditions are met:

- Six (6) commissioned antennas at the AOS released for science operations. *The May 2004 ASAC Report believes that having eight (8) antennas in operation should be the goal.*
- Instrumentation package containing at least two (2) of four (4) standard bands[9], including Band 3, installed and commissioned on each of the operational antennas. *The May 2004 ASAC Report considers the availability of Band 7 to be "mandatory" and of Band 9 "highly desireable".*
- Baselines up to at least one (1) kilometer available
- Both line and continuum observations can be supported
- Phase correction is possible, using fast switching and/or water vapor radiometry. *The May 2004 ASAC Report suggests that **both** are required.*
- Basic modes of correlator commissioned and verified[10]
- Basic operations modes commissioned and verified. *The May 2004 ASAC reports recommends at least single-field interferometry, pointed mosaics (no OTF), and single-dish total power line observations (no continuum).*
- CSV demonstration datasets available in ALMA archive
- Array controllable from OSF (i.e. AOS-OSF fiber connection installed and tested)
- At least one (1) antenna capable of total power measurements available[11]

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[8] See 2002 October ASAC report for further discussion and science rationale.

[9] The possible bands are: Band 3: 86 – 116 GHz (tuning down to 84 GHz feasible without guaranteed performance); Band 6: 211 – 275 GHz; Band 7: 275 – 370 GHz; and Band 9: 602 – 720 GHz. Note that Science IPT has requested that the Band 7 range be extended to 373 GHz.

[10] The exact correlator modes to be commissioned are still TBD and depend on the Early Science Operations Design Reference Mission under development by the Science IPT.

- ALMA User's Manual and ALMA Operator's Manual released (at least Version 1 for both)
- Commissioning of basic end-to-end data management tools completed, including Observing Tool, central archive at OSF, and data delivery system(s)
- ALMA Regional Centers capable of supporting Phase 1 and Phase 2 processes
- Off-line data processing and imaging software tools available, as well as user's manuals

The combination of these requirements will provide capabilities that are sufficiently scientifically significant and operationally stable to warrant the start of Early Operations. The current Level-1 milestone for achieving these capabilities is 2007 Q3.

Early Operations will provide the community with an exciting set of initial functionality. However, it will not be the full-up, 2012 system and not all services and functions envisioned for 2012 will be available. In particular, the system will only be available for operations for limited periods, likely to be days or weeks in length. The rest of the time will be used for systems integration and commissioning work necessary to integrate the continuous flow of antennas (antennae?) as well as commissioning additional operational modes. Furthermore, only a limited number of array configurations will be available, perhaps as small as two – one with short baselines and one with long baselines. Only a few TBD operations modes will be available and images will not be automatically produced, although ALMA is committed to providing desktop data processing and imaging tools with appropriate user documentation at the start of Early Science operations.

The Early Operations stage is currently scheduled to begin during 2007 Q3 and conclude in 2011 Q4, i.e. when the last integrated antenna/instrument package is released to Operations. At first, antennas will be released for use by the external user community in units of 6 – 8 every six months, i.e. not continuously. Towards the end of Early Operations, antennas may be released on a more continuous basis. As stated in the assumptions above, ALMA operations will start with less than 24-hours operations, less than 365 days a year, and a fixed array configuration schedule.

COMMENT:Comment: the decision to release antennas continuously or in discrete increments during Early Operations requires further discussion, in particular about impact on dynamic scheduling and SB construction.

Comment: in their May 2004 report, the ASAC has expressed concern that the phasing-in of additional receiver bands may have a large impact on operations planning. This needs further discussion.

SI and CSV activity continue in parallel with Early Science operations. However, some SI and CSV personnel will transfer to their permanent operations teams assignments at the start of Early Science operations.

Although the main scientific goal of Early Operations is to provide the ALMA community with the earliest possible access to a cutting edge facility, there are a number of operational & technical tasks that must be accomplished, in conjunction with other ALMA teams (in particular Science and Computing IPTs), including:

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[11] Possibly one of the ACA 12m antennas

- Continued staff recruitment & training
- Continued support for SI/CSV activity for expanding system
- Science operations system fine-tuning, including: calibration plan, Scheduler, Simulator, OT, operations management tools, Science Pipeline
- Calibration plan development, including building or improving new sets of astronomical calibration sources, as necessary
- Site characterization metrology
- Optimize array re-configuration strategies – transition to continuous re-configuration mode
- Develop standard observation modes

5.6.4 Full Science Operations Stage

Definition: complete main array (including Japanese-provided cartridges) and complete ACA released to Operations. Current Level-1 milestone: 2012 Q1.As Early Operations continues, the amount of time allocated to science operations as well as the number of antennas and array configurations will steadily increase. Eventually, Full Operations will be achieved, currently scheduled for 2012 Q1. Full Operations commences when the 64-element main array and ACA systems are complete with at least four receivers per antenna. The main array configuration will change from its most compact to most extended configuration and back again over the course of 12 – 18 months, require the relocation of a few antennas every few days. The ACA configuration will change every few months from its most compact to most extended configuration. At least four receiver bands will be available on all antennas (see Section 1) but how many more is still TBD.

Although Full Science Operations does not technically start until the 64th antenna is released to Operations, in fact the Joint ALMA Observatory must reach full staffing and quasi-steady-state operations long before this technical milestone to support various required technical and scientific activities.

Comment: the exact Full Operations system to be offered to users (e.g. number of baselines, bands, correlator modes, array configuration, etc.) is still TBD.

5.7 ALMA Operations Milestones

COMMENT:Comment: this section isvery much a work-in-progress. Milestones will be revised after the antenna delivery schedule is clarified by the JAO (expectation: by mid-2004).September 2004).

Quarterly milestones can be derived from the current Construction schedule and the operations stages discussed above. ALMA Board established Level-1 milestones are indicated in **bold.** N1 is the number of antennas at the AOS ready for SV. N2 is the number of antennas at the AOS released to science operations. All dates are tentative and require Board approval.

Milestones for ARC deliverables to ALMA operations are indicated italics. Milestones for ARC development are the responsibility of the Executives and are not provided here.

These quarterly milestones must be merged with SI and CSV activities.

A bi-annual proposal submission cycle is assumed, with deadlines of 1 April and 1 October. This assumption is illustrative only and is not yet critical – other models are possible.

Year	Q	Relative Date	N1	N2	Milestone
2004	1	T-44			
	2	T-41			
	~~3~~	~~T-39~~			~~ALMA Operations Plan accepted by Board~~ ~~Recruitment of high-level Chilean personnel starts~~ ~~Recruitment/assignment of high-level ARC personnel begins~~
	3	T-39			***In absolute time, these milestones have been missed.*** ALMA Operations Plan accepted by Board Recruitment of high-level Chilean personnel starts Recruitment/assignment of high-level ARC personnel begins
	~~4~~	~~T-36~~			~~Test interferometer, proto-CSV activity at ATF (TBD)~~ ~~Recruitment/training of mid-level and low-level Chilean personnel starts~~
	4	T-36			Test interferometer, proto-CSV activity at ATF (TBC) Recruitment/training of mid-level and low-level Chilean personnel starts
2005	1	T-33			
	~~2~~	~~T-30~~			~~*Begin ARC infrastructure & staffing development*~~
	2	T-30			
	3	T-27			SI team establishes long-term presence in Chile
	~~4~~	~~T-24~~			~~**First Production Antenna & FE Available at OSF**~~ ~~Technical Services personnel & infrastructure ready to transport & support first antenna~~
	4	T-24			**First Production Antenna & FE Available at OSF** Technical Services personnel & infrastructure ready to

Year	Q	Relative Date	N1	N2	Milestone
					Technical Services personnel & infrastructure ready to transport & support first antenna *Begin ARC infrastructure & staffing development*
2006	1	T-21			
	2	T-18			Three-antenna interferometer available at AOS CSV team establishes long-term presence in Chile
	~~3~~	~~T-15~~			~~*ARCs operational*~~ ~~Start Call for Proposals 1 (CfP-01) preparation (T-10)~~ ~~Freeze all Phase 1, Phase 2 support S/W tools for Cycle 1~~ ~~Release tools to ARC staff for final testing, familiarization~~
	3	T-15			
	4	T-12			*ARCs ready to support initial Call for Proposals* *ARCS ready to support end-to-end proposal management process* Start Call for Proposals 1 (CfP-01) preparation (T-10) Freeze all Phase 1, Phase 2 support S/W tools for Cycle 1 Release tools to ARC staff for final testing, familiarization
	~~4~~	~~T-12~~			
2007	1	T-9			CfP-01 released (T-8): 1 Feb 2007
	2	T-6			CfP-01 proposal deadline (T-6): 1 Apr 2007 Regional proposal review complete (T-4): 1 Jun 2007
	~~3~~	~~T-3~~			~~International proposal review complete (T-3): 1 Jul 2007~~ ~~Phase 2-01 complete (T-1): 1 Sept 2007~~ ~~At least one (1) ACA 12m antennas ready in total power mode~~
	3	T-3			*ARCs ready to support end-to-end Phase 2 process* *Chile team ready to create/manage Long-Term Schedule and Long-Term Queue* International proposal review complete (T-3): 1 Jul

Year	Q	Relative Date	N1	N2	Milestone
					2007 Phase 2-01 complete (T-1): 1 Sept 2007 At least one (1) ACA 12m antennas ready in total-power mode
	4	T=0	8	6	**Start Early Science Operations (T=0)** (1 October 2007)
~~2008~~	~~1~~				
	~~2~~				
	~~3~~				
	~~4~~				
2008	1	T+3			
	2	T+6			
	3	T+9			
	4	T+12			
~~2009~~	~~1~~				
	~~2~~				
	~~3~~				
	~~4~~				
~~2010~~	~~1~~				
	~~2~~				
	~~3~~				
	~~4~~				
2009	1	T+15			
	2	T+18			Pipeline produced images delivered for standard modes
	3	T+21			
	4	T+24			Central Archive & pipeline systems operational at SCO
2010	1	T+27			
	2	T+30			ARC Archive nodes operational

Year	Q	Relative Date	N1	N2	Milestone
	3	T+33			
	4	T+36			
2011	1				
	2				
	3				
	4				
2011	1	T+39			
	2	T+42			
	3	T+45			
	4	T+48			
2012	1				**Start Full Science Operations (N = 64)** ACA ready for operation All NA, EU, and JA receivers operational in Main Array
2012	1	T+51	64	64	**Start Full Science Operations (N = 64)** ACA ready for operation All NA, EU, and JA receivers operational in Main Array

6 General Maintenance Concepts

The Joint ALMA Observatory shall have high operational availability once construction has been completed. Existing large, interferometric radio telescopes achieve operational availability, also called operational readiness, values of between 85 and 95 percent.[12] ALMA shall aim for similar operational availability.

Meeting this objective requires a rigorous reliability and maintenance strategy during the design, construction, and operational phases of ALMA. For the operations phase of ALMA, a comprehensive maintenance program shall be defined based on the basic principles presented in this section.

Many of the terms and acronyms used in this section are defined in MIL-HDBK-338B, *Electronic Reliability Design Handbook*, US Dep. of Defense, 1 October 1998. This handbook is an internationally accepted guide that provides a comprehensive overview.

6.1 ALMA Availability

The principal measure of importance to the ALMA user community is the percentage of time that ALMA will be capable of making scientific observations. This **operational readiness** (often also referred to as **operational availability)** is defined to be:

> the probability that at any point in time a system is operating satisfactorily or is ready to be placed in operation on demand.

The equation for operational availability is:

$$A_o = \frac{MTBM}{MTBM + MDT} \times 100\% \qquad (6\text{-}1)$$

where MTBM is **Mean Time Between Maintenance** and MDT is **Mean Down Time,** i.e. the average time a system is unavailable for its intended use.[13] Defined in this way, MDT includes not only system failures but also maintenance delays (e.g. time associated with repair person arriving with the appropriate replacement parts), weather downtime and other non-design factors.

Applying these general definitions to an interferometric system with multiple antennas such as ALMA is more complicated than for a single dish telescope. Often, the complete failure of one or more antennas does not prevent the interferometer from making useful observations. For ALMA , it is unlikely that all 64 antennas will be operational at the same time. Often several antennas will be out of operation due to either corrective or preventive maintenance. Nevertheless the remaining system can be successfully used for observations. On the other hand, when a failure occurs at, e.g. the AOS-OSF fiber link, the most likely result is non-availability of the whole instrument.

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[12] ALMA Memo 370, *A comparison of availability of major radio interferometers*, Gie Han Tan, May 2001. Note that operational availability is somewhat frequency dependent – atmospheric conditions that make sub-millimeter observations impossible may still permit observations at lower frequencies.

[13] Acronyms used are defined in MIL-HDBK-338B~~, *Electronic Reliability Design Handbook*, US Dep. of Defense, 1 October 1998. This handbook is an internationally accepted guide that provides a comprehensive overview~~.

~~It~~Comment: it is beyond the scope of this document to define more specific availability & operational efficiency metrics for ALMA. These definitions are left to the discretion of the Joint ALMA Observatory Director. It is assumed that the experience of the VLA and VLBA systems (among others) would be helpful in this regard.

6.2 Down-Time Components

Regardless of the formal definition of system availability, the Joint ALMA Observatory shall take measures to minimize system and component down-time, consistent with available resources.

Without being exhaustive, down-time includes the following components:

- **Weather**: periods when no science observations are possible due to inclement weather conditions (e.g. high winds, snow storm). Due to the ~~board~~broad frequency range of ALMA, however, periods when absolutely no scientific observation is possible are expected to be rare.
- **Technical failures:** includes both technical (e.g. a defective antenna) and human (e.g. error in observation schedule) failures. **Corrective maintenance** is necessary to bring the system back to operational state. Down-time due to such a failure includes the time to identify the failure, correct it (possibly including the time to wait for maintenance and/or spare parts to be available) and verify that it has been corrected. To minimize the amount of technical failures, regular **preventive maintenance** will be performed. Components will be taken out of service for preventive maintenance and that time will be charged to scheduled engineering downtime, not technical downtime.
- **Calibration:** to meet the required instrument performance, regular calibration observations will be required during which ALMA is not available for executing astronomical observations.
- **Array re-configuration:** the contribution from moving antennas to the down-time is expected to be minimal since only two antennas maximum will be moved at the same time. Only in exceptional cases might it prevent the execution of an observation, e.g. the antenna moved is part of a critical baseline for the observation configuration or other antennas in the vicinity of the antenna to be moved need to be taken out of operation to provide access. The latter can especially occur for the central cluster of the array.
- **Idle time:** defined to be intervals when ALMA system is available, atmospheric conditions are acceptable, but no SB is available for execution. In such a situation the instrument is available but inactive. In practice, this will rarely occur. Nevertheless, the ALMA Director may elect to authorize the creation of observatory filler programs to be activated in the event that such idle time occurs.

The Joint ALMA Observatory shall be responsible for logging and tracking down time in the categories defined above for the complete system and by major sub-system on 1 month, 3 month, 6 month, and life-time intervals.

Weather ~~down-time~~down time is not under the control of the Observatory. Managing calibration and array re-configuration is a requirement for science operations. Idle time can be managed as discussed above.

In the rest of this section, strategies for minimizing technical down-time are discussed.

6.3 Line Replaceable Units

From the perspective of ALMA Operations, the entire ALMA system shall be broken down into a tree of **Line Replaceable Units (LRUs),** i.e. the smallest unit to be repaired or replaced. Thus, ~~sparing~~the stocking of spares is done at the LRU level. An LRU can be a major sub-system (e.g. front end) or a sub-component (i.e. a correlator board). The system-wide application of the LRU concept coupled with the availability of enough spares and adequate personnel resources will ensure that down-time due to technical failures is minimized.

When a system failure occurs, the OSF engineering and technical staff shall isolate the responsible LRU and replace it with a working spare. The defective LRU will then be repaired or discarded, depending on the problem. Routine repairs shall be done at the OSF, with on-site expertise increasing with time from the start of Early Science Operations. Some highly technical repairs shall be done at remote repair facilities, maintained by the Executives as part of their Operations contribution. After each repair, all operational modes of the LRU shall be verified on the bench before returning to service (or to the end of the spare queue).

Each LRU delivered to the Joint ALMA Observatory shall have values for the following parameters (where applicable):

- **Mean-Time-Between-Failures (MTBF):** a basic measure of reliability for repairable items. The mean number of hours during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions.
- **Mean-Time-Between-Maintenance (MTBM):** A measure of the reliability taking into account maintenance policy. The total number of life units expended by a given time, divided by the total number of maintenance events (scheduled and unscheduled) due to that item.
- **Mean-Time-To-Repair (MTTR):** a basic measure of maintainability. The sum of corrective maintenance times at any specific level of repair, divided by the total number of failures within an item repaired at that level, during a particular interval under stated conditions. MTTR includes e.g. time to identify faulty component, actual repair and verification of proper operation after repair.
- **Mean-Time-To-Restore-System (MTTRS):** A measure of the product maintainability parameter, related to availability and readiness: The total corrective maintenance time, associated with downing events, divided by the total number of downing events, during a stated period of time. Excludes time for off-product maintenance and repair of detached components.
- **Mean-Time-To-Service (MTTS):** A measure of an on-product maintainability characteristic related to servicing that is calculated by dividing the total scheduled crew/operator/driver servicing time by the number of times the item was serviced.

In general it is expected that LRUs that can be repaired at the OSF will have MTTR ~ one (1) week while LRUs that must be repaired off-shore may have MTTR as long as 8 – 12 weeks.

In summary, a successful deployment of this LRU strategy to minimize down-time has the following requirements sorted by design, production and operations phases:

- Design phase:
  - Each product used in ALMA shall be designed as a Line Replaceable Unit or assembly of individual Line Replaceable Units.
  - Each LRU shall have sufficient monitoring points to identify failures as quickly as possible.
  - Each LRU shall have a unique identification to be monitored by the control software.
  - The ALMA control software shall monitor each LRU.
  - Each LRU must be easily accessible and removable *in situ.*
- Production phase:
  - For each LRU, sufficient spare parts shall be produced in accordance with its MTBF, MTTR and system availability requirements.
  - Comprehensive operation procedures shall be developed, describing e.g. start-up and shutdown procedures under normal and emergency (e.g. power failure) conditions.
  - Comprehensive maintenance plans shall be developed, describing e.g. preventive maintenance (incl. maintenance staff requirements) and fault trees for corrective maintenance (see extended discussion below).
  - For units that can be broken down into sub-components, complete assembly and dis-assembly procedures must be provided.
  - A complete list of required consumables shall be delivered for each assembly. All assemblies should be delivered with a two (2) year supply of consumables, except in cases where this is impractical due to volume required (e.g. water, diesel fuel) or special handling required (e.g. cryogenics, gases).
- Operations phase:
  - Sufficient resources (including personnel as well as tools), in line with the MTBF, MTTR, etc. specifications of all products within the ALMA system, shall be available.
  - Maintenance operations shall be efficiently organized, incl. spare parts logistics. To fulfill this requirement, the use of Product Lifecycle Management software and a Computer Maintenance Management System is mandatory.

Comment: whenever feasible, LRU production contracts should include a Request for Quote to transfer tooling and knowledge to Joint ALMA Observatory (i.e. technically, one of the ALMA Executives). Depending on the provided quotes, initial transfer costs might be less expensive than having to request repair service from vendors after the warranty periods have expired.

6.3.1 LRU case study: the front-end assembly

As an important example, consider the front-end assembly. When a failure is detected, the standard procedure will be to replace the entire defective front-end assembly with a working spare, available on stand-by at the OSF, and return the defective assembly to the OSF. At the OSF, the defective assembly will be warmed up and disassembled enough to isolate and/or remove the defective sub-component. Suppose this component is a receiver cartridge. It will be removed from the front-end cryostat and then shipped to a remote repair center. In the meantime, a spare receiver cartridge on stock at the OSF will be inserted into the front-end cryostat. After re-assembly, the front-end will be cooled down again and placed on stand-by.

In this example, the LRU concept is applied at two levels: (1) at the sub-system level – a complete front-end assembly, and (2) at the module level – a receiver cartridge.

The time between identifying the failure of a front-end and returning the antenna with a working front-end back to operation can be as low as 4 hours during day-time. A worst-case maximum of 12 hours is expected when such a failure occurs in the early evening and the replacement can only be done the next morning. The indicated times are under the primary assumption that suitable staff is available, a cooled front-end is on stand-by at the OSF, that a FE-service vehicle is available and favorable weather conditions exist.

Repair of the front-end assembly takes about 4 to 5 days. This time includes cryostat warm up (< 24 hours) and cool down (< 48 hours). The remaining time is spent on diagnosis, replacing the faulty unit and verifying that the repaired assembly functions according to specifications.

Repair of the faulty receiver cartridge by a remote repair center is expected to take approximately 2 months. This time consists of transport between the OSF and repair center, diagnosis, actual repair and verification.

Some routine cartridge repairs may eventually be done at the OSF as on-site expertise increases. However, some repairs (e.g. the repair or replacement of SIS mixers) will likely always be done at other repair centers.

6.4 Corrective Maintenance

Failures require corrective action to restore the system to service. This task is labeled corrective maintenance and has the following definition:

- Corrective Maintenance (CM): All actions performed as a result of failure, to restore an item to a specified condition. Corrective maintenance can include any or all of the following steps: Localization, Isolation, Disassembly, Interchange, Reassembly, Alignment and Checkout.

The mean number of expected failures per month is:

$$\overline{N}_{failures} = N^{operational} \times \frac{732_{Month}^{Hours}}{MTBF} \qquad (6\text{-}2)$$

The number of spares per LRU to cope with failures is critical to minimizing technical down-time. Here and below, Hours Per Month = (366 / 12) x 24 = 732. The average number of required spares can be estimated from:

$$\overline{N}_{spares,CM} = N^{operational} \times \frac{MTTR}{MTBF} \qquad (6\text{-}3)$$

This statistical minimum number is shown in Table 6-1. To be conservative, the number of recommended spares (also shown in Table 6-1) is 3 times higher (rounded to next highest integer).

Budget Impact: the spare stocking safety factor of 3 is an assumption that should be reviewed by Project management.

The unit corrective maintenance hours per month per component can be estimated from:

$$T^{CM}_{Month} = N^{operational} \times \frac{(MTTRS + MTTR)}{MTBF} \times 732\frac{Hours}{Month} \qquad (6\text{-}4)$$

This parameter can be used to estimate required CM staffing at the OSF. For example, if a team of M people is needed to correct each failure, the total number of FTE hours per month is $T^{CM}_{Month} \times M$. For most LRUs, 4 hrs ≤ MTTRS < 12 hrs and M = 1. For LRUs repaired off-shore, MTTR ~ 24 hrs to allow for diagnosis, shipping & receiving, and verification upon return.

Some examples of these quantities are given in Table 6-1. For T^{cm}, MTTRS = 10 hours was assumed.

Unit	Worksite	N^{op}	MTBF (Hours)	MTTR (Hours)	Spares Min	Spares Rec	T^{CM} (Hrs/Month)
Antenna	OSF	80	45 000	120	0.2	0	169
FE Assembly (1 Band)	OSF	80	11 000	120	0.9	3	692
Cartridge (single band)	NA/EU/JA	80	175 000	1400	0.6	2	11
BE Module[14]	NA/EU/JA	2000	70 000	1400	40	120	711

Table 6-1: Example Corrective Maintenance (Illustrative Only)

6.5 Preventive Maintenance

The formal definition of preventive maintenance is:

[14] This is generic BE module. In reality, there are several types of BE modules, all with individual MTBF and MTTR. Number of spares per specific BE module still under discussion.

- Preventive Maintenance (PM): All actions performed to retain an item in specified condition by providing systematic inspection, detection, and prevention of incipient failures.

Each major sub-system shall be delivered with a maintenance plan including a section describing preventive maintenance procedure(s). This section shall specify which items need such maintenance, what actions need to be taken, at what interval, what resources are needed, where tasks are performed, and estimated time to completion. Procedures will include an activity checklist. Table 6-2 lists some example preventive maintenance intervals, Mean-Time-To-Service (MTTS) estimates, and the implied preventive maintenance days per month.

The mean number of units to service per month is:

$$\overline{N}_{service} = N^{operational} \times \frac{732_{Month}^{Hours}}{MTBM} \tag{6-5}$$

Sufficient LRU spares to replace units that are being serviced are critical in avoiding unnecessary technical downtime. The average number of required spares to cover PM can be estimated from:

$$\overline{N}_{spares,PM} = N^{operational} \times \frac{MTTS}{MTBM_{PM}} \tag{6-6}$$

This statistical minimum number is shown in Table 6-2. To be conservative, the recommended number of spares (also shown in Table 6-2) is set to zero or multiplied by 2 (rounded to next highest integer).

Budget Impact: the decisions not to provide a spare or to use a spare stocking safety factor of 2 are assumptions that should be reviewed by Project management.

For activity at the OSF, MTTS has two components: time-to-service and OSF-AOS round-trip.

PM ~~days~~hours per month per component can estimated from:

$$T_{Month}^{PM} = N \times \frac{MTTS}{MTBM_{PM}} \times 732_{Month}^{Hours} \tag{6-7}$$

This parameter can be used to estimate required PM staffing at the OSF. For example, if a team of M people is needed to correct each failure, the total number of FTE hours per month is $T_{Month}^{PM} \times M$.

Some examples of these parameters are given in Table 6-2.

Unit	Worksite	N^{op}	$MTBM_{PM}$ (Hours)	MTTS (Hours)	Spares Min	Spares Rec	T^{PM} (Hrs/Month)
Antenna (Major)	OSF	80	45 000	240 + 48	0	0	375
Antenna (Minor)	AOS	80	2 500	24	0	0	562
FE assembly	OSF	80	10 000	120 + 12	1.0	2	773

FE Cryo Compressor	OSF	80	20 000	24 + 12	0.1	1	105
BE Assembly	OSF	80	10 000	40	0.3	1	234

Table 6-2: Example Preventive Maintenance Intervals (Illustrative Only)

Most preventive maintenance procedures will be executed without interrupting regular array operations (i.e. individual antennas). However, some work will require taking the entire array off-line for a fixed interval, as assumed in Section 5.5. Although this section has focused on hardware components, preventive maintenance time will also be needed for software work (i.e. installing and testing new software modules).

6.6 Potential Single-Point Failures

Special attention must be given to sub-systems that could create single-point failures, including: power plant, AOS-OSF fiber connection, correlator, and master LO system. These systems should be designed and built for maximum durability. Appropriate procedures, with enough spare parts, should be put in place to return such sub-systems to operation as quickly as possible.

Particular attention must be given to systems that require continuous power supply to avoid damage which would be expensive to rectify (e.g. specific cryogenic ~~systems).~~ systems such as maser system). For these sub-systems, reliable UPS systems are mandatory with durations as long as 24 hours in case of failure during a major winter storm at AOS.

Special attention should also be given to the various computing sub-systems, where single-point failures (e.g. archive RAID system) might be minimized by providing hot spares and data mirroring technology.

6.7 Maintenance ~~Facilities~~Process

6.7.1 General Considerations[15]

From a maintenance process perspective, the aim of preventive maintenance is to minimize the amount of required corrective maintenance. Once implemented, a preventive maintenance program can usually be executed by well-trained technicians. Conversely, corrective maintenance requires a set of more highly skilled (and therefore more expensive) team of engineers and technicians who can diagnose and correct problems as quickly as possible. For such teams, preventive maintenance usually has lower priority than dealing with the current problem – naturally, fixing today's problem and returning the system to service has higher priority than preventing tomorrow's problem. It is also a reality that corrective maintenance (and development) and preventive maintenance breed different cultures, that attract different people. Given these tendencies, there is a danger that preventive maintenance will be deferred or not executed if it is the responsibility of the corrective maintenance team alone.

[15] For a more extensive discussion of the topics presented in this section, see http://www.ergonetz.e/maintenance/index_e.html

To deal with this issue, it is common practice in industrial settings to create a preventive maintenance group that has only one mission: execute and extend (or develop, as necessary) preventive maintenance procedures. Initial procedures are delivered by manufacturers and/or revised by the integration team. The PM group then executes these procedures. This group does not have to be large, but it does have to be substantially independent of day-to-day corrective maintenance and technical development activities. ALMA should adopt a similar process.

Development and/or verification of preventive maintenance procedures is initially the responsible of the Systems Engineering and Integration teams, and later the responsibility of the various Technical Services groups. Once developed, preventive maintenance execution is the responsibility of the Maintenance Group within Technical Services. However, the leader(s) of each engineering team remain ultimately responsible for the performance and condition of their sub-system. Indeed, the Maintenance Group leader must work with the Antenna and Electronics leaders (see Section 10) to develop and/or extend the preventive maintenance program.

Two kinds of preventive maintenance strategies shall be implemented:

- **Time-based** – execute some service (e.g. greasing bearings) at pre-determined intervals;
- **Condition-based** – monitor the performance or condition of various components, and service them when performance or condition is seen to degrade. Inspection occurs at regular (e.g. daily, weekly, monthly) intervals.

Thus preventive maintenance plans must include maintenance schedules as well as inspection schedules.

6.7.2 Maintenance Process Management

An integrated, cross-group maintenance & problem reporting system, also called **Computer Maintenance Management System (CMMS),** shall be implemented at the OSF. All ALMA problems (hardware, software, operational) will be reported, tracked, and closed using this system. All maintenance activity will be logged and time-stamped using this system. If possible, activity cost (number of staff-hours, cost of parts, etc) should be recorded. The system will allow searching by LRU number.

An LRU inventory control system shall be implemented. The location and status of each LRU will be maintained within this system. An LRU identification system will be implemented to facilitate this activity.

The CMMS system will track LRU inventory by accessing the ID numbers embedded in each Monitor and Control interface.

6.7.3 Local Facilities

There will be no specialized maintenance facilities at the AOS. Maintenance at the AOS will be limited to simple maintenance tasks that are not efficiently performed elsewhere, or are inextricably linked to the site, such as fiber optic connectors. The hostile environment combined with the impaired capabilities of maintenance staff at the high altitude prohibits any other maintenance activities.

The bulk of the Joint ALMA Observatory maintenance work shall be done at the OSF, limited mainly by the need for specialized tools, skills or knowledge. The OSF-based engineering & technical staff will be sized to provide sufficient preventive & corrective maintenance (including LRU repair in most instances). Detailed estimates of required staffing levels are provided later in this document.

Complete verification of LRUs in Chile is required. As a consequence, the OSF shall have the same test infrastructure available in-house as was used for acceptance testing during the construction phase of ALMA. Either the test setups used during construction can be moved to the observatory in Chile or new test facilities can be acquired. These test setups will allow the qualification of all locally (or remotely) repaired equipment before storage as spare or installation in array, significantly reducing the likelihood that a faulty spare is installed in the system.

Budget Impact: is complete verification of all LRUs in Chile really possible? What about drive motors for antennae, encoder systems, secondary units, etc? Cost implications (staff and equipment) must be analyzed.

For electronic repair, standard mounting tools, for example as may be required for ~~SMT~~surface mount technology (SMT) support, together with qualified staff shall be available at the OSF. Repairs requiring specialized mounting techniques, e.g. wire bonding and ball grid arrays, are not performed at the OSF. Such work will be either contracted out to dedicated companies or handled by the remote maintenance facilities operated by the Executives.

6.7.4 Remote Facilities

As stated above, it is assumed that the Joint ALMA Observatory in Chile will not maintain the facilities and personnel necessary to perform all LRU repairs. ~~Rather, it is assumed that the Executives will maintain such repair facilities as part of their Operations contribution.~~

By implication, repair of some LRUs will be done in repair centers maintained by and/or contracted to the Executives. Contracted service providers could include the original manufacturers, designated laboratory groups, and/or commercial firms. Note that it is unlikely that the original manufacturers will be willing or able to repair their products indefinitely. Over time, the Joint ALMA Observatory (either directly or through the Executives) will likely find it necessary to perform this class of repair in-house.

When an LRU leaves the OSF for repair, it shall be checked-out using the inventory control system. When it returns to the OSF, it shall be checked-in using the inventory control system. The warehouse management team shall be responsible for this check-out and check-in activity.

Budget Impact: ~~the mission, management structure, staffing, budget, location, days per year used, interfaces to ALMA Observatory in Chile, and relationship to ARCs are all TBD for the remote facilities.~~which LRUs fall into this category, what facilities are needed, and the costs of these activities is all unclear at this draft. ***The current draft contains no budget estimates for this major activity,***

6.8 System Performance Diagnostic Software

During both the CSV and Operations phases, it must be possible to access and display jointly the archived monitor information and correlator visibilities. This functionality is necessary to evaluate and diagnose array performance issues. Capabilities must include the ability to plot visibility for one or more antenna pairs against hour angle, elevation, declination, sidereal time, front-end temperature, IF total power, etc. It must also be possible to plot monitor data against derived quantities such as antenna-based complex gain or closure errors, monitor data against visibilities, or derived quantities against derived quantities.

These same functionalities will be needed in real-time for on-line diagnostics.

7 ALMA Science Operations Concepts & Deliverables

This section collects and summarizes various ALMA science operations policy and deliverables concepts. As these issues are still under discussion by the Executives and the ALMA Board, it can be assumed that some or all of this section will need revision.

7.1 Overall Operations Concepts

The following high-level operations concepts can be extracted from the Project Plan, Chapter 6:

- The overall science operations concept is based on supporting service observing, driven by the need for flexible (dynamic) scheduling to match approved programs with actual observing conditions.
- The Joint ALMA Observatory shall be responsible for the long-term monitoring and consistent calibration of the array.
- All observations will be executed in the form of Scheduling Blocks (SBs), each of which contains all the information necessary to schedule and execute the requested observation.
- The default output to the astronomer shall be reliable images that can be readily used for scientific analysis.
- The Joint ALMA Observatory shall be responsible for the ~~quality of the data products and delivery to the ALMA archive.~~data product quality.
- Science observations are carried out 24 hr per day, except during planned maintenance and instrumental downtime or when weather conditions prevent acquisition of scientifically useful data and/or endanger ALMA personnel or equipment.
- All science and calibration raw data are captured and archived.
- Eavesdropping, in which the astronomer monitors the progress of observations in real time, and preset breakpoints in the program are planned capabilities in accord with the recommendations of the ASAC, although neither capability will be available at the start of Early Science operations (see Section 5.4).

7.2 Proposals, Projects, ObsUnitSets, and Scheduling Blocks: A Quick Overview

At regular intervals (TBD), users will be invited to submit **observing proposals** using ALMA-provided software tools. These proposals will be reviewed for scientific merit and technical feasibility.

Accepted proposals are converted into **observing projects**. Using the same software tool as before, each successful user adds to their observing project whatever additional information is necessary to allow their proposed targets to be observed. In general, users do *not* directly create or revise observing procedures.

Based on this high-level user input, the software tool then creates **observation unit sets (ObsUnitSets)** that join all the individual observations needed to achieve a desired science goal. For example, some science goals may only require a single main-array configuration while others may require multiple configurations coupled with both ACA and total power observations. The observations contained within a unit set may take months to complete, depending on conditions and array configuration required. The ultimate output of an observation unit set is a single image produced by processing all the individual observations. Intermediate images (e.g. main-array only, ACA only) may be possibleproduced for some unit sets.

Finally, for scheduling purposes, the software tool splits each observation unit into a series of typically 30 – 60 minute observation sets known as **scheduling blocks (SBs)**. Splitting observation unit sets in this manner allows ALMA to adapt more quickly to changing conditions. In essence, an SB is the smallest schedulable unit.

Fundamentally, an SB contains an observing script, i.e. a sequence of low-level commands to be executed by the ALMA system. This script will be automatically generated for standard ALMA observing modes by the ALMA-provided observation preparation software. External users will not be able to modify this script. If users wish to execute an observation sequence not supported by the general tools, they must provide a scientific and technical justification in their Phase 1 observing proposals. If such proposals are accepted, ALMA staff will work with the users to plan and execute the observations.

An observing project is considered to be completed when when:

- all scheduling blocks have been completed, the quality assurance process has demonstrated that the resultant data has acceptable quality, and all data products have been delivered;

completed orand/or all unexecuted or incomplete scheduling blocks have been administratively removed from the scheduling queue.

- execution queue, and all data products have been delivered.

Queue administration is discussed further in Section 7.7.3.

7.3 ALMA Archive and Operational Data Flow

In the ALMA context, the archive is not just a science archive,archive – it is a system for capturing and managing all information necessary for the scientific and technical operation of ALMA.

The ALMA central archive shall be located in Chile. It will contain all raw and calibration data, all monitor (engineering) data, all data products produced by the standard pipeline (i.e., calibrated images and/or spectra, reduction and imaging scripts), logs of all operations carried out by the array, and environmental and site-condition data. It will also contain copies of all accepted observing proposals (including scientific justification) along with observing and reduction scripts as submitted and as run.It will act as the regional archive node (see below) for the Chilean ALMA user community. It will not be accessible by the Virtual Observatory (VO).

The ALMA science pipeline shall be co-located with the ALMA central archive.

Initially, the central archive will be installed and commissioned at the OSF. Within 24 months,18 – 24 months after the start of Early Science Operations, it will migrate to the Santiago Central Office. After that migration is completed, an archive node remains at the OSF to capture all data and information being produced by ALMA. The OSF node shall be connected to the central archive via a high-high-bandwidth Internet connection, so that all data produced by ALMA flows to the central archive immediately.

It must be possible to operate fully the ALMA main and compact arrays even if the Internet link between the OSF and all external sites (including the SCO) is broken.

Each Executive shall receive and maintain a complete copy of the central archive. It is expected that these copies will be hosted at the ALMA Regional Centers and are henceforth called the ARC archive nodes. The~~ initial delivery and activation of the~~se ARC archive nodes ~~is still TBD but shall occur~~will be delivered, commissioned, and activated as soon as possible after the ~~start of Early Science operations.~~SCO node is commissioned and activated.

The ARC archive nodes will be synchronized with the central archive on two different timescales. Small information sets (e.g. proposal and observation preparation information, science pipeline images) shall be replicated to the ARC nodes immediately. Larger data sets (e.g. unprocessed correlated *uv* data, engineering data stream) will be moved via physical media (probably hard-disks).

Budget Impact: very high-bandwidth Internet links between the central archive and the ARC nodes are not foreseen for Early Science operations and therefore not included in the budget projections. Such links are estimated to cost 500 K€ per year per ARC node, i.e. approximately a factor of 10 greater than managing and transporting hard-disks. A system based on hard-disk transport has the additional advantage of being easily and cheaply expandable to accommodate increased data volume (e.g. higher correlator sample rates). Note that the system design does not prevent changing to high-bandwidth Internet connections whenever funding becomes available.

All proposal and observation preparation information shall flow from external users to the central archive via ALMA-supplied software tools over the Internet. This information shall then be replicated immediately to the OSF and ARC archive nodes.

ALMA archival raw and processed data for specific programs will be available to the PIs of those programs as soon as possible after the data are physically present in the regional archives. Archive data will be available to the general user community via a VO-compliant interface from the ARC nodes after relevant data proprietary periods are completed. Users will receive assistance with archive use from ARC staff. User registration shall be required for archive use.

The ALMA central archive will not in general contain user created data products. It is possible at some future date that ALMA may choose to host the output of large, homogeneous projects with wide scientific value, such as large area and/or deep surveys. The criteria and process for accepting such data product sets is TBD. In this area, ARC archive nodes may choose to adopt different policies as part of their enhanced scientific services.

The ALMA archive should contain a list of science papers published that used ALMA observations. Entries in this list should be linked to the actual papers (i.e. by providing links to the Astronomical Data Service, ADS) as well as all Archive information related to the original program under which the data were obtained.

Budget Impact: Archive services for the Chilean astronomical community are currently unspecified. Needs discussion, direction from Executives.

7.4 Calibration Plan

It is the responsibility of the Joint ALMA Observatory to obtain the minimal set of calibration data necessary to monitor system performance, maintain archive quality, and process the scientific data. A calibration plan will be prepared and published. Time necessary to acquire calibration observations based on the official calibration plan will not be charged to individual users. These standard calibration data shall have no proprietary period and will be available to all users from the ARC archive nodes as soon as possible after those nodes receive the data.

Individual PI science observations may require observing mode specific calibration data. These data will be acquired automatically as part of normal science operations. Time used to acquire these data shall be included in the operational overheads charged to the users (as are other mandatory operational tasks, e.g. target acquisition). These data shall have no proprietary period.

Individual users may wish to obtain additional calibration data. If so, they must propose appropriate observations during Phase 1 and detailed observing project information during Phase 2. Time required to obtain such additional calibration data will be charged to the users. As for standard calibration data, these additional calibration data shall have no proprietary period.

7.5 Scheduling

The Joint ALMA Observatory requires scheduling activities that occur on different time-scales. These activities are related to both science and technical operations. The ADO is responsible for coordinating and executing these activities, which include:

- **Long-Term Schedule (LTS):** scientific capabilities, array configuration plan, and time-blocks assigned to science and technical activity over a scheduling cycle.
- **Medium-Term Schedule (MTS):** detailed array configuration schedule based on anticipated monthly weather, spectrum of accepted programs, personnel task force available on-site, preventive maintenance and antenna/receiver update. Comes after Phase 2, as real details are needed. Must be coordinated between Science Operations and Technical Services departments.
- **Short-Term Schedule (STS):** actual selection and execution of science observations, with appropriate calibration. Domain of Dynamic Scheduler, but must be monitored to react to system failures, etc. During Early Operations, it seems likely that the Astronomer-on-Duty will have to monitor this process closely while the dynamic scheduling system is being tuned.

Fundamentally, the LTS is a list of time blocks for technical activity and scientific observations. Technical activity includes commissioning & science verification, testing, preventive maintenance and Board-approved upgrades. Technical time is requested and coordinated by the Joint ALMA Observatory Director. During scientific blocks, observations will be queue scheduled – except in rare circumstances, science users will not visit ALMA in person.

A related long-term scheduling concept is the **Long-Term Queue (LTQ),** i.e. the list of all observing projects available for dynamic scheduling and execution. Projects enter the LTQ as a result of the Phase 1 proposal review and scheduling process. Projects leave the LTQ when they are completed or terminated administratively. The LTQ management process is described in more detail below.

The antenna transporters are critical Medium-Term and Short-Term schedule resources. With only two (2) transporters available, antenna movement (between OSF and AOS as well as between AOS pads) must be coordinated carefully. Some contingency for unscheduled maintenance must be built into the transporter schedule. The manager of the Array Operations Group (see Section 9.2) shall ~~It would be desirable to appoint one person~~act as Transporter Scheduler[16] with the authority and responsibility to manage the transporter schedule.

For programs that require coordinated main array and ACA observations, care must be taken to ensure that the time separation between these observations is not excessively long. This issue affects the LTS, MTS, and STS processes and requires further discussion.

Comment: the usefulness of weather forecasting and its possible impact on short-term scheduling as a function of frequency should be investigated at some point.

7.6 ALMA User Support Homepage and Helpdesk

To maximize user accessibility, it is critical that ALMA establish a centralized presence on the Internet. It is not necessary that ALMA information content be centralized, only ALMA information interfaces.

ALMA shall establish a single-point contact **Web homepage**. The proposed address is www.alma.int.[17] This homepage will provide links to:

- general system information and status;
- information about how and when to apply for observing time;
- information about how to use the Archive, including how to locate and retrieve data;
- user software tools and manuals;
- generic descriptions for ALMA deliverables;
- off-line data processing modules & documentation.

The Chile-based Department of Science Operations shall maintain this Web site in coordination with the various ARCs.

ALMA shall establish an e-mail based single-point contact **helpdesk** system. The proposed address is **alma-helpdesk@alma.int**. E-mail to this address will flow to a central server, where it will be time-stamped, logged, and assigned a unique ID automatically. The user will receive an automatic response acknowledging the receipt of the message.

The Deputy Director of Science Operations will work with the ARC Managers to set-up an e-mail monitoring and response ~~process.~~

[16] aka *Lord of the Transporters* (with apologies to J.R.R. Tolkien)

[17] The ALMA Project is currently investigating the possibility of obtaining this domain name. If that name is not available, some other suitable name will be found.

process. On a rotating basis, someone will be assigned to helpdesk triage, either in Chile and/or at the ARCs (TBD). The assigned triage person will review incoming messages on a regular basis (every few hours during slow periods, several times an hour during peak periods). If possible, the assigned triage person will answer the message and close the event. If not possible, the help request will be re-assigned to an appropriate staff member. The assignee can re-assign the ticket but in general the triage process should be precise enough to pass help requests to the right person a very large percentage of the time. All interactions with users and/or between internal staff members will be logged in a worklog area.

As resources permits, ALMA should implement thatthe concept of a **user portal**, i.e. a dynamically created Web page for each user that contains links to dynamically created summaries of all information about that user's programs, raw data, and pipeline products in the ALMA Archive. To connect to their pages, users would login from the ALMA user support homepage.

User documentation and tools that are common across the entire ALMA community (e.g. the Observing Tool and associated user manual) shall be served to the community from Chile, with the exception of Archive services. Once Archive services are available from the ARCs, all Archive information and data shall be served from the ARC.

It is expected that each ARC will want to have it's own Web site, to help maintain separate identities and provide region-specific information. Whenever possible, these Web sites should not duplicate information maintained centrally.

7.7 Phase 1: Observation Proposal Management

7.7.1 Proposal Submission

The proposal submission process is region-based.

For each scheduling period, a Call for Proposals (CfP) for the Joint ALMA Observatory will be issued. The CfP will inform the community about the available capabilities and provide necessary information and material for the submission of electronic proposals.

In support of Call for Proposals preparation, the Joint ALMA Observatory Director must publish on a regular basis a description of the expected scientific capabilities of the Observatory over the next 12 – 18 months, as well as the anticipated technical activity schedule over the next scheduling cycle.

Proposers will be required to provide enough scientific & technical information to allow a complete and thorough evaluation of their proposal. In particular, they will be required to request time-on-target including standard operational overheads. In general, they will not be required to request time for calibration data, if the published ALMA calibration plan provides for adequate calibration either included in the standard observing mode, or in staff-controlled calibration sessions. Proposers may elect, however, to request additional time to acquire additional calibration data specific to their program.

Proposers may also be required to provide evidence that detailed plans exist for complete and timely data analysis and that the proposing individual or team will have sufficient time and resources to carry out the analysis. This requirement is still under discussion.

Proposers shall be required to submit observing proposals (see Section 7.2) using software tools provided by the Joint ALMA Observatory. Functionality will be provided to allow scientific & technical justification, target specification, time-on-target plus overhead specification, sensitivity and integration time estimation, atmospheric conditions requirements (e.g. transparency and seeing), etc. All ALMA proposers shall be required to use the same software tools during any given proposal submission cycle.

Each proposal shall identify a single individual who will act as the Principal Investigator (PI) and will be responsible for the proposed scientific program. The PI shall be the contact person for all communication with the Joint ALMA Observatory.

Once submitted, all proposals will be assigned automatically a unique identification code.

Proposals for observing time may be submitted by scientists from any institution. Observing time allocated to each proposal will be counted against the allocation of the Executive (i.e. ARC) that processed and reviewed the proposal. Each Executive may implement its own policy regarding proposals from outside their regions.

The local ALMA Regional Center (ARC) shall be the primary interface between proposers and the Joint ALMA Observatory during proposal submission. On behalf of the Joint ALMA Observatory, each ARC will issue the Call for Proposals and any supporting material and tools to its regional user community. The ARCs shall provide all user support during this submission process, consulting with the Chilean operations staff as necessary.

The Joint ALMA Observatory Science Operations department shall be responsible for issuing to the ARCs the material and software tools necessary to support Phase 1 activities.

The Call for Proposal release schedule, proposal submission deadlines, and observing period cycles are all TBD. The Joint ALMA Observatory may wish to set submission deadlines such that ALMA proposers are not also submitting proposals to other observatories simultaneously.

Comment: this section describes the steady-state goal. During the first few proposal review cycles, a less complex process would be highly desirable from the operations development perspective for two reasons: there will be no ARC Archive nodes until 24 – 30 months after Early Operations and the ALMA Phase 1 submission and management tools will be immature and untested in a real operational environment. Chances of operational success would be improved if the process were centralized around one international program review committee supported by the ALMA science operations staff in Chile. ARC staff would still provide user support for proposal preparation. The experience gained during this initial phase would make roll-out of the more distributed region based system more straightforward and less expensive in terms of staff required and staff stress.

7.7.2 Proposal Review

Before each proposal review cycle starts, the Joint ALMA Observatory Director must provide a LTS status report to the Executives and the ALMA Board. This report shall provide an estimate of scientific time available for each Executive in the next scheduling cycle as well as a list of incomplete high-priority programs sponsored by each Executive. Additional TBD details, such as issues with local over-subscription and under-subscription (i.e. too many or too few scheduled observations than available time in some parts of parameter space), will be provided. Based on this report, each Executive may decide to terminate one or more incomplete high-priority programs to make more time available to new programs, as discussed above.

Submitted proposals will be peer-reviewed in the following manner, as specified by the ALMA Board. Proposals will be ranked primarily by their scientific merit and importance of their contribution to the advancement of scientific knowledge. Each Executive will convene a regional program review committee (PRC). Each regional PRC will provide scientific ranked and recommended time allocation for each submitted proposal in their region. In general, PRCs should **not** reject proposals completely, so that it is possible to populate a wide-range of potential observing parameter space. Proposals should be rejected at this stage only if they fail to meet minimal scientific credibility.

The PRC membership selection and review processes are the responsibility of the Executives. However, it is assumed that all regional processes and committees will use the same ALMA-provided tools and infrastructure.

Each PRC makes a recommendation to its Executive. Each Executive may then chose to review and/or modify the PRC recommendations. In addition, each Executive should designate some programs as high-priority, corresponding to 10 – 20% of their available time. These programs will, in general, be kept in the Long-Term Queue until they are completed, even if this takes several scheduling cycles. Programs without high-priority status shall be terminated automatically at the end of each scheduling cycle.

Each Executive shall have the option of terminating high-priority programs from their specific region at the end of each scheduling cycle. When a high-priority program is terminated, the Executive shall provide the affected PI and the ALMA Director with a termination rationale and effective date.

All proposed projects approved by the Executives are forward to the International Program Review Committee (IPRC) after the Executive review & revision process is completed. The IPRC is responsible for producing the final merged list of newly accepted observing projects. The policies and exact merging process ~~is~~are still TBD.

~~COMMENT:~~Comment: the ALMA Board should make recommendations about: (1) how Chilean programs are selected and what their priority is relative to all other programs; (2) how duplicate or overlapping programs are dealt with by the IPRC; and (3) where Chilean programs are submitted, how they are managed, and who provides Phase 1 support.

7.7.3 Proposal Scheduling

After the work of the IPRC is completed, scientifically ranked list of potential projects will be forwarded to the Joint ALMA Observatory Director for merging into the **Long-Term Queue (LTQ)**. During the merging process, the Observatory Director shall ensure that to the greatest extent possible, observing parameter space (i.e. required LST, atmospheric conditions, and array configuration) is covered uniformly and not unduly over-subscribed at any point.[18] Fulfilling this requirement may

[18] During Phase 1, over-subscription refers to the number of hours requested vs. the numbers of hours available. During LTQ merging, over-subscription refers to the number of hours scheduled vs. the numbers of hours

require modifying the priority of or rejecting a small number of programs, subject to the review and approval of the IPRC. The Joint ALMA Observatory Director shall also ensure that the Observatory is meeting its fractional time allocation obligations to the Executives, averaged over some TBD interval.[19]

In coordination with this LTQ merging process, an Observatory-based technical review process will be executed. The technical review occurs after the scientific review as it is anticipated that the number of programs recommended by the IPRC will be less than the number of submitted proposals, reducing the technical review load on the Observatory staff. It is expected that only a few proposals will be rejected on technical grounds at this point.

~~Once the revised LTQ is ready for release, the~~The ALMA Director shall notify the ALMA Board and the Executives of LTQ revisions on a quarterly (TBC) basis. PIs with newly approved or terminated programs shall be notified by the Joint ALMA Observatory and provided with information about the Phase 2 process (especially completion deadline). Concurrent with this notification, each PI shall receive PRC and/or IPRC comments (if any) in written form.

PIs ~~will~~shall also be provided with estimated **program execution likelihood (PEL).** Each program in the LTQ shall be assigned a PEL ranging from 1 (high-priority, guaranteed) to 0 (never). This likelihood is based on the combination of IPRC priority and requested stringency[20] – programs with low IPRC priority but loose stringency have larger PEL than programs with low IPRC priority and tight stringency. PEL is indicative only and thus requires only one decimal place. Further discussion of PEL is beyond the scope of this document.

During normal operations, the Joint ALMA Observatory Director may introduce minor modifications into the LTS or LTQ to accommodate unforeseen scientific, operational or technical activity. The Joint ALMA Observatory Director shall notify the ALMA Board and the Executives whenever such revisions are necessary. In particular, at the discretion of the Joint ALMA Observatory Director, ALMA operations may be interrupted to observe sudden unpredictable astronomical events of high scientific importance. If several individuals or groups submit requests of equal scientific merit concerning the same event, in principle the request received first will be given priority.[21]

7.8 Phase 2: Observation Preparation

After the Phase 1 process is completed and the LTS revised, PIs with newly approved observing projects will be invited to complete an observation preparation phase. For projects with low PEL, some PIs may elect not to complete Phase 2. All other PIs shall provide all additional information not supplied during Phase 1, required to schedule and execute individual observations. This information

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available. In both phases, the number of hours available is a function of scheduled technical time, requested wavelength, and required atmospheric conditions. The latter is a statistical parameter that varies with time of year.

[19] An interval between 6 and 18 months is recommended.

[20] Stringency has been defined by the ASAC as the inverse fraction of time that a certain set of atmospheric conditions can be met relative to all time available for science observations.

[21] The ALMA Board may wish to adopt a policy of Target of Opportunity pre-allocation, i.e. specific groups allowed to observe certain events (e.g. GRBs) to the exclusion of other groups.

shall be submitted using software tools provided by ALMA. The local ALMA Regional Center (ARC) shall be the primary interface between proposers and the Joint ALMA Observatory during this observation preparation phase, consulting with the Chile-based operations staff as necessary.

Using software tools and documentation provided by ALMA, each observing project will be broken down into one or more observing unit sets, which in turn consist of sets of scheduling blocks (see Section 7.2). The ARCs shall provide direct user ~~support, except for Chilean users who will receive support from the Chilean science operations staff.~~support to users in their respective regions. In the event of sudden unpredictable Target of Opportunity events, Phase 2 support will be provided by the Chile-based science operations staff.

All submitted Phase 2 material will be reviewed by staff from the appropriate ARC. It is ~~an~~a Joint ALMA Observatory goal to automate this review as much as possible.[22] If problems are found, users will be notified and asked to revise their material. Until such problems are resolved, user-provided observations will not be scheduled for execution.

Once all Phase 2 material is found to be correct, it will be certified and released to ALMA operations in Chile for scheduling and possible execution. Users shall be allowed to modify their observing projects after this point only after seeking and receiving approval from their local ARC. In general, such changes will be discouraged as they can have an unpredictable impact on the scheduling queue.

For each scheduling cycle, the Joint ALMA Observatory shall establish a Phase 2 completion deadline. All programs with incomplete Phase 2 submission at the deadline will be removed from the LTQ and not executed.

Budget Impact: it is unclear who provides Phase 2 support to the Chilean community.

7.9 Phase 3: Observation Execution & Problem Resolution

~~Only~~In general, only observations corresponding to programs approved by the Executives and inserted into the LTQ by the Joint ALMA Observatory Director shall be executed. Exceptions include unforeseeable Target of Opportunity observations (e.g. local supernova) and Director's Discretionary Time programs (see Section 7.17).

Observations will be prioritized primarily by scientific ranking, followed by technical requirements such as array configuration, source position, atmospheric conditions, and hardware status. All other things being equal, priority will be given to programs closest to completion. To fulfill these conditions, ALMA will use a **dynamic~~al~~ scheduler** to select potential observations and present them to the operation staff for approval and/or execution. During science time, observations are carried out 24 hours per day unless weather conditions prevent the acquisition of scientifically useful data.

The use of sub-arrays for the same target in the same SB may be allowed if supported by science & technical cases at Phase 1. Possible use-cases include: simultaneous observation of time-variable target

[22] It is likely that such an automatic validation system will need refinement during Early Science operations. During Early Science operations, it is possible that most submitted Phase 2 material will have to be reviewed manually.

in two or more frequencies, simultaneous observation of two or more active Solar regions, and use of frequency bands not available for all antennas. Note that the ACA will largely observe independently of the main array.

When an SB problem is detected at run-time, execution for this SB and all other related SBs will be temporary blocked. ALMA staff at the OSF will investigate the problem as soon as possible. Problems caused by system failures (e.g. software bugs, hardware failures) will be corrected without interaction with the relevant ARC or user. If the OSF staff cannot identify and fix the problem promptly, the appropriate ARC will be notified of the nature of the problem and OSF recommendations for problem resolution (if any). The ARC will then work with the relevant PI to fix the problem. The ARC will then re-validate the SBs and release them for scheduling. The on-duty Chile-based staff will not work directly with end-users except under extraordinary circumstances (e.g. important time-critical observation).

If an SB is executed under better than expected conditions, it may be possible that the user-requested sensitivity is reached before the user-requested integration time is reached. If so, execution of that SB shall be terminated and the execution of another SB initiated.

In the event of a sudden and unexpected astronomical event that requires immediate observation, the ALMA Director shall have the authority to interrupt normal operations and take whatever measures are necessary to complete the observation.

7.10 Post-execution Data Processing

Data processing pipelines will support calibration and science data reduction. For science data, they will provide calibrated images for science analysis. For calibration, the pipeline will apply appropriate phase and amplitude calibration data. It will apply ~~pass-band~~bandpass calibrations to spectral line observations and any other meteorological information as may be provided (such as measurements with an FTS).

Phase, amplitude, pointing and focus calibration results will be fed back to the observing process in near-real-time, allowing immediate correction of antenna pointing errors and the adjustment of dwell times on target and phase calibrator to respond to rapid changes in atmospheric phase noise. These results will be made available to the ALMA operator and to the scheduler as well. Whenever the calibration data identify hardware problems, a status report will be logged at system level for maintenance purposes, and made available to both the operator and dynamic ~~scheduler, with the relevant information also submitted for incorporation into the ALMA archive.~~ scheduler.

For standard observing modes, the science data pipeline will operate in fully automated mode. The products will be calibrated images. All the data previously obtained since the project started will be available for processing, i.e. from ACA or different array configurations, including total-power data for measurements of zero and short spacings. This means raw data and calibration data obtained in different array configurations, including total power data for measurements of zero and short spacings.

7.11 Quality assurance

The Joint ALMA Observatory shall be responsible for delivering data obtained under user specified atmospheric conditions and within normal end-to-end system performance ranges.[23] To achieve this goal, the Joint ALMA Observatory shall implement a quality assurance program with the primary goals of monitoring both short-term and long-term system performance to ensure that system problems are detected and corrected promptly. This quality assurance program will be based on the calibration plan that specifies what observations must be acquired and at what intervals to monitor system performance. Such monitoring will include flux, baseline, and pointing accuracy as well as other things such as focus and antenna tracking.

Information on data quality and array performance will be made available via the Web to Joint ALMA Observatory staff as well as external users.

The Joint ALMA Observatory shall not be responsible for undetectable user errors generated at Phase 2 such as faulty source coordinates, inadequate frequency setting (e.g. wrong redshift), inadequate integration times (or conversely, inadequate sensitivity limits), or inadequate uv plane coverage, unless the error occurred due to faulty information or tools provided by the Observatory.

The following multi-tier quality assurance program shall be adopted:

- **QA0** – near-real-time verification that system performance is nominal. Assessment performed by astronomer and array operator on duty at the OSF. Assessment based on output of quick-look system and calibration pipeline.
- **QA1** – execution & analysis of SBs that measure current system performance. Required SBs are specified in observatory calibration plan. Data produced by SBs are processed automatically without deconvolution. Pipeline processing produces a number of TBD QA1 parameters (specified in the calibration plan). QA1 parameters are stored in the ALMA central archive and replicated to all ALMA archive nodes immediately, so that they can be examined and/or analyzed by staff members at any ALMA site. These QA1 parameters are compared to analogous historical QA1 parameters to detect both sharp (i.e. from day-to-day) and gradual (i.e. slowly with time) changes in system performance. Text and/or graphical reports shall be generated automatically and updated every few hours and/or on-demand. Password protected, Web-based reports are preferred. These reports shall be reviewed at the start of each OSF operations shift or as required for problem investigation.
- **QA2** – science pipeline quality control check. Output of the science data pipeline will be assessed for quality via a TBD mixture of expert-scientist reviews and automated checks. Parameters, procedures and related reports are all TBD, but associated with calibration plan. All computed QA2 parameters should be stored in the ALMA central archive, associated with relevant images, and replicated to all ALMA archive nodes. Based on this QA2 review, observations may be scheduled for re-execution or re-processing. Results of this process will

[23] More specifically, the ALMA Observatory Director is responsible to the Executives via the ALMA Board for the delivery of data of verifiable high-quality.

be used to guide pipeline development. It is recommended that a limited number of staff astronomers based in Chile be responsible for this task to ensure homogenous, consistent reduction and calibration of the data and uniform data quality.

- **QA3** – detailed examination of images delivered by ALMA to end-users or images produced by users using ALMA-provided off-line data processing tools. 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 Joint ALMA Observatory for investigation and resolution.

In regard to QA0, quick-look system requirements should be driven by operations and technical diagnostic needs. Quick-look output should be stored for some TBD period in the ALMA central archive. From there, it should be replicated to other ALMA archive nodes as soon as possible to allow review by other ALMA staff members.

As part of the quality assurance program, the Joint ALMA Observatory will develop and maintain a variety of calibration information including but not limited to: phase & flux calibrator catalogs, pointing source catalogs, spectral line catalogs(s), antenna gain curves, and primary (polarized) beams. This information will be publicly available from the ALMA Archive through a TBD interface.

Software tools will be developed, including pipeline modules, to facilitate this activity. Without such tools, the number of staff required for quality assurance would have to be substantially increased.

Comment: responsibility for developing more detailed QA requirements is unclear but should be tied to the development of the calibration plan.

7.12 Science Deliverables

Joint ALMA Observatory shall deliver the following items to its scientific user community:

- *uv* plane astronomical source and calibration data
- Processed images, with supporting processing and quality assurance information
- Off-line data reduction software, including user support for installation and basic usage
- Software tools for proposal and observation preparation, including appropriate user documentation
- ALMA Users Manual

Raw (correlated) *uv* data shall not be delivered automatically to the end-users after the central pipeline system is operational – these data will be available to end-users from their ARC archive node as soon as the data arrive from Chile. The time-scale for availability after observation depends on the TBD Chile-ARC data transmission method. When new *uv* data become available in the ARC, the end-user shall be informed automatically via e-mail. All information necessary for *uv* data processing shall be available from the archive, as discussed further below.

Before the pipeline is operational (i.e. during the first 18 – 24 months of Early Science operations), the raw *uv* data shall be delivered to the user automatically, along with any necessary calibration data and system logs. Users shall also have access to ALMA-produced data processing and imaging modules as well as cookbooks for these modules.

Although it is a high-level ALMA goal to deliver reliable images ready for science analysis, the Joint ALMA Observatory shall not guarantee that delivered images are suitable for all science projects. To assure archive uniformity, the ALMA science pipeline shall process data in a standardized and ALMA-controlled manner. If users require non-standard processing, they can use ALMA-~~provided~~ provided off-line data processing modules or their own preferred data processing system.

Science image creation and/or delivery shall be triggered the following events:

- **Observation unit set completed:** a science image shall be created whenever the following conditions are met: (1) ObsUnitSet completed; (2) ObsUnitSet calls for image creation (not always true); and (3) all ObsUnitSet data have been ingested into ALMA central archive. After these conditions have been met, a science image shall be created within 12 hours and stored in the ALMA archive. After the Chile-based quality assurance process (see above) has been completed, the PI shall be informed via e-mail that a new image is available for retrieval via the Internet. For complex observation unit sets (e.g. combinations of main array and ACA observations), it is a goal to deliver intermediate images whenever possible.
- **Project completed:** when an entire project has been completed or terminated and all images have been produced, a data package on physical media (e.g. DVDs) containing all images for that program as well as TBD supporting information (e.g. observing & processing scripts) shall be created and delivered to the PI. Package definition and organization shall be the responsibility of the Chile-based data management staff. At the start of Early Operations, media mastering and delivery will be done by Chile-based staff. Within 24 – 30 months, this activity will transition to the ARCs.

7.13 Data Analysis Support

The ALMA Regional Centers will provide basic data analysis support, ranging from simple advice, to provision of appropriate data analysis documents and products (which could be standard pipeline or off-line data processing software packages), to in-depth assistance for users who require it. Within the core ALMA operations budget, it is not foreseen to create data analysis centers which users can visit physically to receive data analysis support. Each Executive may decide to provide such services to its region.

7.14 Data Rights

Successful proposers will have exclusive access to their scientific data for ~~the duration of a one (1) year~~a TBD proprietary period (see above). Once this period expires, data will be made publicly available in the archive. This period shall start on the date that data have been provided to the PI in a form suitable for scientific analysis.

Comment: the exact process of applying the proprietary date and which data objects it refers to is still TBD.

Exceptions may be granted for complex or long-term projects, such as thesis projects, surveys or projects requiring many array configurations, or projects that require main array and ACA combinations. In these instances, the proprietary period may start once all the relevant data have been collected. Such extensions will not be granted automatically. Extension requests must be sent to the Joint ALMA Observatory Director for review and decision, on behalf of the ALMA Board.

All calibration data, whether generated from Joint ALMA Observatory observations or PI observations, will be made public immediately.

ALMA staff shall have access to all data at all times as necessary for technical analysis and tuning of system performance. ALMA staff shall not use ALMA data for scientific purposes for which they are not PI until the appropriate proprietary period has ended.

7.15 Publications[24]

Publications based on observations obtained with the Joint ALMA Observatory should mention on the first page

> *Based on observations obtained for program XXX at the Joint ALMA Observatory, jointly operated by the European Southern Observatory and the National Radio Astronomy Observatory (managed by Associated Universities, Inc. on behalf of the National Science Foundation and National Research Council of Canada).*

where XXX should be replaced by the program ID.

Publications based on Joint ALMA Observatory archival should mention on the first page

> *Based on archival observations obtained with the Joint ALMA Observatory, jointly operated by the European Southern Observatory and the National Radio Astronomy Observatory (managed by Associated Universities, Inc. on behalf of the National Science Foundation and National Research Council of Canada).*

The Joint ALMA Observatory and/or the Executives shall set up a system to record information about publications that make sure of ALMA observations, including number of pages, author(s), project identification, region, ~~etc.~~

etc. This information should be available in the ALMA archive, linked to the actual article (e.g. via the Astronomical Data System, ADS), and linked to all other information in the Archive about the original program(s).

7.16 Monitoring of ALMA Time Use

The Joint ALMA Observatory Director will monitor the distribution of ALMA observing time. Statistics will be provided to the ALMA Board on an annual basis, showing the distribution of time among the ALMA partners, the Republic of Chile, and other countries. This analysis shall be done in two ways – by summing the time over all participating partners taking into consideration PI origin only and by summing the time over all participating partners taking into consideration PIs and Co-Is. The

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[24] These statements shall be expanded eventually to acknowledge NAOJ and/or the Japanese funding agency, as the Japanese Executive requests.

amount of technical time used for commissioning, maintenance, upgrades, and system tests will also be indicated, as well as down-time due to technical problems (by major sub-system) and weather.

7.17 Director's Discretionary Time (DDT)

On behalf of the Executives, the ALMA Board controls and manages ALMA observing time. The ALMA Board should consider granting the Joint ALMA Observatory Director up to 5% (TBC) of the available science time. Proposals for this Director's Discretionary Time shall in general fall into one of the following categories:

- observations on a hot and highly competitive scientific topic
- follow-up observations of a program recently conducted from ground-based and/or space facilities, where a quick implementation should provide break-through results
- pilot projects of a somewhat risky nature to test the feasibility of a program
- time-critical observations that must be scheduled and completed before the next IPRC meeting; and could not be foreseen at time of previous IPRC

Requests for DDT time will be submitted to the Joint ALMA Observatory Director for review and a time allocation decision. The DDT submission and review process is TBD. Preference will be given to projects likely to result in a timely publication. PIs granted DDT time shall follow the normal Phase 2 procedures established by the Joint ALMA Observatory and their local regional center. Within one month of the receipt of their final data release, PIs will be required to submit a report to the Joint ALMA Observatory Director describing the outcome of their project and how the data are being used.

The Joint ALMA Observatory Director shall provide an annual report to the ALMA Board summarizing how Director's Discretionary Time was allocated over the last year.

7.18 Target-of-Opportunity (ToO) Guidelines

Target of Opportunity (ToO) events fall into two categories.

7.18.1 One-time ToO events

At random intervals, unforeseen astronomical events occur that require urgent and/or immediate observation. Observations of such events shall be handled within Director's Discretionary Time.

It shall be possible to submit proposals to observe such random requests at any time using the standard ALMA proposal submission system. It shall be possible to flag proposals as DDT/ToO. Immediately after submission, the following people will be notified via e-mail: the Joint ALMA Observatory Director, the Deputy Director of Science Operations, the chairperson on the International Program Review Committee, and the Astronomer-on-Duty (AoD) at the OSF. The AoD will contact the Joint ALMA Observatory Director and/or Deputy Director of Science Operations and request permission to proceed. If permission is granted, the AoD will prepare the appropriate scheduling blocks and execute the ToO observation.

Comment: these processes need further development to include multiple requests to observe the same event, competing proposals from different Executives, etc.

7.18.2 Generic ToO events

Certain classes of astronomical transient events occur at frequent and unpredictable intervals (e.g. gamma ray bursts). Investigators wishing to study such events as a class shall be required to submit proposals at the time of regular proposal submission. Such proposals must specify number of expected events per scheduling period, execution time required per event, and total requested time. Generic ToO proposals will be reviewed in the same fashion as other non-time critical proposals. If approved, Scheduling Blocks shall be submitted that contain a complete description of the observation except for target coordinates.

When an event occurs, the PI (or designee) will submit a request for observation (i.e. trigger) via e-mail to a TBD address. This address shall be monitored at TBD intervals by the Astronomer-on-Duty at the OSF. Each trigger e-mail must specify which SB(s) to execute and the corresponding target coordinates. When a trigger is received, the AoD will enter the proper target coordinates into the specific SB and execute the SB as soon as possible.

The PI of an accepted generic ToO program will have priority to obtain the observations provided that a specific request is submitted in time. The observing strategy should be the one approved by the PRC, i.e. users cannot post facto request different system configurations. Allocated time will be regarded as a strict offer limit which might well be not totally used in the absence of enough triggers.

Any request with exactly the same scientific goal and aiming at observing the same object, presented by other groups at the time the event occurs, shall be rejected, except if it is a coordinated project in collaboration with the PI of the accepted ToO program.

7.18.3 ToO Data Delivery

Once a ToO observation has been completed, the raw (correlated) *uv* data will be placed in an ftp area accessible to the program PI. This FTP area will also include any additional calibration data, meta-data, or information necessary to process the science observations. Data pipeline products shall not be included in this distribution, to minimize data delivery time. Once the FTP area is ready, the AoD will notify the user that the data and accompanying information are available, which account to use, and how to obtain the password (e.g. must call someone in Chile operations).

7.19 Narrative: A Typical Proposal Lifecycle

This section illustrates one of the workflows implied by the concepts above. Many of the details may change during implementation.

A user submits a proposal using the Observing Tool, (OT) a software tool provided by the Joint ALMA Observatory. The proposal data is stored in the central Archive node and copied to the regional Archive nodes. When submitted, the proposal is assigned a unique ID and assigned to an ALMA Regional Center (ARC) for support. At some TBD time, each proposal is reviewed by the appropriate regional Program Review Committee (PRC) and assigned a grade, priority, and recommended time. The PRC may attach comments. This information is then based to the International Program Review Committee (IPRC) for final review. The IPRC may attach additional comments. After the IPRC review, the Joint ALMA Observatory updates the Long-Term Queue (LTQ) and users are notified about the outcome of the review, including comments from the review committee(s).

Users with programs in the LTQ are then requested to use the OT to provide additional TBD information. This information flows to the central Archive node and then out to the regional nodes. After the user is finished, the ARC staff reviews the resultant project (e.g. Scheduling Blocks, etc.). At this point, all SBs have status "defined". As part of the review, a Support Abstract is written summarizing the main features of the program and a Support History Log is opened. If the project is OK, it is made available for short-term scheduling and possible execution by changing SB status to *Ready*. If problems are found, the ARC staff log the problem in the Support History Log, change the SB status to *Error*, and then iterate with the user to fix the problem. Note problems can be technical (i.e. user used OT is bad way or OT produced bad result) or operational (i.e. ARC review reveals better way to execute program).

Released Scheduling Blocks can be executed at any time without further intervention from users or ARC staff. If a problem is found at run-time, execution of the SB and all associated SBs is halted – their status is changed to *Error*. A SPR is opened and assigned to the relevant ARC. The ARC must then work with the user and/or the OT development team to fix the problem. Once the problem is resolved, the SPR is closed and the SB(s) is/are re-released for scheduling. The *Ready/Error/Ready* cycle is handled by status flags attached to each SB.

The data produced by an SB passes through a multi-tier quality assurance (QA) process. During execution, system status and observing conditions are monitored (QA0) by the Astronomer-on-Duty (AoD). Any non-nominal conditions are recorded in the Observing Log – the SB ID number is used as an association key. After execution, the resultant Execution Block (EB) is assigned a QA0 status (e.g. *Good*, *Bad – Do Not Repeat*, *Bad – Repeat When Possible*). Each EB is also given a QA1 status (based on processing of telescope calibration data) and QA2 status (based on processing of science data). The QA1 is given by the AoD, while the QA2 status is given by the Data Management astronomer monitoring the central pipeline output.

At some point, the science pipeline is triggered and an image is produced, along with a variety of QA parameters and other meta-data. This image package is replicated to the various Archive nodes but not released until it is reviewed. Once reviewed, QA2 information is attached and the user is notified that an image is available. This *Hold/Review/Release* cycle is controlled by status flags. Once the state changes to *Release*, the user is informed via e-mail. If the user has questions or finds something wrong, s/he contacts the regional ARC. If necessary, a SPR is opened and assigned to the Chile-based pipeline QA team for review and resolution.

Each day, the Chile-based Program and Data Management (PDM) staff review program status. At this point, some programs are declared *Completed* (all SBs executed) or *Terminated* (no more SBs will be executed, for TBD reasons). Low-priority programs will be terminated at the end of each semester. Whenever a program is completed or terminated, a TBD process is executed to close out the program and deliver any outstanding information to the user.

On TBD basis, the Observatory Director will provide reports about system performance and time allocation. These metrics must be defined and built into the system so basic reports can be generated on demand for arbitrary periods. Many of these reports will be based on actual execution history, e.g. time-on-target vs. technical overheads, time-on-target per region vs. total available time, etc.

8 ALMA Director's Office

This section describes the tasks and personnel of the ALMA Director's Office~~(ADO)~~ in 2012. A ramp-up analysis is provided in the Budget ~~Summary~~Overview section.

The ADO supports the activities of the Joint ALMA Observatory Director and Deputy Directors. ADO activities are split between the Santiago Central Office (SCO) and the Operations Support Facility (OSF) near San Pedro de Atacama.

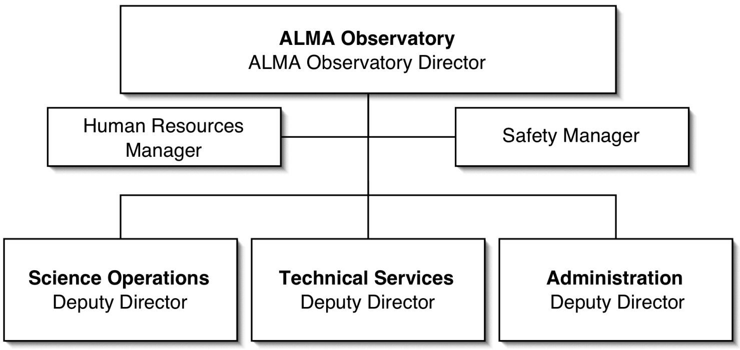

Figure 8-1: ALMA Director's Office Organization

At both the SCO and OSF, there are offices for the Director and the Deputy Directors. Each person is provided administrative support as follows: Director ~~(1 LSM, 5x2,~~(ISM, 5+2, SCO), DD Admin ~~(1 LSM, 5x2,~~(LSM, 5+2, SCO), DD Science operations ~~(1 LSM, 8x6 = 2 employees,~~(ISM, 5+2, OSF), and DD Technical Services ~~(1 LSM, 8x6, 2 employees,~~(ISM, 5+2, OSF). It is assumed that the DD Admin will spend most working days at the SCO while the DD Technical Services will spend most working days at the OSF. Since there are Science Operations activities in Santiago and at the OSF, the DD Science Operations will spend time in both places on a regular basis. The Director will spend all his time on planes, per normal practice.[25]

As discussed in Section 5.1, the ALMA **Safety Manager** (ISM, 5+2) reports directly to the Joint ALMA Observatory Director and is therefore part of the ADO. The Safety Manager has an office at the OSF.

As discussed in Section 11.2, the ADO shall include a **Human Resources Manager** (LSM, 5+2) hired to implement and manage the human resource policies agreed upon by the Executives. This HR Manager shall be based in Santiago, report directly to the Joint ALMA Observatory Director, and have administrative support (1 LSM, ~~5x2,~~5+2, SCO). It is expected that the HR Manager will visit the OSF frequently.

[25] A small joke to see if anyone is still reading at this point. Seriously, the Director will split his/her time between Santiago and the OSF.

It is assumed that the Executives will take the initiative in the area of education and public outreach activity, in coordination with the Joint ALMA Observatory Director.

Budget Impact: a separate Chile-based Education & Public Outreach officer has ***not*** *been included in this plan.*

The ADO shall create and coordinate an internal, Web-based newsletter for the purpose of disseminating news between all the various ALMA science and technical operations groups. Input to the newsletter will come from both Chile-based and ARC-based teams. This newsletter shall be updated at least at monthly intervals, perhaps more frequently as warranted by breaking news. This newsletter is intended to be informal in nature.

On a more formal basis, the ADO ~~will coordinate~~shall be responsible for the production of a bi-monthly report. This bi-monthly report shall contain TBD input from all ALMA operations teams and all development teams funded by operations. This report shall be made available to all ALMA staff as well as the ALMA Board and Executives.

9 Department of Science Operations

This section describes Department of Science Operations responsibilities and staff in 2012. A ramp-up analysis is provided in the Budget ~~Summary~~Overview section.

The Department of Science Operations (DSO) has the following major responsibilities:

- Array operations, including monitoring & coordination of all AOS activity
- Observation scheduling: Long-Term, Medium-Term, and Short-Term
- Observation execution
- Data processing and quality assurance
- System performance quality assurance
- Maintenance and execution of Calibration Plan
- Delivery of data to end-users, ALMA Archive, and ARCs
- ~~ARC support to Chilean user community~~
- ~~Procedure verification and modification~~
- ~~Staff training~~

DSO operates 24 hours per day, 365 days per year with activities at both the OSF and the SCO. OSF-based DSO activity is coordinated by the Astronomer-on-Duty (AoD, see below). Daily meetings are held by video between the OSF and SCO to coordinate DSO activities. Weekly meetings are held by video between the DD of Science Operations and the ARC Managers to coordinate science operations activities.

All DSO activity at the AOS will be executed from the OSF. No DSO personnel ~~will~~are foreseen to work at the AOS.

~~Comment:~~Budget Impact: research-grade astronomers form the core of the DSO staff. Recruiting such talented and motivated astronomers to Chile for ALMA for long periods may be relatively harder than recruiting equivalent staff for ESO or NSF/AURA optical facilities in Chile simply because the pool of radio astronomers is about 10 – 15 % of the pool of optical astronomers. Dealing with this challenge may require flexibility in staff contractual terms & conditions as well as innovative operational infrastructure and processes.

9.1 Management Structure

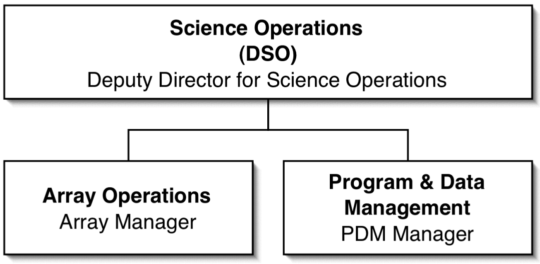

Figure 9-1 Department of Science Operations Organization

Science operations activities in Chile are the responsibility of the Department of Science Operations, under the leadership of the Deputy Director for Science Operations (see Figure 9-1). The Science Operations department will be split into the following groups:

- **Array Operations (AOG):** responsible for day-to-day array operations, meteorological site monitoring, and AOS activity monitoring. The AOG is also responsible for antenna transporter scheduling.
- **Program & Data Management (PDM)**: responsible for day-to-day management of observation execution, data processing, archive operations, and data quality control, as well as coordination with ARC science operations activities.

Although all Chilean science operations tasks could occur at the OSF, this is not necessarily required, desired, or cost effective. Defining the exact locations and distribution of these tasks within Chile, as well as the development of the necessary interfaces to the ARCs, is the responsibility of the Joint ALMA Observatory Director and DD Science Operations.

Video and intra-net links between the OSF and SCO will be maintained with sufficient bandwidth for high quality communications. High-bandwidth video and IP links will also be possible between the OSF, SCO, and ARCs.

The Science Operations staff consists of three types of personnel:

- **Staff Astronomers:** internationally recruited astronomers with approximately 50/50 functional/research splits. Functional time is split between the OSF~~(25%)~~ and the SCO ~~(25%)~~. Rest of time is dedicated to research activity at the SCO. Staff astronomers will be expected to make regular visits to the ARCs. ~~One staff astronomer is the **PDM Group Manager**.~~Staff astronomers work task-specific turnos as described below.
- **Array Operators:** Local Staff Members responsible for day-to-day array operations at the OSF. ~~One array operator is the **AOG Manager**.~~Array operators work 8+6 turnos.

- **Data Management Operators:** Local Staff Members responsible for day-to-day data management tasks. DM operators work 8+6 turnos if assigned to OSF or normal Monday-Friday schedules if assigned to the SCO.

9.2 Array Operations Group (AOG)

~~Assigned to~~The Array Operations ~~is one AOG Manager (LSM, 5x2) who is~~Group is lead by the **AOG Managers** (LSM, 8+6, two employees). One manager shall be designated leader and the other deputy. The AOG Managers are responsible for managing the array operators as well as for developing and maintaining the weekly AOS activity schedules. The AOG managers shall also act as Transporter Schedulers (see Section 7.5), and are ~~schedule, including~~responsible for maintaining the antenna transportation schedule, in coordination with ~~the Antenna Team and other Technical Services groups. The AOG Manager oversees also~~all other Observatory operations teams. Finally, the AOG Managers oversee the array of meteorological instruments monitoring atmospheric conditions.

Array operations are a round-the-clock activity requiring three operators per day, each working an eight hour shift. ~~This is equivalent to~~Operators shifts are expected to be 0700 – 1530, 1500 – 2330, and 2300 – 0730, 0700 – 1530 (i.e. 8.5 hours per shift, 30 minute overlap). There are 1095 shifts per year. Assuming 150 shifts per year per operator, eight (8) operators (LSM, ~~8x6) are required.~~[26]

8+6) are required.[27] The AOG Managers shall be able to act as on-duty operators; however, they will not regularly act as on-duty operators.

Budget Impact: this array operator staffing model assumes that in steady-state one (1) person can operate the main array and the ACA. If this is not true, the number of required operators doubles. During Early Science operations and/or ACA commissioning, it is almost certain that one array operator per shift will not be sufficient. This issue needs further discussion.

The array operator executes SBs approved by the AoD; checks logging of observing parameters, equipment status, equipment safety and monitors progress of the observations. The operator also monitors traffic between the AOS and the OSF, monitors AOS activity for developing safety problems, notes improper operation of array equipment, and monitors metrological conditions at the AOS, ordering antennas to be stowed when conditions become marginal. The operator works closely with the antenna transport group to facilitate movement of antennas and determination of new baselines. All personnel working at the AOS must communicate their activity to the array operator at regular intervals to prevent accidents from happening. The array operator shall have the authority to halt array operations to prevent harm to visitors, personnel, or equipment.

[26] ~~An alternative is two 12-hour shifts per day. This reduces the number of shifts per year to 730 and the number of operators to 730/150 = 5. This is the model used at the IRAM interferometer.~~

[27] An alternative is two 12-hour shifts per day. This reduces the number of shifts per year to 730 and the number of operators to 730/150 = 5. This is the model used at the IRAM interferometer.

9.3 Program & Data Management Group (PDM)

There shall be one (1) Program & Data Management (PDM) group manager. The PDM manager is an ISM astronomer, expected to spend alternate work weeks at the OSF and SCO.

9.3.1 Program Management Tasks

Program management consists of a number of closely related near-real-time tasks performed at the OSF, including:

- Science and calibration observation scheduling & execution
- Calibration Plan execution
- Site conditions metrology monitoring
- Scheduling Block (SB) execution & tracking
- SB execution problem detection & resolution (in conjunction with ARCs)
- Data quality assurance (QA0 and QA1)
- Observing program progress tracking

Related non-real-time activities (performed at OSF or SCO as determined by PDM Manager)SCO, as needed) include:

- Schedule (LTS/MTS/STS) management
- Long-Term Queue (LTQ) management
- User documentation management (various software tools, data reduction system)
- Phase 1 (observation proposal) technical reviews
- Phase 1 and Phase 2 (observation preparation) support to ARCs as necessary
- Web content management
- ALMA instrumentation & systems development

• Provision of core ARC services to Chilean user communityExecution of these activities shall be coordinated by a staff astronomer designated as the **Science Program Manager** (ISM). This person typically works 8 or 9 days at the OSF, followed by 2 work-days off as compensation time for OSF weekend work, followed by 10 week-days at the SCO designated as research time.

The near-real-time tasks at the OSF are the responsibility of the Astronomer on Duty (AoD). The Astronomer on DutyAstronomer-on-Duty (AoD). The Astronomer-on-Duty is responsible for the transfer of Scheduling Blocks from the Archive to the array operator for execution on the array.[28] The AoD orchestrates calibration observations to meet observers' goals and to achieve consistency with

[28] It is assumed that SBs are validated for accuracy and completeness by ARC astronomers during the Phase 2 process.

archive specifications. The AoD may, for example, implement pre-observations, as required, to select a fast switched phase calibrator The AoD ensures the validity of site characterization data entering the dynamic scheduler; the AoD has the authority to overrule the dynamic scheduler should the AoD think Scheduling Blocks inappropriate for current weather or technical conditions have been selected. The AoD has access to site characterization data that may be used to judge dynamic scheduler operation. The AoD reviews quick-look system output, assesses system performance and assigns a completeness grade to executed SBs. As necessary, the AoD reports system problems via a cross-Observatory problem reporting system.

A high-level ALMA goal is to automate most of these tasks so that under normal conditions so the AoD will be simply monitoring system performance. It can be anticipated that during Early Operations, the duties of the AoD will be more manually intensive than later when the system has been completed.

AssumingThere shall be two (2) AoD shifts per day, thereday. These shifts are expected to be 0800 – 2030 and 2000 – 0830, i.e. 12.5 hours per shift, with a 30-minute overlap between shifts. There are 730 AoD shifts per year. These shifts shall be staffed by a combination of Joint ALMA Observatory staff astronomersin Chile shall spend 25% of their functional time as AoD at the OSF (55 shifts).[29] (The other 25% functional time is spent on Data Management tasks, see below.) To cover the entire year, 13 staff astronomers (ISM, 8x6) are needed, if no other support is available.

Budget Impact: it is further assumed that ARC staff astronomers involved in providing core ARC scientific support services shall visit Chile on a regular basis and participate in PDM activity, acting as AoDs on a regular basis. These visits arebased in Chile and at the ARCs. Involvement of ARC staff is critical for developing and maintaining system proficiency as well as good relations and communication between the Chile-based and ARC-based ALMA staff.

ESO/VLT experience suggests that at least 3 – 4 OSF trips per year would be optimalper individual ARC astronomer are necessary to maintain proficiency and good esprit de corps. Assuming eight (8) OSF shifts per trip, four (4) staff astronomers per ARC visiting the OSF in any given year, and an average of 3.5 trips per year per ARC staff astronomer, each ARC can cover 8 x 4 x 3.5 = 112 OSF shifts per year. For two (three) ARC model, this is a total of 224 (336) OSF shifts per year. *For the three ARC model these are almost half of all AoD shifts per year in steady state.*

Visiting ARC astronomers shall be required to spend two (2) days at the SCO before traveling to the OSF to prepare for OSF shifts and interact with off-shift staff at the SCO. Since there are two AoD shifts per day, it would be desirable to have DSO and ARC staff astronomers on opposing turno shifts so that the ARC staff astronomer has support for re-familiarization (if necessary).After the initial training cycles for ARC astronomers, this frees up time for Chilean staff astronomers to focus on their other functional responsibilities (e.g. LTS management, procedure development, documentation maintenance, Chilean ARC support, liaison trips to ARCs, quality assurance development, etc). In short, DSO staff astronomers are not only responsible for AoD shifts. Therefore, the number of DSOTo be conservative, it is assumed that ARC staff will serve 200 OSF AoD shifts per year, roughly evenly

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[29] Total possible work-days per year: 52 x 5 = 260. Assumed number of holiday and leave days: 30. Schedule-able work-days: 230. Staff astronomers are hired to spend 50% of their time on function duties, half at OSF (230 x 0.25 = 57 days) and half at SCO (57 days).

split between day and night shifts. Furthermore, it is assumed that each ALMA staff astronomers based in Chile assigned to AoD should not be reduced just because ARCduty will serve 56 shifts per year. [30] Thus, 530/56 ≈ 10 staff astronomers are assigned AoD shifts.needed in Chile.

In addition to these Chile-based and ARC-based staff astronomers, a small cadre of post-doctoral fellows based in Chile would be highly desirable. Such fellows would bring fresh scientific ideas and perspectives into the Chile-based team on a regular basis as well as providing additional FTEs to release long-term staff for other activities. A regular changing pool of fellows would also provide a conduit to return ALMA knowledge back to the broader community (as well as increasing the number of truly expert users). Finally, the Observatory could opt to retain the best fellowsit is likely that fellows with previous ALMA operations positions will be strong candidates for staff positions in Chile or at the ARCs. The ideal arrangement would be 4 – 6 fellows on three-year contracts: two (2) years in Chile and one (1) year at an ARC. In principle, this ARC year could be served at any of the ARCs. It would be highly desirable to provide some small amount of guaranteed ALMA observing time to these post-doctoral fellows, extracted from Director's Discretionary Time.Alternatively, the third year could be spent at any institute in the ALMA community, with little or no functional responsibilities beyond sharing ALMA expertise with the host institution.

It is assumed that the functional effort of a fellow is equivalent to 40% of a Chile-based staff astronomer; thus, 4 – 6 fellows provide the equivalent work of two (2) staff astronomers. This additional effort shall be used to support the non-real-time activities listed at the start of this section (e.g training of ARC astronomers, procedure development, documentation maintenance, liaison trips to ARCs, quality assurance development, etc.), either by direct participation of fellows or by relieving staff astronomers from AoD duty so they can focus on non-real-time tasks.

Budget Impact: if no post-doctoral fellows are hired, two additional staff astronomers will be required.

Each ALMA staff astronomer based in Chile shall be required to make one (1) trip per year to one of the ARCs, to improve understanding of ARC based processes and issues and to exchange information. The Program Manager will assure that these visits are distributed roughly evenly across all ARCs. Typical visits will last 4 – 5 working days with two days for travel.

9.3.2 Data Management Tasks

Data management consists of a number of closely related semi-real-time tasks including:

- ALMA central archive/pipeline technical operations

[30] Total possible work-days per year: 52 x 5 = 260. Assumed number of holiday and leave days: 30 (note that NRAO and ESO have different policies in this regard). Schedule-able work-days: 230. Staff astronomers are hired to spend 50% of their time on function duties: 115 work-days. Functional time is split between OSF and SCO duties. OSF function time includes actual time as AoD plus compensation time. Each OSF turno contains 8 days of duty time plus 2 days of compensation time for weekend work and two additional compensation days if on night shift. Increasing number of OSF turnos per astronomer decreases number of required astronomers. Here, 7 OSF turnos per astronomer are assumed, implying 7 x 8 = 56 days at OSF plus 7 x 2 = 14 or 7 x 4 = 28 compensation days, for a total of 70 or 84 functional days for day or night shift, respectively. The remaining functional days (45 or 31) are spend at SCO working on non-real-time program and data management tasks.

- Post-observation data processing & imaging
- Calibration (including post-calibration as discussed in the ALMA Calibration Plan)
- Distribution of data products to end-users (at least in 2007 – 2009)
- Database content management
- Data quality assurance (QA1 and QA2)

These tasks shall be co-located with the central archive/pipeline system. AtTherefore, at the start of Early Operations, these tasks will be executed at the OSF. Within 24 months, these activities will move to the SCO with the central archive/pipeline system. As stated early in this document, it is assumed that the central archive node and the OSF archive node will be connected by a large enough bandwidth connection to minimize data transfer time between the two nodes.

Budget Impact: this central archive/pipeline transition scenario implies that data management technical staff will have to follow the turno system until the central system is moved to the SCO. To be reviewed.

PDM staff astronomers spend 25%roughly 20% of their time on data management tasks, mostly in the area of science data quality assurance (see next section for further discussion).(specifically QA1 and QA2, see Section 7.11). In the first 24 months of operations, PDM astronomers will complete these activities at the OSF. Once the central archive/pipeline system moves to the SCO, PDM astronomers will complete their quality assurance activities in Santiago.

COMMENT: analogous to ARC staff astronomers and PM activities, ARC data analysis scientists should make regular visits to Chile to participate in DM activities. This concept will be further developed in a later draft.

*COMMENT: it might be desirable to assign one staff astronomer as the Quality Assurance Manager. To be considered further in a later draft.*To coordinate these activities, one staff astronomer shall be designated the **Data Manager** (ISM). During Early Operations, the Data Manager will follow the same turno schedule as the Program Manager. Once data management activities shift to the SCO, the Program Manager will be based at the SCO and work Monday to Friday schedule, making physical trips to the OSF only as needed.

Technical data management tasks are performed by two (2) archive/pipeline operators per OSF turno (LSM, 8x6,8+6, OSF, 4 employees) and one database specialist/content manager per turno (LSM, 8x6,8+6, OSF, 2 employees). Exact task definition & distribution is TBD. Analogous to the staff astronomers, theseDetailed knowledge of the ALMA archive system and its underlying database technology will be required. These technical staff members shall work initially at the OSF and then later migrate to the SCO.

9.3.3 System PerformanceManagement Tasks

PDM is also responsible for related system performance tasks such as:

- Schedule (LTS/MTS/STS) management

- Long-Term Queue (LTQ) management
- Calibration plan maintenance & development;
- Calibrator selection & monitoring;
- Array performance & validation data products;
- Array re-configuration support (base-line calibration, delay calibration, pointing re-calibration, beam shape monitoring, antenna surface re-setting)

These activities are supported by twoTo perform these activities, there shall be three **ALMA System Astronomers**(one per shift) (ISM,8x6, SCO/OSF, 23 employees). These astronomers are expected to become the Joint ALMA Observatory system ultra-experts, providing advice and assistance to operations & development teams through the Observatory and the ALMA user community. Essentially, these astronomers continue the work of the CSV team. They do not act as AoDs on a regular basis.

team with the additional responsibility of managing the LTS and LTQ. These astronomers are required to spend 88 days at the OSF (11 x 8 days) with 22 compensation days (for weekend work). Alternative schedules are possible since some tasks can be completed at the SCO. Unlike the AoD or array operators, it is not necessary to have a System Astronomer present at the OSF every day of the year.

Comment: the responsibilities of the System Astronomers and System Engineers (discussed in next section) are complementary – these staff members should work as a coordinate team, not as separate teams.

10 Department of Technical Services

This section describes Department of Technical Services responsibilities and staff in 2012. A ramp-up analysis is provided in the Budget ~~Summary~~Overview section.

The Department of Technical Services (DTS) has the following major responsibilities:

- Preventive maintenance for major array sub-systems, including: antennas, instrumentation packages, LO, correlator, and site monitoring equipment
- Corrective maintenance (i.e. fault isolation and correction) for same sub-systems
- Performance trend analysis for same sub-systems
- Problem reporting & tracking
- Antenna transportation and array re-configuration
- System configuration status tables
- Maintenance procedure verification & modification
- IT support, including system, network, and database administration
- Procurement, development and/or maintenance of maintenance & engineering software
- Training and certification of technical staff

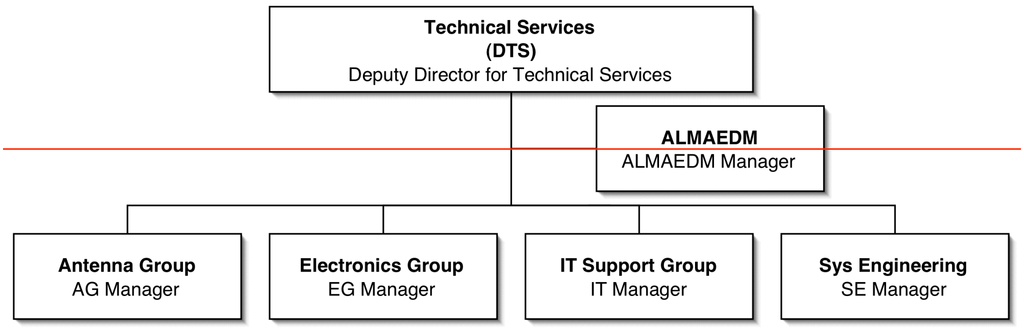
*~~The~~Budget Impact: the DTS is **not** responsible for, nor staffed to support, major technical development activity. The Joint ALMA Observatory will rely on engineering & technical expertise from the Executives to carry out major system development activity.*

~~COMMENT:~~Budget Impact: work done at AOS requires minimum two-person teams working fixed time intervals. Introduces overhead into response model and FTE estimates. Must verify that FTE estimates have taken this into account.

Budget Impact: staffing estimates in this section assume a high-degree of similarity between analogous main array and ACA components. If this is not the case, significant additional technical staff may be required.

Budget Impact: exact details of staffing (numbers and skill mix) in the Antenna and Electronics teams may have to be revised once the nature of the production systems under their responsibility is clarified.

10.1 Management Structure



~~Figure 10-1: Department of Technical Services Organization~~

Technical services activities in Chile are the responsibility of the Department of Technical Services, under the leadership of the Deputy Director for Technical Services (see Figure 10-1). It is assumed that the main array and the ACA are operated and maintained as a single integrated facility, i.e. there are not separate technical support teams for the ACA.

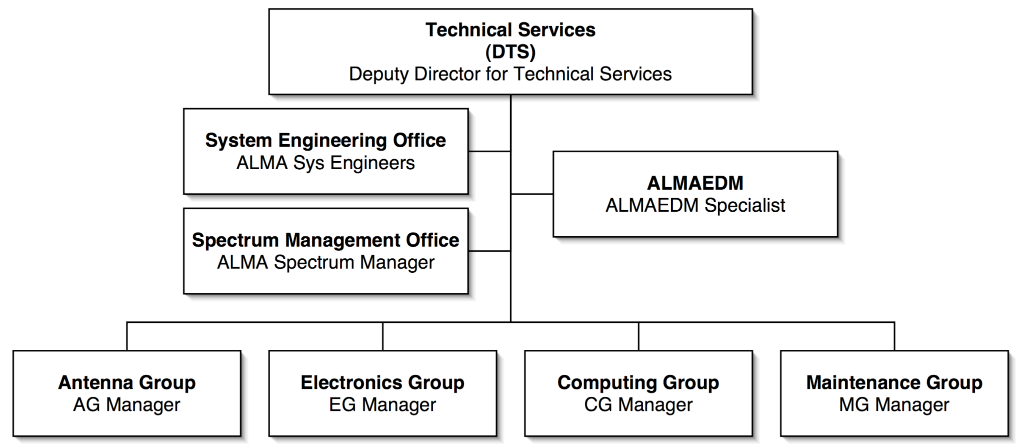


Figure 10-1: Department of Technical Services Organization

The ALMA Electronic Data Management (ALMAEDM) shall be transferred to the SCO at some TBD point. There shall be an **ALMAEDM** ~~**Manager**~~**Specialist** who reports to the DTS DD[31] and is based in

[31] It might be more natural to move the ALMAEDM Manager inside the Systems Engineering Group.

Santiago. This person shall also be responsible for archive and ~~librarian~~library activities at the OSF. Regular visits to the OSF are anticipated.

The Technical Services department will be split into the following groups and offices:

- **Antenna Group (AG):** responsible for day-to-day antenna maintenance and transportation.
- **Electronics Group (EG):** responsible for day-to-day maintenance of front-end instrumentation packages, back-end electronics & communication packages, local oscillator system(s), and correlator(s).
- **Computing Group (CG):** responsible for day-to-day maintenance and support for all IT systems in Chile.
- **Maintenance Group (MG):** responsible for executing and extending preventive maintenance programs developed by Antenna and Electronics groups, as well as related facilities maintenance tasks.
- **System Engineering ~~Group (SEG):~~Office (SEO):** responsible for maintaining ~~system performance &~~operations and development system engineering practices. ~~A related task is array re-configuration support (baseline calibration, pointing re-calibration, beam shape monitoring). This small team~~Essentially, it continues the work of the ~~Construction CSV team.~~System Engineering IPT.
- **Spectrum Management Office (SMO):** responsible for monitoring the electromagnetic environment, especially at radio frequencies, and for administering requests for proposed transmitter installations within ALMA coordination zone.

Each group has a designated manager, as discussed below.

The Technical Services Department is responsible for the maintenance of all major array sub-systems. Daily TSD work begins normally with a daily meeting at 0800 where planned activities and new problem reports are reviewed and prioritized with the Astronomer-on-Duty. All work at the AOS must be coordinated with the on-duty array operator.

Night-time work is not normally anticipated. Exact day-time shifts are TBD.

Comment: the hiring of Chilean undergraduate science and engineering students as co-operants and summer students within DTS should be considered during the development of more detailed operations plans.

10.2 Antenna Group (AG)

10.2.1 Tasks & Personnel

The Antenna Group shall be lead by the **AG Managers** (ISM, engineers, 8+6, 2 employees). One manager will be designated the leader and the other deputy leader.

Antenna Group activity consists of the following tasks:

- **Antenna relocation:** it is currently assumed that four (4) main array antennas will be moved every fourth day, resulting in approximately eight (8) relocation days per month. ACA re-configurations are expected to occur only four (4) times per year, lasting two (2) days each. The Antenna relocation team consists of 11 people:the following personnel: one supervisor (engineer, ISM, 5x2), two drivers (LSM,(LSM,, engineer), two drivers 5x2),(LSM), four antenna mechanics (LSM, 5x2), and 4 helpers (LSM, 5x2).

- **Transporter maintenance:** the antenna transporters will need maintenance once per month, performed by the transporter drivers.out sourced to service provider.
- **Antenna minor (in-situ) preventive maintenance:** each antenna will need preventive maintenance once every 2500 hours. For 80 antennas, this implies 23 preventive maintenance days per month (see Section 6). This work requires one antenna mechanic (LSM, 5x2) and one antenna electrician (LSM, 5x2). *After training, this activity can be turned over to the Maintenance Group.*
- **Antenna major preventive maintenance:** each antenna must undergo a major overhaul once every 45 000 hours, lasting 10 days. For 80 antennas, this implies 16 events per year (~ 16 days per month including AOS-OSF round-trip transport, see Section 6). Tasks include painting, panel adjustment, improvements, etc. During these events, the following people are required: one supervisor (engineer, ISM, 5x2),(LSM), one antenna mechanic (LSM, 5x2),(LSM), and one antenna electrician (LSM, 5x2), and one helper (LSM, 5x2). The antenna must also be transported back and forth between the high-site and the OSF. (LSM). *The Maintenance Group is assumed to participate in this activity.*
- **Antenna major corrective maintenance:** major antenna failures, requiring return to OSF, are estimated to occur once every 45 000 hours and last 5 days.require maintenance periods lasting 5 days, plus 2 days for AOS-OSF roundtrip transportation. For 80 antennas, this implies 16 unplanned maintenance events per year, covering 16 weeks. Depending on scheduled overhauls, these events could be folded into overhaul events. During this week, the following people are required: one supervisor (engineer, ISM, 5x2), one antenna mechanic (LSM, 5x2), one antenna electrician (LSM, 5x2), and one helper (LSM, 5x2). The antenna must also be transported back and forth between the high-site and the OSF.

Taking into account the various activity cycles, the following Antenna group staff per turno is derived:

- one AG Manager (ISM, 5x2)
- two supervisors (engineer, ISM, 8x6 = 48+6 = 5 employees)
- three drivers (trained workers with mechanical background, LSM, 5x2)two drivers (LSM, 8+6 = 5 employees)
- one antenna mechanic (control specialists, ISM, 8x6 = 2specialist, ISM, 8+6 = 3 employees)
- one antenna mechanic (CFRP specialist, ISM, 8x6 = 28+6 = 3 employees)
- two mechanical technicians (LSM, 5x2)8+6 = 5 employees)
- two electrical technicians (LSM, 5x2)8+6 = 5 employees)
- two helpers on turno (LSM, 8x6 = 4 employees)

- ~~two helpers not on turno (LSM, 5x2).~~
- ~~Total group size: 22 employees.~~machinists (LSM, 8+6 = 5 employees)
- two helpers (LSM, 8+6 = 5 employees)

Total group size per turno:14 employees + one on-duty AG Manager.

The Antenna Group has responsibility for developing and maintaining a transporter schedule. As discussed in Section 7.5, this transport schedule must be coordinated with Long-Term and Medium-Term Schedules.

Comment: several antenna related issues require further discussion: (1) the need for additional staff for antenna LRU refurbishment is under investigation; (2) strategies for minimizing antenna round-trips between the AOS and OSF need to be fleshed out ASAP – especially if this could have an impact on antenna design requirements; (3) related to Item 2, more detailed plans for antenna maintenance in-situ need to be developed (or if already exist, need discussion with Ops Group); (4) for things like replacing cabling etc – do we need a temporary antenna barn at the AOS, with ~~O2?~~enhanced oxygen? More input to Ops Group needed here; (5) impact of Japanese systems needs to be re-assessed once current negotiations are concluded.

10.2.2 Required Equipment & Documentation

These activities are supported by two (2) antenna transporters and an assortment of spare parts bought from the ~~Construction~~TBD budget. Required operational equipment is listed in Table 13.2. Estimated total cost: 2525 k€.

10.3 Electronics Group (EG)

The Electronics Group (EG) is responsible for day-to-day maintenance of front-end instrumentation packages, back-end electronics & communication packages, local oscillator system(s), and correlator(s). The EG has responsibility also for servicing of the water vapor radiometry units.

~~Each shift, there is an EG shift leader (electrical engineer, ISM, 8x6 = 2 employees) with overall responsibility for EG activity.~~ The EG shall be lead by the **EG Managers** (ISM, engineers, 8+6, 2 employees). One manager will be designated the leader and the other deputy leader.

10.3.1 Tasks & Personnel – Front-end

The following front-end related activities must be supported:

- **FE preventive maintenance:** within the FE unit, the following sub-units need periodic maintenance: cryo-cooler & associated pumps (10 000 hours = 1.2 years), compressor (20 000 hours = 2.4 years), and control unit. *After training, some of this activity can be turned over to the Maintenance Group.*
- **FE corrective maintenance:** the assumed FE MTBF exceeds 11 000 hours. For 64 antennas, this is equivalent to about 1 FE failure per week. Repair process includes swapping out defective FE modules/components, making repairs at OSF if possible & authorized, shipping modules to Repair Centers if not, and testing repaired modules. Newly installed components/modules must be calibrated and aligned.

- **AOS FE support:** includes AOS on-site FE inspection and FE swapping & transport

To support these activities, the following personnel (per turno) are needed:

- FE Lead Engineer: one (1) engineer per shift (electrical, ISM, ~~8x6~~8+6 = 2 employees)
- Remove/install receivers: two (2) technicians (electrical/electronic, LSM, ~~8x6 = 4~~8+6 = 5 employees)
- Repair/test receivers: two (2) electrical engineers ~~(1 ISM/1 LSM, 8x6 = 4~~(LSM, 8+6 = 5 employees), two (2) technicians (electrical/electronic, LSM, ~~8x6 = 4~~8+6 = 5 employees)
- Cryogenic/Vacuum support: two (2) technicians (mechanical technicians, LSM, ~~8x6 = 4~~8+6 = 5 employees)
- ACA addition: estimated add two (2) electrical technicians (LSM, ~~8x6 = 4~~8+6 = 5 employees) and one (1) electrical engineer (LSM, ~~8x6~~8+6 = 2 employees).

Total FE support staff per turno: 9 (+ 3 for ACA)

10.3.2 Tasks & Personnel – Back-end & Correlator

The following back-end & correlator related activities must be supported:

- **BE preventive maintenance:** modules and fiber optics cables (disconnecting, inspection, cleaning, and re-connecting fiber optics cables). Tasks include: down-converter testing (test bandpass performance ~~once/year/module~~once per year per module or 2.4 modules per week); DTS channels (test ~~BER/data channel/year or 1.2~~Bit Error Rate once per year per data channel or 1.5 antennas (12 channels per ~~antenna)/week;~~antenna) per week; checks on maser/laser synthesizer/high frequency LO ~~once/week;~~once per week; repair of BE equipment in the FE Integration Center; and maintenance & calibration reporting. *After training, this activity can be turned over to the Maintenance Group.*
- **BE corrective maintenance:** modules and fiber optics cables (splicing and connectorizing as necessary at the AOS). For 80 antennas, there will be approximately 1875 BE modules. Assuming MTBF of 8 years, four (4) BE module repairs per week are expected. Repair includes swapping out defective module at the AOS, making whatever repairs are authorized for the OSF, shipping modules not authorized for OSF repair to the appropriate repair facility, and testing modules for complete operation once repaired.
- **Array re-configuration support:** tasks include: re-routing DTS, LO, and M&C fiber cables at AOS TB and disconnecting and re-connecting fiber cables at antenna after antenna move (4 antennas/week)
- **Correlator support**: the preliminary predicted failure rate is one board per two weeks. Diagnostics verifying chip-to-chip, board-to-board, bin-to-bin, and rack-to-rack interfaces as well as internal board operations will be scheduled to run regularly, probably during antenna moves. Fault isolation will occur almost entirely in software, identifying typically one or two boards and possibly a cable as suspect. Restoration of service will be accomplished by board

or other module replacement, in line with the LRU concept. Board-level repairs other than ball array chip replacement will be handled at the OSF.

To support these activities, the following personnel (per turno) are needed:

- BE Lead Engineer: one (1) engineer per shift (electrical, ISM, ~~8x6~~8+6 = 2 employees)
- ~~Scheduled maintenance: three (3) technicians (electric/electronic, LSM, 8x6 = 6 employees)~~
- ~~Unscheduled~~Corrective maintenance (repair): two (2) technicians (electric/electronic, LSM, ~~8x6 = 4 employees) plus one (1) clerk to maintain spare part inventory, track purchase orders & shipping (LSM, 5x2).~~8+6 = 5 employees).
- Support for array re-configuration: two (2) technicians (opto-mechanical, LSM, ~~8x6 = 4~~8+6 = 5 employees)
- Correlator support: one (1) correlator engineer (LSM, ~~5x2)~~8+6, 2 employees) and one (1) correlator technician (LSM, ~~8x6 = 2~~8+6 = 3 employees) (hired and trained during initial correlator installation & check-out).
- ACA Support: an estimated two (2) additional technicians per turno (LSM, ~~8x6 = 4~~8+6 = 5 employees) are needed to support ACA BE modules.

Total BE support staff required per turno: ~~11~~7 (+ 2 for ACA).

Initial training of local hires can be done at regional FE & BE integration centers as needed.

10.3.3 Miscellaneous Electronics Support Tasks

Budget Impact: this section still under development. Some of these items already accounted for in other groups (?). Budget implications are currently not estimated. Needs review & resolution.

The Electronics Group should (?) also support the following systems:

- AOS site monitoring equipment
- antenna servo systems
- programmable logic controllers (PLCs)
- computer numerical control (CNC) equipment
- ~~Visitor Center equipment~~
- vehicle electronics
- radio communication gear
- HVAC proportional integral differential (PID) controllers
- ~~fire alarms~~
- ~~weather stations~~

10.3.4 Required Equipment & Documentation

Hardware necessary to support EGElectronic Group operations is listed in Table 13.2.14.2. Estimated total cost: XXXX k€.

Documents required to support EG activities:

- Documents required from Product Assurance Plan, ALMA-80.11.00.00.001-A-SPE
- Block diagram of data flow from antenna to correlator
- Block diagram of LO and timing reference
- Hardware definition document: enough documentation to build an entirely new module, if necessary: Description, schematics, timing diagrams (as appropriate), BOM, mechanical and cabling drawings, data sheets, listings for firmware, inputs, outputs, explanation of all status and control bits.
- Maintenance document: Common failure modes and action to take, scheduled maintenance tasks, explanation of all status bits and maintenance action to take for each one, a quality assurance procedure that explains how to check every function for complete and correct operation of the equipment, adjustment and calibration procedures.
- Human documentation: manpower, personnel, and training required to support equipment; shipping, storage procedures; and safety, hazard analysis.

10.4 Computing Group (CG)

10.4.1 Tasks & Personnel

The Computing Group will be responsible for day-to-day maintenance, support, and administration of all IT systems in Chile, including:

- Telecommunication systems: telephone, local and wide area networks (LAN and WAN), bulk data transfer;
- Computing hardware & cabling: staff workstations, archive/pipeline systems, Web systems, network
- System & database administration:
- Installation of new releases of software, patches, and upgrades as developed by Executives or designees
- Fixing minor bugs that need urgent attention
- Troubleshooting & reporting all computing problems in the Chile-based ALMA systems.

Major software development & maintenance is not planned to take place in Chile – most software will be developed and maintained by the Executives or affiliated institutes they may choose to involve. The CG group is responsible for the integration of newly delivered software packages and updated versions of existing packages. This implies close collaboration with the Executives.

The Joint ALMA Observatory shall have overall responsibility for assuring that the software packages are developed according to common specifications.

~~COMMENT:~~Budget Impact: the responsibility and authority for ALMA computing development, maintenance & prioritization during Operations is unclear. Presumably, high-level authority and responsibility will be delegated by the Board to the Joint ALMA Observatory Director. But it is not clear who has day-to-day ~~responsibility. Needs discussion.~~

responsibility, especially given the large number of resources (~30 FTE) related to the ARCs. It is also unclear who monitors IT evolution and "the market" to decide when and how to upgrade ALMA IT systems.

Budget Impact: the Computing IPT estimates that 9 FTEs per year are required between 2004 and 2011 (inclusive) to develop operations support software, above and beyond their current Construction budget. They propose to charge this to the Operations budget. These numbers will be reviewed and confirmed as part of the Computing IPT Critical Design Review 2 (CDR2) in mid-2004. ***These FTEs have not been included in this draft plan.***

Budget Impact: the Computing IPT estimates that 30 FTEs per year are needed to maintain and extend the core ALMA computing system, mostly in the area of software, starting with 20 FTEs in 2007 and then ramping up. This is an Operations cost assumed to be administered by the Executives, and split between North American and Europe. ***These FTEs are included~~in this draft plan,~~ under~~the~~ ARC technical support services~~budget.~~***. *Additional support may be necessary to support the Japanese contributed systems.* ***FTEs to maintain Japanese computing contributions are not included in the current draft.***

It is assumed that:

- Archive operations are the responsibility of the Science Operations Program & Data Management group;
- Database and Web *content* management is the responsibility of the Science Operations Program & Data Management group.

The Computing Group shall be lead by the **CG Managers** (ISM, engineers, 8+6, 2 employees). One manager will be designated the leader and the other deputy leader. The OSF is the CG Manager duty station.

Based on these activities and assumptions, the following Computing Group in Chile is derived:

- ~~Group Management: one (1) manager (ISM, 5x2) who will split time as necessary between the OSF and Santiago.~~
- Software Engineering: ~~six (6)~~two (2) software engineers ~~(LSM) who split their work-time between OSF and SCO. Assumed to be two (2) SW engineers at OSF every day of year. Rest~~

of work time is spent at SCO, on Monday-Friday schedule. per day at OSF (ISM, 8+6, 5 employees). One (1) software engineer at SCO after archive/pipeline operations start there (ISM, 5+2, 1 employee). Estimated additional ACA support: one (1) software engineer per day at OSF (ISM, 8+6, 2 employees).

- OSF IT Support: one (1) database administrator (LSM, 5x2)8+6, 3 employees) and three (3) IT systems support personnel (CSM, 8x6 = 6 employees).8+6 = 7 employees). Estimated additional ACA support: one IT systems support person (CSM, 1 employee)
- SCO IT Support: one (1) database administrator (LSM, 5x2)5+2) and three (3) IT systems support personnel (CSM, 5x2).5+2). It is assumed that IT support is only needed on weekdays at the SCO – weekend support can be provided as needed on an on-call basis. The SCO IT staffing requirements may change depending on the adopted central archive/pipeline facility model.
- ACA Support: to support ACA, two (2) SW engineers (LSM) will be added to SW Engineering team as well as one OSF IT contractor per turno (CSM, 8x6 = 2 employees).
- MIS Support: to support administration & business systems, two (2) IT contractors (5x2,(5+2, CSM) based in Santiago but with trips to OSF as necessary.

Total staff per OSF turno: 8 (+ 2 for ACA). Total staff per SCO work-day: 7.

10.4.2 Required Equipment & Documentation

Budget Impact: list of equipment to be charged to Operations budget still under discussion.

10.5 Maintenance Group (MG)

Fundamentally, the Antenna and Electronics group leaders are responsible for the performance of their sub-systems within established norms, including the development of appropriate preventive maintenance procedures. As discussed in Section 6.7, the execution of these preventive maintenance procedures shall be the responsibility of the Maintenance Group.

10.5.1 Tasks and Personnel

MG activity is coordinated by the **MG Managers** (engineer, LSM, 8+6, 2 employees). One MG Manager shall be designated as group leader, the other deputy group leader. In parallel to their activity coordination roles, the MG Managers will work with the AG and EG Managers to develop and/or extend the preventive maintenance program.

In coordination with the Antenna and Electronics Groups, the MG is responsible for:

- all scheduled non-specialized AG and EG preventive maintenance
- all regular (daily, weekly, monthly) AG and EG inspections

Besides the MG Managers, the MG shall consist of six (6) technicians per turno (LSM, 8+6, 15 employees) with a TBD mix of mechanical, electrical, and electronic backgrounds will be needed.

The MG shall also be responsible for technical facility and infrastructure maintenance tasks, including:

- **Mechanical Maintenance & Operations:** Maintenance and small modifications of all mechanical systems within buildings, such as cranes, compressed air systems, HVAC systems, hot and cold water piping, hot water production equipment, pumps, valves, gates and special metal doors, sewage systems and sewage treatment systems, water storage and distribution systems, fire suppression systems, sanitary and bathroom fixtures, kitchen equipment including refrigerated storage, fuel station, and water treatment systems.
- **Electrical Maintenance & Operations:** Maintenance and small modifications of all electrical systems within buildings, including electrical distribution systems, switchboards, electrical finishes, lighting fixtures, lightning protection devices, equipment connections, electrical systems of the power station, UPS systems, exterior lighting.
- **Building Maintenance, Fire and Smoke Alarm and Control Systems (BMS & Control Systems):** Maintenance and small modifications of the building management system, access control systems, board & lodging control systems, fire & smoke alarm systems, HVAC control systems, minor programming and modifications.
- **Power Station Maintenance & Operations:** Day-by-day maintenance and operation of power station, including scheduled oil changes, gas supply systems, fuel storage systems, control of fuel usage, spare part management, maintenance of operations and events logs.

Most, if not all, of these facilities maintenance and operations tasks shall be out-sourced.

~~10.5~~10.6 System Engineering ~~Group~~Office (SEO)

10.6.1 Tasks & Personnel

The ~~SEG is a mixed team responsible for maintaining high-level technical standards, verifying, monitoring, and maintaining system performance, and controlling electromagnetic emission. In essence, it~~SEO continues the work of the~~Construction SI and CSV teams.~~

~~SEG~~Systems Engineering IPT during operations. It has the following technical tasks:

- ~~Configuration control board(s)~~
- ~~Standards definition & maintenance~~
- ~~Telemetry monitoring~~
- ~~Maintenance Planning: preventive & corrective~~Lead configuration control board(s), including Data Interface Control Board (DICB) (see next sub-section)
- Manage technical standards: define, maintain, revised, and/or extend
- With other DTS groups, develop telemetry monitoring procedures
- ~~Interfaces~~Manage interfaces to Executive-based system development activity
- ~~Equipment certification~~Technical certification of equipment
- Maintain~~ing~~ computer maintenance management system

- ~~Training program development~~With other DTS groups, develop training programs for DTS staff

These tasks are coordinated by ~~an **ALMA System Engineer** (ISM, 5x2, OSF) who is also responsible for the overall activity of this group. As necessary, technical staff from other groups spend time on these activities.~~the **ALMA System Engineers** (ISM, 8+6, OSF, 2 employees). There are no other staff specifically assigned to this office – rather, engineering and technical staff are involved in SEO activities on an as-needed basis.

Given the complex and distributed nature of the ALMA system, configuration control is critical. Configuration control board(s) must be established in all critical areas (e.g. antenna, instruments, computers & networks, control software, data formats) and must involve people from affected sites, departments, and groups, both technical and operational.

~~Finally, the SEG is also responsible for electromagnetic emission issues, such as:~~

- ~~Monitoring the site for changes in electromagnetic emission, especially at radio frequencies~~
- ~~Administering requests, through SUBTEL, for proposed transmitter installations within the ALMA coordination zone.~~

~~These activities are assigned to the **ALMA Electromagnetic Emissions Control Engineer** (ISM, 5x2, OSF).~~ The SEO also provides support to the ALMA System Astronomers (see Section 9.3.3) as needed, in the areas of array reconfiguration support and system performance measurement and verification.

10.6.2 Required Equipment & Documentation

Comment: ~~this need further study.~~no specific SEO equipment foreseen at this time.

10.6.3 Data Interface Control Board[32]

~~The ALMA Observatory~~On behalf of the Joint ALMA Observatory, the SEO shall establish a Data Interface Control Board (DICB) to promote the standardization of, and enforce, configuration control on data structures:

- Used by ALMA to deliver data products of any kind to the astronomical community,
- Needed by users of ALMA to submit observation related information to the organization,
- Flowing through the various ALMA end-to-end data management systems (e.g. Archive, pipeline, OT)

The data interface covers data and file formats, naming conventions, meanings and physical units where applicable. Examples include, but are not limited ~~to,~~to: FITS headers, data structures, XML structures, and instrument configuration descriptions. The data interface also specifies VO compliant data structures and interfaces.

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[32] Based on the ESO Data Interface Control Board concept, as described in the ESO Data Interface Control document (GEN-SPE-ESO-19940-794/2.0), Appendix A, available on-line from http://archive.eso.org/DICB/.

The DICB shall~~issue and~~ maintain a Data Interface Control (DIC) document. The ALMA Program and Data Management group shall maintain a definitions database containing all keywords, data structures, and formats under configuration control. This database shall be available on-line for consultation by the community. Version 1 of the DIC document is a Computing IPT deliverable.

~~The DICB shall be chaired by the ALMA System Engineer (see Section 10) and consist of representatives from the ALMA science operations and software development teams.~~

One of the ALMA System Astronomers shall be designated DICB chairperson. The rest of the Board shall include the other Systems Astronomers, the Systems Engineers, the DSO Data Manager, and one representative with the Antenna, Electronics, and Computing Groups.

Comment: it is unclear who or what group should be responsible for data interface control during the Construction phase.

10.7 Spectrum Management Office (SMO)

Comment: this section is based on a proposal written by Harvey Liszt (NRAO).

Successful operation of any radio telescope requires a clean electromagnetic environment. In the case of ALMA, this will require management of radio frequency interference from ALMA and non-ALMA sources. To this end, the Joint ALMA Observatory shall establish a Spectrum Management Office (SMO) with the following responsibilities:

- Liaison with local, national, and international authorities on issues related to spectrum management
- As necessary, work with local, national, and international authorities to establish and/or maintain an ALMA Radio Quiet Zone
- Participate in local, national, and international meetings and conferences related to spectrum management
- Monitor the AOS for changes in electromagnetic emission, especially at radio frequencies
- Administer requests for new transmitter installations within the ALMA coordination zone
- Test all equipment to be installed at the AOS for electromagnetic emission, especially at radio frequencies

These activities are assigned to the **ALMA Spectrum Manager** (engineer, ISM, 5+2) who is based at the SCO but expected to make regular trips to the OSF. The SMO is also assigned two (2) engineers per OSF turno (engineer, LSM, 8+6, 4 employees) who will be responsible for site monitoring and equipment testing.

The SMO will require an equipment testing facility at the OSF, as well as TBD spectrum site monitoring equipment.

Comment: these SMO engineers and their responsibilities could be merged into the Electronics Group.

11 Administration Department

This section describes Administration Department responsibilities and staff in 2012. A ramp-up analysis is provided in the Budget ~~Summary~~Overview section.

The scope of activities for Administration Department (ADM) covers the functions necessary to provide efficient support to the scientific and technical operations of ALMA.

11.1 Management Structure

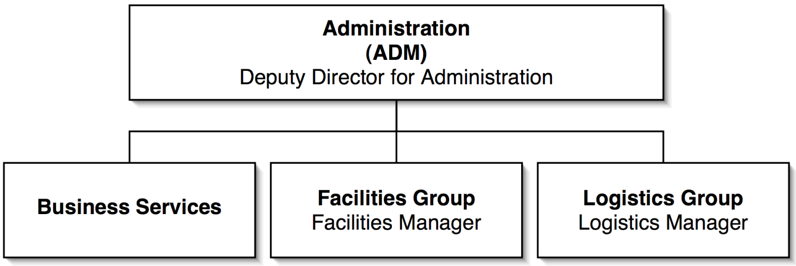

Figure 11-1: Administration Department Organization

Administration, facilities, and logistics activities in Chile are the responsibility of the Deputy Director for Administration (see Figure 11-1).

The ADM department will be split into the following groups:

- ~~**Administration Support:**~~**Business Services:** responsible for coordination between Joint ALMA Observatory and Executives in areas of budget & accounting, contracts & procurement, and purchasing.
- **Logistics Management:** responsible for board, lodging, and housekeeping services for all ALMA sites in Chile, as well as travel agency services.
- **Facility Management:** responsible for day-to-day maintenance and development for all ALMA sites in Chile.

Each group has a designated manager, as discussed below. ADM has activities at all ALMA sites in Chile. It has offices in Santiago as well as at the OSF.

~~**11.2Administration Support Group**~~

~~*From the Project Plan, Version 1, Chapter 6:*~~

~~Administrative services include:~~

- ~~**Budget and accounting.** Accounting and budgeting will support the ALMA activities in Chile, in the frame of the financial rules and procedures to be developed for the project. It includes accounting of the assets, billing services, insurance, the administration of the budget information according to the WBS for the in-house users and feedback to the regional centers~~

abroad. It does not include the overall financial and budgetary management between the ALMA partners. The local accounting service will be largely automated and rely on contractors for the detailed development.

- **Contracts and procurement.** This service will establish the contracts according to the ALMA policies and procedures, including price inquiries, calls for tenders, and assessment of the offers. Procurement for the supplies according to the purchase requests from internal users is another essential function of the service. This requires a close coordination with the requirements and objectives of users; therefore the service must operate in close collaboration with the technical and scientific teams at the OSF.
- **Human resources management.** This is the domain of the Human Resources Manager[33] who will report directly to the ALMA Director, to ensure an active development of staffing according to requirements of the ALMA technical and operational services. The staff concerns should be properly addressed, in view of the particular conditions and environment of the ALMA Observatory. The HR Manager and the assistants will also be responsible for harmonizing the staff regulations and procedures to ensure a coherent policy across the organization.

COMMENT: the concepts presented above are currently under discussion by the Executives and JAO. At the time of this draft, the final outcome of these discussions was not available. It is not known how or if these people will report to the ALMA Director or the Executives. Here, we assume the following support staff for the ALMA Observatory Director: two accountants (LSM, 5x2, SCO), two contracts & procurement managers (LSM, 5x2, SCO), one purchasing agent (LSM, 5x2, SCO), and one import-export officer (LSM, 5x2, SCO). Administrative support has also been provided (1 LSM, 5x2, SCO). The Executives will provide additional personnel to fulfill and manage their legal obligations in Chile.

11.311.2 Logistics ManagementBusiness Services

Comment: it is assumed that the Construction PMCS will also support Business Services activity during Operations.

The following was extracted from the Project Plan, Revision 23 March 2004, Section 6.5 (with minor grammatical corrections):

During construction and operations, the business services required to support Chilean-based activities will be managed and executed by the North American and European Executives Staffs which, with the exception of legal and accounting/finance issues, will be in response to the programmatic direction from the ALMA Director. These business services include the following activities: logistics, human resources, contracts/procurement, legal issues, finance and accounting.

In performing these functions, the North American and European Executives will follow their respective NRAO and ESO policies and procedures appropriately tailored for ALMA activities.

[33] This position was called Head of Personnel in Project Plan, Version 1, Feb 2003.

In order to maximize efficient use of staffing, and to foster image of ALMA in Chile as a single unified entity, the North American and European Executives will, whenever possible co-locate persons performing logistic, human resources and procurement/contracts. Additionally, whenever possible, the Executives will share positions and will cross-train their staffs to be knowledgeable about the unique requirements of each Executive. Whenever possible such functions will be out-sourced with the appropriate contractual oversight exercised by the Executives.

The Executives Staff management shall ensure that persons performing these functions do so in a manner that (1) is consistent with the JAO/ADO direction while (2) adhering to the Executives' respective policies, procedures, contractual requirements and legal regimes.

Budget Impact: the concepts presented above are currently under discussion by the Executives and JAO. At the time of this draft, the final outcome of these discussions was not available and no specific guidance about staffing has been provided. Here, we assume the following Business Services staff will be charged to the Joint ALMA Observatory operations budget for the Joint ALMA Observatory Director: two accountants (LSM, 5+2, SCO), two contracts & procurement managers (LSM, 5+2, SCO) one purchasing agent (LSM, 5+2, SCO), one import-export officer (LSM, 5+2, SCO), and one administrative assistant (LSM, 5+2, SCO). Whether more or less staff is required is still TBD.

11.3 Logistics Group

The Logistics Management Group (LMG) is led by the Logistics Manager (LSM, 5x2,Group (LG) is led by the Logistics Manager (LSM, 5+2, SCO). It supports activities in the following areas:

- **Travel Services:** contracted services to arrange all Joint ALMA Observatory related travel (intra-Chile and international) for Chile-based staff (2 FTE, contractors, 5x2).CSM, 5+2). Travel agency office is located at SCO.
- **Safety & Security, First Aid, and Fire Fighting Operations:** Includes security services at OSF gate houses (e.g. entrance & exit registration & control for personnel and material, baggage check) (3 FTE, contractors, 8x6CSM, 8+6 = 6 people). Also includes paramedic at OSF (1 FTE, contractor, 8x6CSM, 8+6 shift = 2 people).[34] Fire brigade manned by trained ALMA staff. Group led by*This team reports to Joint ALMA Observatory Safety* Engineer*Manager (see above) and off-shift deputy.*
- **Logistical Operations:** Includes provision of board, lodging, and laundry at ALMA Residencia and contractors camp. Also includes reception services, phone services, visitor management, mail services, entertainment management, events, drivers services and personnel transport. Executed by three ALMA staff (Logistics specialists, LSM, 8x68+6 = 6 employees) supported by 1 driver (contractor, 8x6(CSM, 8+6 = 2 people) and 33 persons (TBC) from service firms.

  Logistical operations also includes:

[34] OSF activity runs 24/7 –should there be paramedic coverage 24/7?must be available 24/7.

- **Warehouse** ~~services~~Services including receiving and dispatch, general merchandise, office supplies, spare part storage & monitoring, packing, and shipping (local & international). This activity is supported by service ~~firms (3 warehouse specialists, 5x2). Necessary weekend emergency warehouse activities are supported by other logistic staff members.~~firms, who will provide seven (7) day per week coverage (CSM, 3 people).

~~• *Vehicle maintenance services for oil, tire, shock absorbers, mufflers as well as small paint jobs and car cleaning. This activity is supported by service firms (1 car maintenance mechanic, 5x2). Note that this service does not include heavy vehicle maintenance (e.g. ground vehicles and antenna transporters).*~~*Budget Impact: warehouse management is a mission critical function. Observatory upper management may wish to use LSM positions to support this activity.*

11.4 ~~Facility Management~~Facilities Group

The Facilities~~Management~~ Group (F~~M~~G) will provide the support for OSF and AOS infrastructure. The group will focus on the supervision and coordination of the contracted support in the area of civil engineering and electrical installations (not including the power installation at the antenna and ancillary instrumentation). It is the group's responsibility to develop the working programs, maintenance schedules and, thereafter, to monitor and commission the execution phase. Last, but not least, contractor compliance with the safety regulations is under their responsibility.

During an emergency, the F~~M~~G will have pre-selected supervisors who will become Emergency Services Directors. These Directors and a shadow organization of emergency response personnel shall be trained to assume full control of the observatory in the event of an emergency such as a natural disaster, a serious accident, a bomb threat, or other event that threatens life and property. The team will be prepared to protect life and property, and to organize and direct egress from the observatory property as necessary.

Comment: this concept of Emergency Service Directors is needed, but perhaps this is not the best place. To be discussed.

There shall be two **Facilities Managers** (ISM, 8+6, OSF), one designated as leader, the other as deputy, on opposing turnos. All other facilities staff will be provided by service firms.

The F~~M~~G has various sub-groups:

- **Grounds:** Maintain road (including road to OSF and between OSF and AOS) and paved areas, including cleaning, re-painting of road striping, repair of crash barriers, snow removal, etc. Also maintain landscaping, including watering, trimming, and minor earthwork. Worked contracted out to service firm(s) (3 FTE). Shift is normally Monday – Friday ~~(5x2)~~(5+2) but in winter may shift to every day ~~(8x6)~~(8+6) to due increased snow removal and road maintenance needs.
- **Civil Works:** Maintain approximate 10 000 m^2 buildings, small paint jobs, floor, ceiling, windows, door maintenance and repair, window treatments. Minor ~~work tasked to ALMA staff (1 roving handyman + 1 unskilled assistant, LSM, 5x2).~~and Major maintenance and modifications contracted out to service firms.

- ~~**Mechanical Maintenance & Operations:** Maintenance and small modifications of all mechanical systems within buildings, such as cranes, compressed air systems, HVAC systems, hot and cold water piping, hot water production equipment, pumps, valves, gates and special metal doors, sewage systems and sewage treatment systems, water storage and distribution systems, fire suppression systems, sanitary and bathroom fixtures, kitchen equipment including refrigerated storage, fuel station, and water treatment systems. Minor work tasks performed by ALMA staff (1 roving handyman + 1 unskilled assistant, LSM, 5x2). Major maintenance and modifications contracted out to service firms.~~

- ~~**Electrical Maintenance & Operations:** Maintenance and small modifications of all electrical systems within buildings, including electrical distribution systems, switchboards, electrical finishes, lighting fixtures, lightning protection devices, equipment connections, electrical systems of the power station, UPS systems, exterior lighting. Minor work tasked to ALMA staff (2 roving electricians, LSM, 8x6 = 4 employees). Major maintenance and modifications contracted out to service firms.~~

- ~~**Building Maintenance, Fire and Smoke Alarm and Control Systems (BMS & Control Systems):** Maintenance and small modifications of the building management system, access control systems, board & lodging control systems, fire & smoke alarm systems, HVAC control systems, minor programming and modifications. Minor work tasked to ALMA staff (1 Electric & electronics technician, LSM, 8x6 = 2 employees). Major maintenance and modifications contracted out to service firms.~~

- ~~**Power Station Maintenance & Operations:** Day-by-day maintenance and operation of power station, including scheduled oil changes, gas supply systems, fuel storage systems, control of fuel usage, spare part management, maintenance of operations and events logs. Executed by ALMA staff (1 mechanic, LSM, 8x6 = 2 employees). Major repairs and scheduled maintenance other than oil changes contracted out to service firms.~~

- ~~This group is led by one group manager (ISM, 5x2), one electrical engineer (LSM, 5x2) to supervise electrical & power station maintenance work, and one mechanical engineer (LSM, 5x2) to supervise grounds & mechanical maintenance work.~~**Vehicle maintenance services** for oil, tire, shock absorbers, mufflers, etc. as well as small paint jobs and car cleaning. This activity is supported by service firms (1 car maintenance mechanic, 5+2). Note that this service does not include heavy vehicle maintenance (e.g. ground vehicles and antenna transporters).

Comment: FG support for SCO is still TBD.

12 ALMA Regional Centers (ARCs)

At the time of this draft, concepts presented in this section still under discussion between Executives and ALMA Board and therefore subject to change.

Each Executive shall establish an ALMA Regional Center (ARC). Each ARC shall have a Manager. The internal structure of these ARCs is the responsibility of the Executives. In particular, each Executive may elect to out-source some of the services it provides.

12.1 Core Services

Each ARC will be responsible for providing a core package of operationally critical services to ALMA operations in Chile and their respective regional user communities. The final definition of this core package is TBD and subject to Board approval. As part of the Board approval process, each part of the core package will be assigned a cash value. These cash values will be considered part of the Executives' contribution to the Joint ALMA Observatory operations budget.

Standard operational overheads such as utility costs, office space, basic IT hardware and support, office supplies, and research activity support (e.g. conference travel, page charges, etc) will be counted as part of the Executives core operations contribution value. Estimating the costs of these overheads is beyond the scope of this document.

12.1.1 Scientific support services

Core scientific support tasks include:

- Phase 1 operations (e.g. proposal preparation user support, proposal handling, and proposal scientific ranking);
- Phase 2 (e.g. observation preparation user support, observation submission review, SB validation)
- Data quality assurance (QA3)
- Data product support (e.g. user support for standard ALMA data products and data processing tools, basic data reduction support);
- ALMA archive operations (e.g. holding & serving a copy of the ALMA Archive, basic archive user support, VO interface).
- Feedback on ALMA operational processes & tools (from staff and end-user perspectives)
- Astronomer-on-Duty shifts at OSF for staff astronomers.

It is assumed that all direct scientific user support will occur at the ARC, including helping users fix SBs found to be faulty at run-time.

A suggested model for scientific support staffing is:

- ~~five (5)~~Six (6) staff astronomers (assumed to have 50/50 functional/research split) ~~for Phase 1, Phase 2, and ALMA Chile support~~to support proposal preparation (Phase 1), observation preparation (Phase 2), and observation execution problem resolution (Phase3), as well as to provide AoD support at the OSF (see below);

- ~~four~~Four (4) scientists (functional/research split TBD) for data analysis support;
- ~~four~~Four (4) technical support staff for Archive operations (including data package mastering and shipping)
- ~~one~~One (1) FTE for database administration

*Budget Impact: the initial ARC archive/pipeline system is currently **not** an ALMA Construction deliverable. Estimated start-up cost per ARC: ~~500 000 USD.~~250 000 USD. System will require upgrades every 3 – 4 years, estimated to be 250 000 USD per upgrade (in year 2000 dollars).*

ARC running costs for core functions shall be charged to the ALMA operations budget. Exact values need to be negotiated by Executives.

~~The~~Based on the assumptions in Section 9.3.1, the FTE cost of providing AoD support can be estimated as follows: ~~four (4) staff astronomers, 3.5 trips per year, and 8 OSF-days per trip + 4 travel-days per trip = 12 days per trip implies 112 OSF-days per year and 169 travel-days per year. Including travel-time, this is 169/230 = 0.73 FTE per year. This is equivalent to the functional workload of 1.5 50/50 staff astronomers. One (1) ARC~~104 AoD shifts per year / 8 shifts per trip = 14 trips per year; overhead per trip = 4 travel-days + 2 days at SCO + 2 compensation days for weekend work = 8 days per trip or 112 days per year; total days per year per ARC = 112 + 112 = 224 days; assuming 115 functional days per ~~staff astronomer has been added in partial~~year per astronomer (see footnote 28), 224 days = 1.9 FTE (astronomer) per year. Two (2) ARC staff astronomers have been added in compensation of this load. Travel, room, & board costs during these trips shall be charged to the ALMA operations budget.

In short, each ARC is requested to provide 14 trips to Chile per year by ARC astronomers. These trips could be averaged over all six ARC astronomers (i.e. 2.3 trips per astronomer), focused on four ARC astronomers (i.e. 3.5 trips per astronomer), or restricted to only two ARC astronomers (i.e. 7 trips per astronomers or more likely 3 longer trips per astronomer). The last option has several advantages: training overhead at the OSF is minimized (fewer people to train), fewer people traveling (reducing global disruption due to travel and reducing travel costs), and fewer tasks per person (more time to focus). A different pair of ARC astronomers could travel each year. When not in Chile, these ARC astronomers would have no other functional duty except to provide expert advice to their ARC colleagues. In practice, all ARC astronomers should probably visit Chile once per year even if they are not allowed to perform Science Operations duties due to lack of training. Such trips are essential for maintaining familiarity and lines of communication.

It would also be highly desirable for each ARC staff astronomer to make at least one trip per year to a different ARC. The coordination of such trips is the responsibility of the ARC Managers.

ARC data analysis support staff shall also travel to Chile at least once per year to participate in TBD on-site data management activities. Travel, room, & board costs during these trips shall be charged to the ALMA operations budget.

Budget Impact: the actual ARC staffing model and cash value are dependent on final agreement on core scientific support services by Executive and ALMA Board.

~~*COMMENT: a more complete description of ARC/DSO interfaces will be provided in a later draft.*~~

Budget Impact: support for the Chilean community in these areas is currently unspecified and unbudgeted.

12.1.2 Technical support services

As discussed elsewhere in this document, each Executive shall provide technical support services, e.g. remote repair facilities & continuing software maintenance support. At the Executives' discretion, these services could be executed in-house or out-sourced. The Executives, as represented by their ARC Managers, remain responsible for the management & delivery of these services.

As requested by the Joint ALMA Observatory Director, the ALMA Board shall review all proposed technical support services. For each Board-approved technical support service, the ALMA Board shall assign an official cash value that shall be considered a contribution by the affected Executive to the ALMA operations budget.

Budget Impact: per Computing IPT assumptions (see Sec 10.4), it is assumed the European and North American ARCs will contribute 15 FTEs each of continuing ALMA computing maintenance and development support, starting in 2007.

~~COMMENT:~~Comment: details and costs of these technical support services, as well as ARC/DTS operational interfaces, is still TBD.

12.1.3 Development support services

As discussed elsewhere in this document, each Executive shall provide development support services, as recommended by the Joint ALMA Observatory Director and approved by the ALMA Board. For each approved development project, the ALMA Board shall assign an official cash value that shall be considered part of the Executives' contributions to the ALMA operations budget.

12.2 Enhanced Services

Each Executive may elect to provide enhanced ARC services above and beyond Board approved operational critical activities. Such additional activities have no formal cash value in the context of the Bi-lateral Agreement and do not form part of the Executives' contribution to the Joint ALMA Observatory operations budget. They may include, but are not limited to:

- extended archive & data reduction support (e.g. one-on-one data processing support in a dedicated physical location, modified pipeline versions, re-processing of large and/or complex datasets, advanced simulation development);
- support for special projects (e.g. public surveys and large programs);
- science community development (e.g. financial support for ALMA research, post-doctoral fellowships, training schools & workshops, ALMA-related specific science workshops, and advanced public outreach activities).

Further discussion of these enhanced services is beyond the scope of this document.

13 Santiago Central Office: Preliminary Infrastructure Requirements

As previous sections describe, the Santiago Central Office (SCO) host a number of ALMA administrative and operational activities. In this section, the inferred infrastructure requirements are presented.

Budget Impact: ~~in this draft, the budgetary analysis of these requirements has not been completed.~~SCO requirements, and thus costs, are still under development.

13.1 General Requirements

SCO must have high-speed internal LAN (1 Gbit) to all offices as well as wireless (WiFi) capability. Each office should have at least four (4) network connections and perhaps more if telephony over IP is the chosen technology.

Additional general requirements include:

- One large auditorium/meeting room (50 seats) for colloquia, symposia, staff meetings and public lectures
- Two (2) small meetings rooms (10 – 20 seats) for smaller staff meetings
- Kitchenette, lunch-room, coffee-bar area
- Standard office facilities: mailroom, storage room(s), toilets, showers, copy machines, printing/photo shop (?), etc.
- Parking facilities for ~~X automobiles~~75 – 100 staff automobiles, plus 25 spaces for ALMA vehicles

13.2 ALMA Director's Office

As described in Section 8, single offices are needed for the Director, Safety Manager, and Human Resources Manager. One (1) double office is required for the ADO administrative assistants based in Santiago.

13.3 Science Operations

13.3.1 Research support

As described in Section 9, the Science Operations staff includes 13 staff astronomers plus a Deputy Director who spend 50 – 75% of their time in Santiago. Fourteen (14) single offices should be provided to promote a productive research environment. An additional ten (10) double offices should be provided to accommodate post-doctoral fellows, ARC staff on duty-trip in Chile, and scientific visitors.

Scientific staff must have access to research-grade library facilities (both on-line via Executives and off-line at Santiago research institutes). Journal page charge support, conference travel support, and a visiting researcher program are also required. Regularly scheduled ALMA supported research mini-breaks (e.g. two months every two years at institute of choice) for long-term scientific staff are strongly recommended.

To facilitate increased scientific interactions and enliven the SCO scientific environment, it is highly desirable that the SCO be located close toco-located with one of the pre-existing astronomical research groups in Santiago.

When the NRAO/Tucson offices are shutdown, the library will be packed and stored, with the ultimate goal of re-deploying this library at the SCO for the use of the scientific staff and their visitors. Thus, library space is needed.

Comment: if co-location with pre-existing group occurred, the NRAO/Tucson library could be merged into a pre-existing library.

Budget Impact: library budget requirements (e.g. for librarian, acquisitions, periodicals, etc) unclear at this time.

13.3.2 Data Management

When the ALMA central archive/pipeline system moved to the SCO, several large computer labs will be required for the hardware systems – the exact floor space requirements is TBD. One (1) single office is required for the database administrator. One (1) large office (40 sq meters) is needed for four (4) archive/pipeline operators.

13.4 Technical Services

Technical Services staff work mostly at the OSF. At the SCO, one (1) single office is required for the Deputy Director, one (1) single office for the ALMAEDM Manager and three (3) double offices used on a rotating basis.

13.5 Administration

As described in Section 11, a number of Administration (ADM) activities will occur at the SCO, including: budget & accounting, contracts & procurement, purchasing, and travel agency. These activities require seven (7) offices.

Additional TBD office space will be needed for the Executive-provided local management teams.

Additional space is needed for business & administration IT equipment (e.g. printers, servers, copy machines, etc.) as well as filing cabinet space.

13.6 Computing Support

Three kinds of computing support activity occur in Santiago:

- General IT support for SCO: two (2) double offices for four CSMs
- Software Engineering: four (4) double offices for eight engineers splitting time between SCO and OSF.
- MIS support: one (1) double office for two CSMs

Additional floor space is needed for miscellaneous IT equipment (e.g. printers, servers, network equipment, telephony equipment, etc).

13.7 Summary: SCO Office Requirements

Based on this section, SCO office requirements are:

- ADO: X offices
- AFL: X offices
- DSO: X offices (staff + post-docs + visitors)
- DTS: X offices
- IT: X offices

Comment: these requirements are not final.

	Single	**Double**	**Quad**	**Other**
ADO	3	1	0	
ADM	7	0	0	MIS machine room, cabinet space
DSO	16	13	1	Library, Archive/pipeline lab(s)
DTS	2	3	0	
IT	0	7	0	Printer/media server area(s), network equipment room, servers (compute, telephone, network, etc)
Total	28	24	1	

14 Budget Overview

This section provides estimates for ALMA operational activities approved by the ALMA Board and funded by the Executives. Personnel, capital, running, and future development costs are included. A cost ramp-up analysis is provided.

14.1 Personnel

14.1.1 Individual Positions

Table 14-1A[35] lists every ALMA employee described in the preceding sections. For each person, the following information is provided:

Column	Description
IDX	Running number within department
Dept	Department
Group	Group
Title	Position title
Skill	Basic skill required for position
Site	Main work site: OSF, SCO, ARC, Both = OSF/SCO split
Con	Contract Type: ISM = Int'l Staff Member, LSM = Local Staff Member, CSM = Contractor
N	Number of people at OSF per day (2012)
B/T	B = Bilateral project, T = Trilateral add-on
Shift	Contiguous Workdays at OSF x Days Off
Start	Year of position start
Payroll: ISM	International Staff Member (international recruitment)
Payroll: LSM	Local Staff Member (Chile-hire)
Payroll: CSM	Contractual Staff Member (from TBD service providers)
Payroll: RSM	Regional Staff Member
Payroll: Tot	ISM+LSM+CSM
Beds:Res	Bed in Residencia
Beds:Camp	Bed in Contractors Camp

[35] Distributed within separate PDF document: ALMA-Personnel-YYYY-MM-DD.pdf

Table 14-1B[36] provides a summary of the total number of Observatory personnel, broken down by contract type (ISM, LSM, CSM, RSM).

14.1.2 Staff Ramp-Up

Comment: this section will eventually include a staff ramp-up analysis

14.2 Equipment

Table 14-2[37] lists the equipment needed by various operational departments and groups with cost estimates. It is assumed that all ADM equipment will be purchased and installed by the Site IPT using Construction funds. It is assumed that the DTS equipment will also be purchased with Construction funds but the source is TBD.

Budget Impact: this equipment list is a work-in-progress. In particular:

- *Many DTS teams requested IT hardware. This hardware may already be in the Computing IPT Construction budget. Should be investigated.*
- *List of Computing IPT equipment to be charged to Operations still under discussion.*
- *No office furnishings or equipment has been specified. Who specifies and who pays?*
- *There is no information about the Santiago offices.*
- *Need to add budget line for radio communication systems (portable radios, radios in cars, repeaters, etc) – special RFI requirements*
- *Number and type of general purpose vehicles need to be further specified.*

14.3 Operations (Running) Expenses

In this sub-section, the continuing (operations or running) costs of the Joint ALMA Observatory in Chile in the year 2012 are discussed and estimates are provided. The following conversions are assumed: 600 pesos = 1 USD and 1 Euro = 1.20 USD. When ESO/Paranal costs are used as basis for estimates, all cost values are for 2003.

Budget Impact: estimates derived from ESO/Paranal costs need to be reviewed to determine Antofagasta/Calama cost differences, if any.

14.3.1 OSF/AOS Power

Budget Impact: at the time of this draft, the power generation plan in the early years was unclear to the Operations Group. This needs discussion. It appears that the long-term solution will be a dual-fuel system based at the OSF. Annual operating costs appear to start at circa 850 000 USD per year.

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[36] Distributed within separate PDF document: ALMA-Personnel-YYYY-MM-DD.pdf

[37] Distributed as separate PDF document: ALMAOperationsPlan-Equipment-YYYY-MM-DD.pdf

QUESTIONS: need to have some emergency generation on site? If yes, lease or buy? What are UPS requirements? What UPS "hold-time" is needed at AOS? Do certain items (i.e. maser) require longer UPS times?

14.3.2 OSF/AOS Water & Sewage

Well water will be used for basic sanitation uses (i.e. toilets, showers, laundry, etc). Well water will be hauled to the AOS for these purposes. The amount and cost of this water is under study.

Bottled water will be used for eating, drinking, and cooking. Tap water should be potable, if not necessarily drinkable.

A sewage treatment plant will be installed at the OSF. Waste water at the AOS will be captured in a septic tank. This tank will be periodically emptied and the sewage hauled down to the OSF treatment plant. After sterilization, effluent water from the treatment plant will be used for road stabilization and landscaping.

Assuming 350 liters per person per day (Paranal consumption) and 150 persons per day, annual water consumption is circa 19.2 million liters (= 19 200 cubic meters). If water were delivered and cost 1.25 x 5 USD per cubic meter (Antofagasta-to-Paranal cost), the annual water cost estimate is 120 000 USD. Note that the factor of 5 is the delivery factor – the OSF delivery factor may be much ~~smaller.~~

smaller, given the proximity of San Pedro (or even Calama).

14.3.3 OSF/AOS Hot Water

It is assumed here that OSF/AOS hot water generation cost is part of the power generation cost.

Hot water at AOS is assumed to point-of-service, i.e. small, local tanks.

~~Hot water generation at OSF is still under discussion. It may be possible to generate hot water as a byproduct of power production.~~

14.3.4 OSF/AOS Room Air Conditioning

It is assumed here that OSF/AOS air conditioning (cooling and heating) cost is part of the power generation cost. It is provided by either central A/C systems or point-of-service.

Comment: ESO/Paranal spends about 100 K€ per year in general facility HVAC maintenance (not including staff). This is dominated by HVAC costs of telescope enclosures.

14.3.5 OSF Food Service

Food service will be a contracted service. Based on ESO/Paranal experience, a good approach is to have separate contracts for food delivery and food preparation. A combined contract makes it too tempting for the contractor to order lower quality food products to increase profit margins.

Per ESO/Paranal experience, food service cost is assumed to be 25 USD per day per person. Assuming 150 people per day, the annual cost estimate is 1.4 million USD.

14.3.6 OSF Housekeeping

OSF housekeeping will be a contracted service that falls into two categories:

- Bedroom cleaning: based on ESO/Paranal experience, the estimated cost is 2000 pesos (= 3.33 USD) per bed. Assuming 150 beds per day, the estimated annual cost is 75 000 USD.
- General facility cleaning: general cleaning, waste disposal, etc. Based on ESO/Paranal experience, the estimated cost is 24 000 USD per month or 288 000 USD per year.

COMMENT:Comment: someone should discuss with the larger San Pedro de Atacama hotels (e.g. Explora) how they handle this activity. If possible, preference should be given to local San Pedro providers to help local community relations.

14.3.7Comment: general facility cleaning scales with floor space. OSF/AOS Groundsfloor space may be significantly smaller than Paranal floor space, so general facility cost may also be lower. To be investigated during contract negotiations.

14.3.7 OSF/AOS Grounds & Buildings

OSF/AOS Grounds is a contracted service. Primary activity is road & landscape maintenance. Larger repairs by separate contracts as needed. ESO/Paranalmaterial costs for service providers and materials in 2003 for this activity was 300were 75 000 USD.

QUESTION: what was Paranal cost for people?OSF/AOS Buildings is also a contracted service. Primary activity is basic building maintenance. Larger repairs by separate contracts as needed. ESO/Paranal costs for 2003: 250 000 USD for service providers and materials.

14.3.8 OSF/AOS Medical Support

Medical Support is a contracted service. Activities include 24/7 on-site paramedic(s) and rapid response/evacuation services. In 2003, ESO/Paranal costs were 30 000 USD for 24/7 paramedic support and 6 000 USD for materials.

This activity is the responsibility of the ALMA Safety Manager.

14.3.9 OSF/AOS Security

Security is a contracted service. Primary activity is physical site security at OSF and AOS, under the responsibility of the ALMA Safety Manager.

At the time of this draft, the exact security model is unclear. Based on ESO/Paranal costs in 2003, an annual cost of 200 000 USD is assumed.

14.3.10 OSF Warehouse Management

OSF Warehouse Management is a contracted service, coordinated by Logistics Manager. Based on ESO/Paranal costs in 2003, three Warehouse Specialists per turno are assumed to cost 90 000 USD per year.

14.3.11 SCO Expenses

Budget Impact: at the time of this draft, SCO expenses are unclear. An annual budget of 200 000 USD has been assumed, but this is likely to be an under-estimate.

Topics:

~~• Utilities~~

~~• Rent~~

~~• Housekeeping~~Topics: Utilities, Rent, Housekeeping, etc.

14.3.12 Staff Transportation

It is assumed that contractor service providers transport their own staff to and from ALMA sites as part of their service contract.

It is assumed that transport between Santiago and Calama will be provided for 75 turno positions per week. This is equivalent to 75 round-trips per week, since one person is traveling to Calama while the turno-partner is traveling in the opposite direction. Assuming 360 USD per round-trip, the estimated annual cost is 1.4 million USD.

Individuals or small groups traveling between Calama and the OSF for will use ALMA vehicles and drivers. On weekly turno change days, a contract bus will be used at an estimated cost of 12 USD per person or 47 000 USD per year.

ALMA shall pay also for taxi service between various places in Santiago and the airport. Assuming 75 round-trips per week, at a cost of 18 000 pesos (= 30 USD) per trip, the total estimated annual cost is 117 000 USD.

For international staff travel, 100 trips per year at a cost of 3600 USD per trip implies 360 000 USD for international travel.

Staff travel is coordinated by contracted travel agency with implanted office at SCO.

14.3.13 Intra-ALMA Communications

Data transfer costs within Chile are expected to rise to 600 000 USD per year by 2011 assuming a 100 Mb/s link between the OSF and SCO. This expense assumes all data will be transferred between the OSF and SCO in transit to the ARCs and is independent of science operations activity in Santiago.

Additional telecommunications costs (Internet, telephone, media) are estimated to be 120 000 USD per year.

The default bulk data transport option between Chile and the ARCs is moving hard disks. There are many ways to support this option – the following is a conservative cost estimate. The basic operational model is: write data to disks, ship disks to ARC, read disks at ARCs, and ship disks back to Chile for reuse. Assuming 500 Gbytes of raw data per 24 period or 2500 Gbytes every 5 day period and hard-disk cost = 2 USD per Gbyte, the capital cost for one 5-day data set is 5000 USD. For three ARCs, this is 15 000 USD. To allow for transport turn-around time, we need four (4) sets of disks, or 60 000 USD. There are additional costs for reading/writing systems but this is minimal. Note that the storage cost per Gbyte is likely to decrease dramatically by 2010 and that this system is easily expandable to accommodate larger data volume. These are *fixed* costs.

Disk shipping is a running cost. Assume 200 USD per ARC round-trip (rapid courier service) and one shipment cycle every 5 days. Courier service cost may be uncertain by as much as a factor of 2. Under these assumptions, there are 73 shipment cycles per year, costing 14 600 USD per ARC, or 43 800

USD for three ARCs. Note that this shipment plan can be easily tuned to other frequencies. Total estimated running cost per year for three ARCs: 45 000 USD.

A more expensive option is high bandwidth Internet connections. The cost of such connections is uncertain but estimated to ramp up to 600 000 USD per year per ARC by 2011 assuming a 100 Mb/s link to each ARC. Total estimated running cost per year for three ARCs: 1 800 000 USD. This is to be compared to the estimated cost of shipping hard disks.

14.3.14 OSF/AOS/SCO IT Support

IT Support is a contracted service, estimated to cost 6000 USD per year per connected employee. For 200 employees, total cost is 1.2 million USD per year.

14.3.15 Insurance

Budget Impact: at the time of this draft, the exact insurance needs and costs for ALMA are uncertain. Here, we assume 600 000 USD per year in general coverage, consistent with Paranal experience.

14.3.16 OSF/AOS Vehicle Fleet Maintenance & Fuel

Vehicle Fleet Maintenance is a contracted service. It is assumed that the OSF will have basic vehicle maintenance equipment. Major vehicle maintenance will occur at some other location.

Budget Impact: the exact composition of the OSF/AOS vehicle fleet is still under discussion. Based on ESO/Paranal experience, an annual maintenance contract and fuel costs of 110 000 USD and 72 000, respectively, are assumed.

14.3.17 OSF/AOS Office Supplies

Any organization consumes pens, paper, printer supplies, etc.

Comment: ESO/Paranal = 60 000 USD per year.

14.3.18 OSF/AOS Staff Refreshments

For both staff health and moral, remote facilities such as the OSF usually provide refreshments (especially liquid refreshments) to the staff, e.g. coffee, soda, water. ESO/Paranal experience is that staff consumes on average two items per day. The 2003 ESO/Paranal cost for this service was approximately 100 000 USD.

14.3.19 ALMA Calama liaison office

Budget Impact: does ALMA need a Calama liaison office? Estimated annual cost (2 people, ~~5x2):~~ 5+2): 60 000 USD.

14.3.20 ~~Science~~Chile-based science staff research support

For each staff astronomer in Chile, the following research support budget is assumed:

- Two (2) observing trips to other facilities (all expenses): 3600 USD x 2 = 7200 USD
- Two (2) international conference trips per year (all expenses): 3600 USD x 2 = 7200 USD

- Three (3) journal articles per year, 10 pages per article, 150 USD per page: 4500 USD
- One (1) two-month research leave every two years: 3600 USD (airfare) + 60 x 100 USD/day = 9600 USD

Assuming ~~20~~15 staff astronomers, sub-total is ~~20~~15 x (7200 + 7200 + 4500 + 9600/2) = ~~330 000~~355 500 USD/year. Assume 6 additional post-doctoral fellows (who receive not mini-science leave): 6 x (7200 + 4500) = 70 200 USD.

To foster collaboration and improve interaction with broader community, Joint ALMA Observatory shall sponsor a scientific visitor program. Assumptions: five (5) visitors per year, each visit lasts one month (30 days), daily cost (room & board) = 200 USD, airfare = 1500 USD. Estimated cost: 5 x (30x200 + 1500) = 37 500 USD.

Total proposed annual ~~budget: 400~~budget (rounded up): 465 000 USD

14.3.21 ALMA Director Management Budget

The ALMA Director needs a discretionary budget to support miscellaneous Director office activities. It should be large enough to allow (e.g.) the hiring of a few people on short-term contracts for miscellaneous activities, support short-term visitors to the observatory, etc. Assumed: 300 000 USD.

14.3.22 Major Missing Running Costs

Budget Impact: at the time of this draft, estimates for several items were not available. Cost estimates will be included in later drafts. Following items need investigation and cost estimation:

- *Off-shore Repair Center activity: major expense!*
- *ARC costs: travel support to/from Chile, overheads*
- *Vehicle Fleet: replacement costs (e.g. replace all vehicles very 5 years)*
- *IT equipment: replacement costs (e.g. all non-real-time CPUs every 3 years)*
- *Staff Recruitment: costs for local and international recruitment, including relocation*
- *Technical consumables: cryogens, shop materials, gases, solvents, etc*
- *Visitor Center: staff & running costs*
- *SCO library costs: library, material acquisition budget, periodicals, etc.*

14.4 Spare Parts

Budget Impact: this section is still under development. As discussed in Section 6, an adequate amount of spare parts is essential for maximizing system availability. At the time of this draft release, lists of recommended spare parts are still being assembled by the Construction IPTs. The source of funding for spares parts is still under discussion by the JAO.

14.5 Long-Term Development

From Project Plan, Chapter 6, Version Feb 2003

Continuing technical upgrades and development of new capabilities will be required to maintain ALMA as the state-of-the-art facility for millimeter/submillimeter astronomy over the course of its projected life of up to 50 years. In particular, the rapid progress of electronic technology should make new hardware components and subsystems offering improved performance and higher reliability available for insertion into ALMA on much shorter time scales. Equally important, advances in software and computing should also offer improved performance and reliability that translate into more capability and reduced costs of operation.

Development projects are the responsibility of the Executives. The normal procedure is that the Joint ALMA Observatory Director, in consultation with the user community and Executives, will put forward proposals to the ALMA Board for upgrade and development projects. The ALMA Board then decides on the projects, prioritizes them, assigns values and assigns responsibility to one (or both) of the Executives. Thereafter, development projects are conducted in a manner identical to the conduct of the ALMA construction project. Namely, the Executive having task responsibility will assign a project manager who will report to the Executive regarding matters of cost, and he/she will report to the ALMA Director regarding technical scope and schedule.

Development Projects & Budgets

Hardware development for ALMA in the period beyond construction is expected to fall into a number of categories. Some of these items should be considered to be definite, and some will become targets of opportunity as improvements in technology occur and as science requirements evolve to demand new capabilities. Likely efforts are discussed briefly in this section.

The total cost of these efforts is approximately $100 M in 2003 dollars or around $10M per year for 10 years. For some projects, however, a front-loaded budget profile may make more sense to keep ALMA performance on the cutting edge.

Additional receiver bands: it is expected that bands 1, 2, and 5, covering 31.3-45, 67-90, and 163-211 GHz will not be built during ALMA construction. However, the front end dewar is designed to accommodate these bands, and they should be populated as quickly as possible after the construction phase of ALMA ends. Bands 1 and 2 will be HFET amplifier receivers, and band 5 will be a SIS mixer receiver. The Band 1 receiver will likely provide useful response up to about 50 GHz with somewhat degraded performance. There are no significant cost differences among these three bands, and development, fabrication, and installation costs are expected to be about $7M for each band in 2003 dollars, equivalent to a total development budget of $21M in 2003 dollars. The work is straightforward and there are no technical risks.

Second Generation Correlator: the capability of the baseline correlator, enhanced by the tunable filter bank card recommended by the correlator CDR committee, will be significantly greater than originally required, and delay the need for a replacement. However, a second generation correlator will eventually be required for a number of reasons. Some improvement in signal-to-noise ratio will be possible by always correlating three bit instead of two bit samples. The frequency resolution can be improved by providing many more frequency channels, which for some types of observations will also improve observing efficiency by collecting more data per unit time. The science requirements will unquestionably change with time, demanding new correlator capabilities.

Preliminary work by the European, Japanese, and North American teams have resulted in more than one possible second generation correlator conceptual design. Work should continue throughout the ALMA construction period on design concepts, and some support from the ALMA operations budget will be needed for that purpose. It is likely that a new correlator with significantly enhanced capabilities will cost between $15M and $50M in 2003 dollars, depending on just how much advanced performance is demanded by the science. There will also be significant expenditures in computing and archiving hardware associated with the greater amount of data generated. If the new correlator is installed at the OSF instead of the AOS, there will be expense bringing the samples down to the OSF and providing a new building to house the correlator.

VLBI Data Recording: the capability of performing beam combining to provide a signal suitable for Very Long Baseline Interferometry is built into the baseline correlator in the form of digital signal outputs which, if added, will result in the equivalent SNR of a single 96-meter antenna. However, the adder (which may need to be partly digital and partly analog) is not part of the construction project. A VLBI data acquisition terminal capable of recording the combined signal is also not in the construction project. The hydrogen maser frequency standard is in the construction budget, and the local oscillator system is designed to be good enough for VLBI up to about 300 GHz.

Designing, building, and installing the necessary equipment to implement VLBI is likely to cost about $2M in 2003 dollars, exclusive of software expenses.

Upgrades of Front End Cartridges: it is likely that, by the time ALMA construction is finished, improvements in SIS mixer technology will result in receivers with better noise temperatures than those built for ALMA, particularly in the higher frequency bands. These improvements will come from better consistency in Nb wafer yields, better knowledge of how to design SIS mixers, and possibly from the use of materials other than Nb, which could be significantly better for Bands 5-10 and particularly for Bands 9 and 10. At some point, the improvement in array performance possible will make it worthwhile to retrofit old cartridges with new mixers. It is likely that it will be possible to change only the mixer-preamps, rotating all cartridges through a retrofit process over a period a few years.

ALMA operations should support some continuing research in SIS mixer development (perhaps $1M per year including labor) and then support cartridge upgrades when significant benefits are possible. Since only a retrofit is needed, the construction and installation costs are likely to be much less than the original construction costs. A reasonable estimate for implementation is about $2.5M per band in 2003 dollars for bands 6-10.

WVR upgrade: the Water Vapor Radiometer plan is to use uncooled Schottky mixers for measurements of water vapor needed for atmospheric phase correction. The sensitivity of these mixers is good enough to support phase correction, but not to correct pointing errors due to anomalous refraction. In order to perform a tip-tilt pointing correction, the sensitivity of at least a cooled Schottky mixer or even an SIS mixer is needed. If experience shows that significant improvements in sensitivity or calibration accuracy can be achieved with a tip-tilt correction, then the WVRs could be redesigned with cooled mixers of some variety. This would also require some mechanical work to design and incorporate a rotating pick-off mirror. Some components could be re-used, but a cooled system would be a major redesign.

Developing and implementing a cooled WVR system for tip-tilt correction is estimated to cost ????M$ in 2003 dollars.

Semi-transparent vane development: further development of the semi-transparent vane (STV) concept is desirable to improve amplitude calibration, especially in the sub-millimeter. Issues such as improved vane materials, multi-load, and polarizing grid concepts need to be addressed. At this time, it is not possible to provide a development budget estimate for this activity.

Back End upgrades: by the time ALMA construction is completed and the array is commissioned, it is likely that commercial components for high-speed digital data transmission will be much less expensive than at present. At some point, there may be cost advantages in maintenance that would warrant replacing the present digital data transmission components. Advances in semiconductor technology will undoubtedly make high-speed digitization with commercial components much less expensive, and extend the maximum bandwidth possible with a single digitizer. It is conceivable that, ten years from now, it will be possible to use one 4-bit digitizer per 8 GHz IF band instead of multiple 3-bit digitizers for multiple down-converted 2 GHz IF bands, and build the second generation correlator to use 4-bit samples, thus achieving very close to the maximum possible SNR from the received analog signals. This would also significantly reduce the component count in both the analog and digital sides and result in better reliability and maintenance savings.

Improvements in local oscillator technology are likely to result in improved performance in the areas of phase noise, phase stability, power, and added IF noise, particularly in the highest frequency bands. The improvements in array performance may at some point warrant changes in the local oscillator system.

Since these items are dependent on exactly where technology goes, it is impossible to estimate any cost; but ALMA operations will support a number of engineers, who should be encouraged and funded to keep up with the available technology and formulate plans for incorporating it into ALMA at the appropriate time.

Antenna upgrades: it has been the experience at all mm-wave observatories that improvements in antenna hardware can be made from time to time which result in improved performance in one way or another. A short list includes metrology upgrades, servo system upgrades, surface treatments, thermal modeling, and other electronics improvements. The antenna group should be expected not only to maintain the antennas, but also to evaluate their performance and think of possible ways to improve performance and reliability. This work would be outside the scope of normal day-to-day activity, and at some point the expenditure of modest sums might result in significant performance and cost savings. It is impossible to estimate a budget, but we believe some expenditures of this nature will be desirable.

Computing upgrades: basic computing upgrades (e.g. faster processors, larger Archive, new data warehousing techniques) are part of the general ALMA running costs. Above and beyond these costs, ALMA should fund development projects to develop new data processing and imaging tools, as well as improved user support and operations management tools. An annual effort of 10 FTEs (circa 1.2 million USD) is proposed~~, i.e. roughly 10% of the total annual development budget~~.

14.6 Contingency

Budget Impact: contingency estimates are based on total identified personnel and running costs. As these costs evolve, so will the contingency estimates.

To allow unforeseen events and/or changes in operation requirements, a 10% contingency in 2012 is provided. All cost estimates are in 2003 Euros.

14.6.1 Chile-based Operations

The 10% rule-of-thumb is applied as follows:

- International Staff Members: the current plan calls for 38 ISM positions in Chile, implying a *total* contingency of four (4) positions, roughly equivalent to 400 K€ per year.
- Local Staff Members: the current plan calls for 120 LSM positions in Chile, implying a total contingency of 12 positions, roughly equivalent to 900 K€ per year.
- Running Costs: the estimated annual running costs in Chile are currently circa 11 000 K€, implying an *annual* contingency of 1100 K€.

~~COMMENT:~~Comment: the most important missing component here is Santiago operations, for which no budget estimate is available yet.

14.6.2 ARC Operations

The 10% rule-of-thumb is applied as follows:

- ARC science support staff: each ARC has 12 science support staff. Total contingency for each ARC: two (2) positions, roughly equivalent to 200 K€ per year.
- ARC technical support staff: the European and North American ARCs have 10 computing positions each. For these ARCs, a one (1) position contingency per year is assumed.

15 Major Unresolved Issues

This section provides brief descriptions of major unresolved issues affecting ALMA operations planning. It is not the intent of this section to provide enough details per option to allow an immediate decision. It is expected that these issues can and will be closed in further versions of this document.

15.1 Chile turno shifts

In this draft, turno shifts of ~~5x2~~5+2 (managerial) and ~~8x6~~8+6 (technical) are used. For the ~~8x6~~8+6 positions, a staff multiplier of 2.4 was used to cover holidays and sick leave.

As discussed above, other turno shifts are possible, i.e. ~~11/9 or even 14/14.~~11+9 or even 14+14. Longer shifts reduce number of required staff, number of transition days, and intra-Chile travel costs. However, longer shifts may make staff recruitment more difficult. These costs and benefits should be studied more carefully.

15.2 End-to-End Science Operations Implementation Plan

The broad structure of an end-to-end science operations model is presented in the Project Plan and expanded upon in this document. It would be desirable to write a more detailed implementation plan that specifies all operational and technical interfaces, timescales, processes, data flow, etc. Delegated to future DD for SciOps.

15.3 Early Science Operations planning

More detailed planning of Early Science operations is needed, especially in the areas of planned observations and correlator modes, to facilitate SI and CSV planning.

15.4 System Ownership

The following comment was submitted by the European Executive:

Comment (Spyromilio): The other fundamental aspect that is missing from the document is the concept of ownership of the antennas. This is something that has evolved on both La Silla and Paranal in different ways. However, it is the concept that is critical. The telescopes on La Silla are owned by SciOps and on Paranal by Engineering. They are given over to the other team to perform their activities. However, there is always an owner and this owner does not change depending on the activity. The ownership clarifies the responsibility to rest beyond the execution of the task but for the complete system.

15.5 Director, Deputy Director work shifts

In Section 8, the Director and Deputy Directors are assumed to work Monday – Friday on a regular basis. For the DD Admin, this is fine – that person is based at the SCO. It is also fine for Director, who is assumed to split time between OSF, SCO, and various international meetings.

This work schedule is more challenging for DD SciOps, especially during early years when all activity is at the OSF. This schedule implies commuting between OSF and Santiago every week, which is not attractive for perspective candidates. This problem will be reduced once science operations activities are split between OSF and SCO.

The most affected person is the DD Technical Services, as the responsibilities of this person will always reside exclusively at the OSF. It may be be necessary to have two people in this role.

15.6 Chilean user community support removed

At the request of the NRAO Director, all explicit and/or implied user support for the Chilean user community has been removed from this draft. Thus, there is currently no support for proposal preparation, observation preparation, data product analysis, or archive usage. *The Executives must provide guidance in this area.*

15.7 Guidance from upper management needed

ALMA upper management needs to provide guidance on the following issues:

- Spare parts strategy and budget
- Management of computing development/maintenance during operations (30 FTEs)
- Remote repair facilities: tasks, process, management, interfaces to ALMA in Chile
- Chilean user support: Proposal management (Phase 1), observation management (Phase 2 and 3), archive and data products support
- Management of on-going development/maintenance outside of Chile
- Business Services staffing model & budget

15.8 Summary of Unresolved Budget Impact Issues

All items marked as *Budget Impact* in proceeding sections are summarized below:

- To meet current Level-1 milestones, operations money should have started flowing in 2004.
- AOS security model: unclear, no budget estimate
- Integration/Commissioning support ramp-up planning requires further study
- Turno rotations of 11+9 or 14+14 should be studied
- Spare stocking safety factor assumed to be 3, needs review
- Requirement for complete LRU verification in Chile needs review
- Unclear which LRUs require remote servicing at Executive maintained facilities
- Very high-bandwidth links between SCO and ARCs not provided
- Archive support for Chilean community: what, how, cost - all unclear
- Phase 2 support for Chilean community: how, who, cost – all unclear
- No Chile-based Education & Public Outreach Officer included in this plan
- Recruitment of Chile-based staff astronomers likely to be challenging

- Assumption: one (1) array operator can handle main array and ACA in steady-state operations – needs review
- If not ALMA Fellows in Chile, need two more staff astronomers in Chile
- During Early Operations, data management staff will have to work at OSF and work turno schedules – needs review
- Technical Services not staffed to support major development activities
- AOS work requires minimum two-person teams and fixed time intervals at altitude – impact on staffing level needs study
- Details of production Antenna and Electronics components may required revised staffing level and/or skill mix.
- Technical Services staffing estimates assume high-degree of similarity between analogous main array and ACA components – needs validation
- Electronics Group has assigned miscellaneous tasks – exact list needs review
- Responsibility and authority for ALMA computing development, maintenance, and prioritization during Operations is unclear.
- Computing IPT wants to charge 9 FTEs per year to Operations budget to develop operations support software between 2004 and 2011 – needs review and approval.
- ARC budgets include 30 FTEs per year to maintain and extend core ALMA computing system – 15 FTEs per ARC (if two ARCs)
- Staffing model of Business Services team needs clarification with Executives
- Warehouse management: might be better to do hire additional LSMs, and do in-house.
- ARC archive/pipeline systems are not Construction deliverable and will cost 250 000 USD per year.
- Staff model and value of ARC core services will depend on final agreement on core services by Executives
- SCO infrastructure and operating costs unclear.
- SCO scientific library: no budget yet, requirements unclear
- Definition and cost of ARC support for Chilean astronomical community is unclear
- Costs of power generation, especially in early years, unclear to Operations Working Group
- Exact composition of OSF/AOS general vehicle fleet still under discussion.
- Calama liaison office: needed?
- Replacement costs for: vehicles, IT equipment, Archive/pipeline systems (SCO and ARCs)

- Technical consumables: cost unclear
- Visitor Center: services unclear, no budget yet
- Staff recruitment costs: unclear, no budget yet
- ARC overheads
- Spare parts: strategy? Costs?

Although not all items have the same magnitude, the total aggregate additional cost is likely to be several million USD per year. ***Understanding these costs as soon as possible is obviously critical****.*