



**Atacama  
Large  
Millimeter  
Array**

## ALMA Operations Plan

***Provisionally Accepted by ALMA Board  
7 April 2005***


ALMA-00.00.00.00-002-A-PLA

Version: A

Status: Provisionally Accepted


2005-05-15

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	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA  Date: 2005-05-15  Status: Provisionally Accepted  Page: 2 of 94
---	--	---


## Change Record

Version	Date	Draft #	Reason/Initiation/Remarks
A	2005-05-15	0	First Board approved release (based on Draft J1). Corrections relative to J1: (1) changed Project Plan Ver 1 (PP-I) to PP Ver 2(PP-II) in several places (typographical error); (2) added paragraph about Chile Regional Center on p. 17 (to be consistent with PP-II); (3) replaced paragraphs 1 and 2 on p. 17 with language from PP-II (only minor wording change) for consistency.


	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 3 of 94
---	--	---

## Table of Contents


1	EXECUTIVE SUMMARY .....	7
2	INTRODUCTION .....	8
2.1	High-level Assumptions .....	9
2.2	ALMA Operations Working Group .....	10
2.2.1	Operations Working Group Membership.....	10
2.2.2	Operations Working Group Review Process .....	10
2.3	ALMA Board Approved Reference Documents.....	11
2.4	Other Reference Documents.....	11
2.5	Abbreviations and Acronyms .....	12
2.6	Glossary .....	14
2.7	Verb Convention.....	14
2.8	Acknowledgements.....	14
3	NARRATIVES .....	15
3.1	A Typical Day in 2012 .....	15
3.2	A Typical Day in 2007 .....	15
4	JOINT ALMA OBSERVATORY MANAGEMENT STRUCTURE.....	16
5	OPERATIONS DEVELOPMENT CONCEPTS & MILESTONES .....	19
5.1	Safety.....	19
5.2	Environmental Impact.....	20
5.3	Operations Management.....	20
5.4	Construction/Operations Interfaces.....	21
5.5	Operations Development Assumptions .....	24
5.5.1	Key Concept: Early Staff Recruitment.....	24
5.5.2	Sistema de Turno.....	25
5.5.3	Critical Operations Development Assumptions.....	25
5.6	Operations Development Stages.....	28
5.6.1	Early Pre-Operations Stage .....	28
5.6.2	Late Pre-Operations Stage.....	29
5.6.3	Early Operations Stage .....	30
5.6.4	Full Science Operations Stage.....	32
5.7	ALMA Operations Milestones .....	32
6	GENERAL MAINTENANCE CONCEPTS.....	35

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 4 of 94
---	--	---


6.1	ALMA Availability.....	35
6.2	Down-Time Components.....	36
6.3	Line Replaceable Units.....	36
6.3.1	LRU case study: the front-end assembly .....	38
6.4	Corrective Maintenance.....	39
6.5	Preventive Maintenance.....	40
6.6	Potential Single-Point Failures .....	41
6.7	Maintenance Process.....	41
6.7.1	General Considerations.....	41
6.7.2	Maintenance Process Management .....	42
6.7.3	Local Facilities.....	42
6.7.4	Remote Facilities .....	43
6.8	System Performance Diagnostic Software.....	43
7	ALMA SCIENCE OPERATIONS CONCEPTS & DELIVERABLES.....	44
7.1	Overall Operations Concepts.....	44
7.2	Proposals, Projects, ObsUnitSets, and Scheduling Blocks: A Quick Overview.....	44
7.3	ALMA Archive and Operational Data Flow.....	45
7.4	Calibration Plan .....	46
7.5	Scheduling.....	46
7.6	ALMA User Support Homepage and Helpdesk.....	47
7.7	Phase 1: Observation Proposal Management.....	48
7.7.1	Proposal Submission.....	48
7.7.2	Proposal Review .....	49
7.7.3	Proposal Scheduling .....	50
7.8	Phase 2: Observation Preparation.....	51
7.9	Phase 3: Observation Execution & Problem Resolution .....	52
7.10	Post-execution Data Processing .....	52
7.11	Quality assurance .....	53
7.12	Science Deliverables.....	54
7.13	Data Analysis Support .....	55
7.14	Data Rights.....	55
7.15	Publications.....	56
7.16	Monitoring of ALMA Time Use .....	56
7.17	Director's Discretionary Time (DDT).....	56
7.18	Target-of-Opportunity (ToO) Guidelines.....	57

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 5 of 94
---	--	---

7.18.1	One-time ToO events.....	57
7.18.2	Generic ToO events .....	57
7.18.3	ToO Data Delivery .....	58
7.19	Narrative: A Typical Proposal Lifecycle .....	58
8	ALMA DIRECTOR'S OFFICE .....	60
9	DEPARTMENT OF SCIENCE OPERATIONS .....	62
9.1	Management Structure.....	62
9.2	Array Operations Group (AOG).....	63
9.3	Program & Data Management Group (PDM).....	64
9.3.1	Program Management Tasks .....	64
9.3.2	Data Management Tasks .....	66
9.3.3	System Management Tasks .....	67
10	DEPARTMENT OF TECHNICAL SERVICES .....	68
10.1	Management Structure.....	68
10.2	Antenna Group (AG) .....	70
10.2.1	Tasks & Personnel .....	70
10.2.2	Required Equipment & Documentation.....	71
10.3	Electronics Group (EG) .....	71
10.3.1	Tasks & Personnel – Front-end .....	71
10.3.2	Tasks & Personnel – Back-end & Correlator.....	72
10.3.3	Miscellaneous Electronics Support Tasks.....	73
10.3.4	Required Equipment & Documentation.....	73
10.4	Computing Group (CG).....	73
10.4.1	Tasks & Personnel .....	73
10.4.2	Required Equipment & Documentation.....	74
10.4.3	Digital Infrastructure Security in Chile.....	75
10.5	Maintenance Group (MG) .....	75
10.5.1	Tasks and Personnel .....	75
10.6	System Engineering Office (SEO) .....	76
10.6.1	Tasks & Personnel .....	76
10.6.2	Required Equipment & Documentation.....	76
10.6.3	Data Interface Control Board .....	76
10.7	Spectrum Management Office (SMO).....	77
11	ADMINISTRATION DEPARTMENT .....	78
11.1	Management Structure.....	78

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 6 of 94
---	--	---

11.2	General Services .....	78
11.3	Facilities Group.....	79
11.4	Executive-based Business Services.....	80
12	ALMA REGIONAL CENTERS (ARCS).....	81
12.1	Core Services .....	81
12.1.1	Scientific support services .....	81
12.1.2	Technical support services .....	83
12.1.3	Development support services.....	83
12.2	Enhanced Services .....	83
13	SANTIAGO CENTRAL OFFICE: PRELIMINARY INFRASTRUCTURE REQUIREMENTS	84
13.1	General Requirements .....	84
13.2	ALMA Director's Office .....	84
13.3	Science Operations .....	84
13.3.1	Research support.....	84
13.3.2	Data Management.....	85
13.4	Technical Services .....	85
13.5	Administration .....	85
13.6	Computing Support.....	85
13.7	Summary: SCO Office Requirements .....	85
ADO	.....	85
14	BUDGET OVERVIEW .....	86
15	COMMENTARY AND UNRESOLVED ISSUES .....	87
15.1	Board-level areas of concern .....	87
15.2	Items for discussion between JAO and Executives .....	88
15.3	Maintenance Concepts: Comments by Casoli and Vigroux .....	89
15.4	Impact of weather on ALMA operations .....	90
15.5	End-to-End Science Operations Implementation Plan .....	90
15.6	System Ownership .....	90
15.7	Director, Department Head work shifts .....	91
15.8	Summary of Unresolved Budget Impact Issues .....	91

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 7 of 94</p>
---	---	--

## 1 Executive Summary


This is the ALMA Operations Plan.

Fundamentally, this plan has been derived from the ALMA Project Plan, Version 2 (23 September 2004) – in particular, Chapter 6 – based on input from and discussion with the JAO ALMA Operations Working Group (OG).

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*.

At the request of the ALMA Board, the impact of Japanese components on ALMA operations has not been considered in this draft. The Japanese impact will be re-assessed during 2005.

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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 8 of 94
---	--	---

## 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



	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 9 of 94</p>
---	--	--

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 worldwide community after the expiration of a proprietary period of 12 months [TBC] from the delivery to the PI. The ALMA 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 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 2, 2004-09-23).
- 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. *In this version of the Operations Plan, the impact of these additions has not taken into consideration.*

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 10 of 94
---	--	--

- 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 hardware and software development (beyond the basic maintenance described in the last bullet) 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 Working Group

### 2.2.1 Operations Working Group Membership


This plan was created by the Operations Working 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, with David Silva as co-leader. Since mid-2004, David Silva has been acting as the defacto group leader.

Group members as of June 2004 were:

Name	Organization	IPT
Darrel Emerson	NRAO	
David Silva	ESO	
Clint Janes	NRAO	Back-end
Ryohei Kawabe	NAOJ	ACA
Max Kraus	ESO	Antenna
Robert Lucas	IRAM	Computing (SSR)
Jeff Mangum	NRAO	Antenna Evaluation Group
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

### 2.2.2 Operations Working Group Review Process

Drafts A – G of this Operations Plan were created in a totally collaborative manner within the Operations Group. For each of these drafts, there was at least one group-wide review telecon and many e-mail exchanges. The last version reviewed by the entire Operations Group was Draft G3 in February 2004.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 11 of 94
---	--	--

Draft H1 was produced in June 2004 using input from the European and North American Executives, comments received during the mini-ALMA week in Germany, the preliminary May 2004 ASAC report, and various reviewers of Draft G3. Many Operations Group members (but not all) provided input for Draft H2. For the most part, the changes between G3 and H1/H2 were relatively minor. However, there was no formal group-wide review telecon for Drafts H1/H2.

Draft I1 (20 September 2004) was produced mainly based on the final version of the May 2004 ASAC report. Draft I2 (15 October 2004) was identical to Draft I1 except a complete budget overview (including ramp-up analysis) written by David Silva was added. With the exception of the budget overview in Draft I2, the changes between Draft H2 and Draft I1/I2 were relatively minor. Neither Draft I1 nor I2 were formally reviewed by the Operations Group. Darrel Emerson reviewed Draft I1 and the budget overview in Draft I2.

Draft J1 (10 March 2005) was produced based mainly on input from the Board (as organized by Roy Booth and Ethan Schreier) and on improved planning for system integration and commissioning. Sections 5 (Operations Implementation Concepts and Milestones) and 15 (Unresolved Issues and Commentary) were heavily revised. The budget overview (Section 14) was moved to a separate document. All other sections received relatively minor updates. Neither the Operations Group nor Darrel Emerson reviewed Draft J1 before its release to the JAO and the Board. This draft was approved by the ALMA Board on 7 April 2005 at their Pasadena face-to-face meeting, subject to a few requested changes.

Version A is the first official release. Changes relative to Draft J1 are listed in the Change Record on page 2. Although the name of Darrel Emerson does not appear here as co-author (at his request), Darrel played a key role in shaping this operations plan – my sincere thanks for all his work, help and guidance over the last two years.

### 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		2004-09-23	Project Plan II

### 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.<sup>1</sup>

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<sup>1</sup> At 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 12 of 94
---	--	--


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)
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
AIV	Assembly, Integration, and Verification
AIVC	Assembly, Integration, Verification, and Commissioning
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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA  Date: 2005-05-15  Status: Provisionally Accepted  Page: 13 of 94
---	--	--

BER	Bit Error Rate
BGA	Ball Grid Arrays
CM	Corrective Maintenance
CMMS	Computer Maintenance Management System
CSV	Commissioning & Science Verification
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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA  Date: 2005-05-15  Status: Provisionally Accepted  Page: 14 of 94
---	--	--

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. 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, Carlos de Breuck, Fernando Comerón, Jim Hesser, Harvey Liszt, Gautier Mathys, Jason Spyromilio, Roberto Tamai, Rein Warmels, Tom Wilson. The May 2004 ASAC committee also provided comments on Draft G3. Comments on H2 were received from Jim Hesser and Paul Vanden Bout. Comments on Draft I1/I2 were provided by Roy Booth and Ethan Schreier on behalf of the ALMA Board and by Norio Kaifu for NAOJ. Additional comments were provided by Paul Vanden Bout and Laurent Vigroux.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 15 of 94
---	--	--

### 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.

TO BE COMPLETED

#### 3.2 A Typical Day in 2007

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

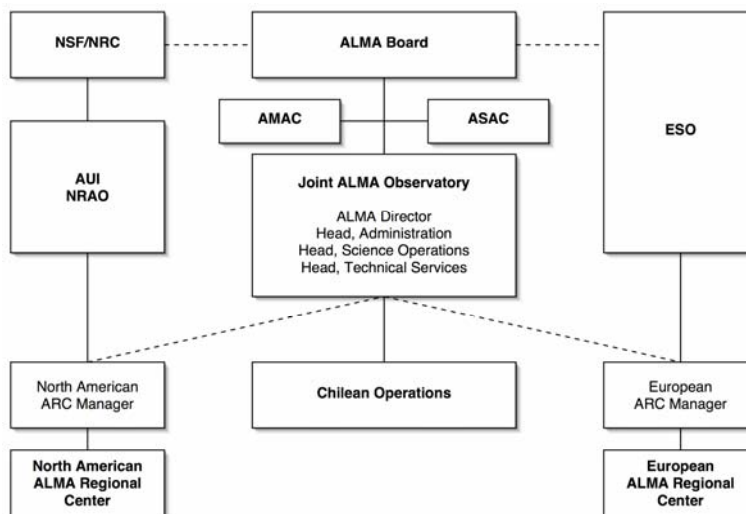
TO BE COMPLETED

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 16 of 94
---	--	--

#### 4 Joint ALMA Observatory Management Structure

*The Executives and ALMA Board 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 ALMA 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:

- ALMA Director
- Head – Department of Administration
- Head – Department of Science Operations
- Head – Department of Technical Services



	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 17 of 94</p>
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The ALMA Director leads the Joint ALMA Observatory and reports to the ALMA Board. The ALMA Director shall have the responsibilities and authorities as stated in the bi-lateral ALMA Agreement. The ALMA Board appoints the ALMA Director and the remaining key personnel in concurrence with the ALMA Director.

In response to the ALMA Director's requirements, the Executives hire the necessary staff ADO activities. All ADO staff will be co-located in Santiago de Chile at the Central Office, except for the tasks better executed at the Operations Support Facility near San Pedro de Atacama, as deemed necessary by the ADO. 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.<sup>2</sup> 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 ALMA 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 part of the Executives contribution to the ALMA operations budget. Each ARC may also provide additional, enhanced services as deemed desirable by the managing Executive. 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 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.


The Republic of Chile anticipates the creation of a separate Chilean Regional Center (CRC). The Joint ALMA Observatory shall provide the CRC with the basic software tools necessary for the preparation and submission of observing proposals, data analysis, and archival research. The possibility of additional support or services from the Joint ALMA Observatory to the CRC or the Chilean astronomical user community at large is subject to discussions at the level of the ALMA Board and Executives. No such additional support or services are planned at this time.

Analogous to the ALMA Management IPT for Construction, the Joint ALMA Observatory shall have a Management Team that consists of the three Department Heads, 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 ALMA Director.

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

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<sup>2</sup> This statement is consistent with available versions of the Project Plan, Chapter 6. However, the Executives and JAO 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.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 18 of 94</p>
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- 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 ALMA Director is solely responsible for resolving operational conflicts between the Chile-based operations group(s) and the ARCs. As necessary, the ALMA 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 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 ALMA 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 ALMA 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 ALMA 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 ALMA 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 ALMA 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 19 of 94
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## 5 Operations Development Concepts & Milestones

*Comment: the ALMA Board has established two Level-1 milestones for operations: Early Science Operations in 2007 Q3 and Full Science Operations in 2012 Q1. At the time of this writing (February 2005), it is clear that these dates will change because the antenna procurement contract has not yet been signed. In this section, dates relative to the start of Early Science ( $T = 0$ ) are used as much as possible.*

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. More detailed planning is the responsibility of the ALMA Director's Office.

### 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 develop, implement, 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 ALMA Director. The duty station of the Safety Manager shall be the OSF. The Safety Manager shall be assisted by one safety officer per turno shift. (Turno shifts are explained in Section 5.5.2).

In particular, the Safety Manager must be cognizant of safety issues related to activity at altitudes spanning 2500 – 5000m above sea level. Since medical and safety research in this area are constantly evolving, the Safety Manager must take steps to stay familiar with the latest information.

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

The responsibilities of the Safety Manager shall include, but are not necessarily limited to:

- 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;
- monitoring the performance of contracted medical and/or paramedical services;
- 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;
- 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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 20 of 94
---	--	--

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.

- Develop, implement, and/or maintain an environmental protection plan (see next section).

*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 – everyone at the AOS shall work in teams of two (2) or more people.** 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. 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 Safety Manager shall be responsible for developing, implementing, and/or maintaining an environmental protection plan. When such a plan is in place, the Safety Manager shall monitor compliance with this plan.

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. A Spectrum Management Office (SMO, see Section 10.7) shall be established.


## 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<sup>3</sup>
- repair history tracking

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<sup>3</sup> If possible, there should be one integrated problem reporting & change request management system across the entire Observatory, including the ARCs.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 21 of 94
---	--	--

- 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.

*Comment: L. Vigroux of the European ALMA Board has expressed concerns that this section is too technocratic, that the required processes are not described in enough detail, and that the implied cost of such an approach is not clearly stated. These concerns should be addressed by the future Head of Science Operations and Head of Technical Services during more detailed planning.*

#### 5.4 Construction/Operations Interfaces


*Comment (February 2005): in this section, the concepts of Assembly, Integration, and Verification (AIV), Commissioning, and Science Demonstration are introduced. In early drafts of this document, the first two concepts were known as Systems Integration (SI) and Commissioning/Science Verification (CSV). Obviously, AIV and Commissioning are strongly linked activities. In recognition of this, the Construction project has created a merged AIVC plan. This section has been heavily revised to reflect current Construction project planning.*

**Assembly, Integration, and Verification (AIV)** is a Construction activity led by the JAO Project Engineer. The primary AIV tasks are to assemble and integrate the major ALMA sub-systems into a working system, establish its initial technical performance, and ensure it meets stated technical requirements. AIV will continue until all antennas are accepted from the 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 AIV 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 tracking system for maintenance activities and problem reporting

AIV activity will start prior to the arrival of the first antenna in Chile and continue until the last antenna has been integrated and verified. By necessity, it will run in parallel to Early Science Operations (see below).

Although the AIV team will be largely self-contained, it will draw on certain Operations funded resources and infrastructure. In particular, current (early March 2005) AIV planning assumes that Operations will supply the following things:

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 22 of 94
---	--	--

1. Array operators to perform all operations involving movement of antennas except for basic functionality check.
2. Equipment operator for all antenna transporter uses.
3. Warehousing staff and facilities at OSF, including logistics support and any shipping costs associated with maintenance.
4. Post-AIV equipment maintenance staff.
5. All power costs, including maintenance.
6. All communication costs for off-site communications (voice and data).
7. IT support for office computing and video at AOS and OSF, including that for AIV staff.
8. All IT infrastructure for office computing by AIV staff (i.e. AIV staff will purchase a desktop computer for each staff but expect that any DHCP servers, communication switches, hubs, firewalls, backup devices, printers, etc. are provided by Operations.)
9. All computing infrastructure needed for array control and the data management (archive) subsystems.
10. Basic security and safety staff and associated equipment.

For each antenna, the AIV team must complete four basic tasks: acceptance testing (at time of vendor hand-over), antenna integration (i.e. installation of ALMA equipment), total power checkout at the OSF, and installation and checkout at the AOS. For the first seven (7) antennas, all four tasks shall be the responsibility of the AIV team. During this period, staff destined for Operations will be trained to perform the last two AIV tasks. Starting from Antenna 8, the first two AIV tasks will continue to be executed solely by the AIV team, while execution of the last two AIV tasks (OSF and AOS check-out) will be shared between the AIV and Operations teams. This is a natural division of tasks – it is unlikely that the Operations staff will ever have to accept and integrate new antennas while the OSF and AOS checkout tasks (or at least some sub-set of them) must occur every time major maintenance is performed on an antenna. The Project Engineer remains responsible for all four tasks until all new antennas are processed.


Based on current (early March 2005) AIV planning (Murowinski, private communication), the staffing required to execute the OSF and AOS checkout tasks has been estimated to be 0.5 mechanical engineer, 0.5 mechanical technician, one (1) software engineer, one (1) electronics engineer, 0.5 electronics technician, one (1) control engineer, and 1.5 astronomers per day *in addition to any other resources needed for commissioning, science operations or maintenance activity* until AIV has been completed for all antennas. It is assumed that some or all of these staff are initially part of the AIV team for training purposes and then transferred to Operations when Antenna 8 is ready for processing. The estimated resources are sufficient to execute the OSF and AOS checkout in parallel on two separate antennas. It is assumed that prior to Antenna 8, these checkout procedures have become routine and trouble-free.

Care should be taken to assure that AIV and Operations staff, facilities, and equipment duplication is minimized. Some duplication is unavoidable, meaning that when AIV is completed, some support hardware may be superfluous and not all AIV staff can transition to Operations.

*Comment: the operations science, engineering, and technical staff should also be familiar with the antenna integration task since many of the related sub-tasks will be required during antenna maintenance. How such knowledge is transferred between the AIV and Operations teams is still TBD.*

**Commissioning** is a Construction activity led by the JAO Project Scientist. After each antenna is integrated into the array by the AIV team, the Commissioning 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,



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 23 of 94
---	--	--

pointing model tuning, and testing of a pre-determined range of operations modes (e.g. continuum imaging at 100 GHz). The Commissioning 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 Commissioning team finds problems with newly integrated hardware or software, it is the responsibility of the AIV team to diagnose and (if possible) correct the problem, with assistance from the various Construction IPTs or Operations as needed.<sup>4</sup> *In essence, the Commissioning team is accepting all ALMA system components, hardware and software, on behalf of ALMA operations.*

AIV and Commissioning are strongly linked activities. In recognition of this, the Construction project has created a merged AIVC plan.

The core Commissioning team will consist of experts associated with the Science IPT who will be assisted by Chile-based operations astronomers. By assisting in commissioning, the operations astronomers will become familiar with the system and spin up on what they need to know for operations. The Science IPT experts will be a mixture of astronomers already associated with the project (e.g. Robert Lucas and Jeff Mangum) plus other people as deemed necessary by the Project Scientist. These other people could be scientists assigned to the ALMA Regional Centers (ARCs) (almost certainly true in the NRAO context), scientists associated with various ALMA-related committees (e.g. ASAC, SSR), or scientists external to the immediate project.<sup>5</sup>


Commissioning has two primary products. The first product is a set of operational procedures and checklists 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 ALMA Director, the datasets shall be released to the ALMA community via the ALMA archive system. In practice, both products (procedures and datasets) are built up and released incrementally as Commissioning progresses.

Commissioning activity starts when a verified three-element array is available at the AOS and continues until all antennas have been added to the array. During the first year (roughly Antennas 3 – 15), Commissioning is a more or less continuous process. After the start of Early Science Operations, use of the array will be shared between the commissioning and science operations activities (i.e. astronomical observations). The fraction of time devoted to Commissioning may be very large at the start of Early Science but will dwindle to almost zero by the end of Early Science operations. During the first year(s), Commissioning and science operations will not occur in parallel, i.e. the system will either be used for Commissioning or for science operations, but not both. At some TBD point, it will become possible to use one sub-array for some specific AIVC activities (e.g. check-out of Antenna 3X when it first arrives at AOS) while the rest of the system is used for science operations.

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<sup>4</sup> IPTs must include the possibility of such support in their detailed planning.

<sup>5</sup> The Commissioning team could include external scientists at least two ways. First, external scientists could participate in the processing of Commissioning data to provide feedback to the Commissioning team. Second, external scientists could temporarily participate in Commissioning 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 Commissioning Participation as far in advance as possible (perhaps one year) to allow external participants to arrange, e.g. sabbatical leaves. In any case, external scientists must be made aware they are part of a managed team and that they will be assigned specific tasks and goals by the team leader (most likely ALMA Project Scientist).

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA  Date: 2005-05-15  Status: Provisionally Accepted  Page: 24 of 94
---	--	--

By extension, the Commissioning team expects the same infrastructure support from Operations as the AIV team (see 10 items listed above) with the addition of data processing infrastructure at all relevant locations. The Commissioning team also expects the active participation of two (2) Chile-based operations astronomers per day when Commissioning activity is occurring so that these astronomers are prepared for their various science operations tasks. As problems arise, the Commissioning team expects technical support from both AIV and Operations as appropriate. More detailed plans, including a Commissioning task and verification matrix, can be found in the *ALMA Commissioning Plan* document (in preparation).

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

**Science Demonstration** is a relatively new concept currently under discussion by the ASAC and the ALMA Board. The model under discussion envisions that the Project Scientist will organize an Announcement of Opportunity for the community to suggest interested observations to demonstrate the capabilities (observing modes) of ALMA and to produce initial scientific results of broad interest. Using this AO as a starting point, the Project Scientist will organize a community of interested scientists from the community to plan the observations and then process the resultant data. ALMA operations astronomers from Chile or the ARCs might assist this committee but this is currently unclear. All information, including raw and processed data, would become available to the community at large as soon as possible. Since ALMA capabilities will be continuously expanding over the first five years, the Science Demonstration process will be an on-going activity. The exact details of this process are still very much under discussion. However, as far as Operations is concerned, the Science Demonstration team is just another user – no extraordinary operations support is foreseen.

## 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 AIVC 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 AIV and Commissioning 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 component fabrication sites outside of Chile, as appropriate, during component fabrication and before component delivery.

Operations personnel training is based on the procedures developed by the AIV and Commissioning 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 the year before Early Science operations begins when there will be significant Commissioning and science operations preparation tasks running in parallel. During this period, ALMA must endeavor to staff the combined AIVC/Operations teams at the proper level. In concept, this is akin to over-staffing the AIVC teams in the beginning with people who will become the startup Operations staff. By the time all antennas have been delivered, all AIVC staff have transitioned to Operations or left the Project.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 25 of 94
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### 5.5.2 Sistema 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 de Turno*. In Chile, all international observatories and most mining operations use the turno system. 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 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 8+6 schedule is more appropriate for skills needed every day. It provides 72.5 work-hours over a two-week period. It covers 6 hours on day 1 starting at 1330 hours, consists of 10 work-hours each on days 2 through 7, and ends at 1530 on day 8. Replacement personnel overlap on days 1 and 8.


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

It is assumed here that ALMA will follow the 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). Longer turno rotations (11+9 or 14+14) might be considered on a case-by-case basis. For each turno employee (international or local), ALMA shall provide room, board and transportation to and from pre-established pickup points in Calama and Santiago. Typically, transportation between Santiago and Calama shall be by air while transportation between Calama and the OSF shall be by road. 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.

### 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 ALMA 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


	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 26 of 94
---	--	--

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 ALMA Director and/or the Head for Science Operations or Head 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 AIV and Commissioning 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 at least 30 antennas are available (number 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.
- **Limited use of sub-arrays at start:** before at least 30 antennas are available (number 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 AIV team is responsible for the development or verification of all technical procedures (primarily in the areas of setup and maintenance) while the Commissioning team is responsible for the development or verification of all operational procedures.
- **Staff development:** it is assumed that the AIV and Commissioning teams will host and train the initial operations staff contingent. From the Operations perspective, the AIV and Commissioning teams host the core Early Science operations teams.
- **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 by the start of Early Science (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 (e.g. unpredictable and time-critical astronomical event). 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 AIV and Commissioning.
- **Indirect user interaction:** in the spirit of ASAC recommendations,<sup>6</sup> a minimal eavesdropping capability will be implemented with the goal of delivering execution and quality assurance

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<sup>6</sup> See October 2001 ASAC report (Appendix C).


	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 27 of 94
---	--	--

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<sup>7</sup>, 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:** as instructed by the Board, ACA operations are not explicitly taken into account in this plan. This plan will have to be reviewed and updated after discussions with the Japanese are concluded. Subject to the outcome of those discussions, the following principles are thought to be valid. As much as possible, main array and ACA operations shall be merged. In the specific area of science observations, main array and ACA observations may be coordinated in time on an as-needed basis – but the two systems are not necessarily required to point at the same target and/or execute the same SB at the same time. 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 observations 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.*
- 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 ALMA Director, additional down-time shall be scheduled for major system-level maintenance or upgrades.
- Pipeline generated 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 generated automatically by the pipeline 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. In short, ALMA shall deliver the necessary tools and documentation to allow users to calibrate their data and produce images at home.
- 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 Commissioning 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.
- Staged central Pipeline deployment:** at the start of Early Science Operations, the central pipeline system shall be located at the OSF and 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).

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<sup>7</sup> ASAC, *ibid.*

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 28 of 94
---	--	--

- **Delayed delivery of ARC archive/pipeline systems:** it may not be possible to deliver commissioned and operational archive/pipeline systems to the ARCs until 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). In any case, ARC staff shall provide data product and analysis support.
- **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. By the end of this period, the members of the AIV team are on site continuously. At the start of this period, the Commissioning team is still based outside of Chile, coming to Chile only as necessary. However, by the end of this period, the Commissioning team is also based in Chile.

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 development
- Initial arrival & acceptance of Construction deliverables (e.g. transporter, OSF facilities, etc.)
- Start ALMA Regional Center development & staff recruitment (responsibility of Executives)
- Start AIV and Commissioning support
- Transport integrated antennas to AOS as requested
- Accept 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. By the end of this period, the initial complement of operations staff and infrastructure must be in place and ready to support AIV and Commissioning activities.

During this period, various proto-commissioning and science operations preparation activities may be occurring at the ATF. These activities are assumed to be the responsibility of the Science IPT. The involvement of operations personnel in these ATF activities is still TBD.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 29 of 94
---	--	--

### 5.6.2 Late Pre-Operations Stage

Definition: period from availability of three-antenna interferometer to start of Early Operations. During this period: (1) AIV activity continues; (2) Commissioning 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 AIV and Commissioning 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. (This is a joint ARC/Chile activity organized and lead by the Head of Science Operations).
- 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 may 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. The staff responsible for Early Operations should do this task with as little as possible assistance from the AIV or Commissioning 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 Head for Science Operations. It could be coupled to the execution of Science Demonstration projects.

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

Relative Date (months)	Actor	Task
T-10	JAO	Start Call for Proposals preparation
T-8	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 information predicted evolution in number of antennas
T-6	ARC	Observing proposal submission deadline
T-4	ARC	Regional program review work complete
T-3	ARC/JAO	International program review work complete, LTQ ready, Phase 2 begins

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 30 of 94
---	--	--

T-1	ARC	Phase 2 complete, all SBs certified correct by ARCs
T = 0	JAO	Early Science Operations start
T+2	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.

*Comment: the number of available antennas will increase quick rapidly with time during the first few years of ALMA operations. When preparing the Call for Proposals, it might be wise to advise users to consider projects for different numbers of antennas in different configurations. Needs further discussion.*

### 5.6.3 Early Operations Stage

Subject to Board approval, and following the recommendations of the ASAC<sup>8</sup>, Early Operations shall begin when the following conditions are met:

- At least six (6) commissioned antennas at the AOS released for science operations.
- Instrumentation package containing at least two (2) of four (4) standard bands<sup>9</sup>, including Band 3, installed and commissioned on each of the operational antennas. *It would be highly desirable to have at least one submillimeter band available (ASAC May 2004).*
- Baselines up to at least one (1) kilometer available (and longer if possible).
- Both line and continuum observations can be supported
- Phase correction is possible, using fast switching and/or water vapor radiometry. *Both options are highly desirable (ASAC May 2004).*
- Basic modes of correlator commissioned and verified<sup>10</sup>
- Basic operations modes commissioned and verified. *Basic modes should include single-field interferometry, pointed mosaics (no OTF), and single-dish total power line observations (no continuum) (ASAC May 2004).*
- Commissioning 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<sup>11</sup>
- ALMA User's Manual and ALMA Operator's Manual released (at least Version 1 for both)


<sup>8</sup> See 2002 October and 2004 May ASAC reports for further discussion and science rationale.

<sup>9</sup> 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.

<sup>10</sup> 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.

<sup>11</sup> Possibly one of the ACA 12m antennas



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 31 of 94
---	--	--

- 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.

Early Operations will provide the community with an exciting set of initial functionality. However, it will not be the full-up system and not all services and functions envisioned for the full-up system 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.

At the start of Early Operations, 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: the decision to release antennas continuously or in discrete increments to the user community during Early Operations requires further discussion, in particular about impact on dynamic scheduling and SB construction.*

AIV and Commissioning activity continue in parallel with Early Science operations. However, some AIV and Commissioning personnel will transfer to their permanent operations team 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:

- Continued staff recruitment & training
- Continued support for AIV/Commissioning 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

A more exact description of the early science program is beyond the scope of this document. However, it is noted that the ASAC has recommended that science operations start with demonstration science projects, consisting of a mix of public demonstration images and science demonstration projects. These

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 32 of 94</p>
---	--	---

concepts have been generally supported by the Board but require further development by the Project Scientist.

#### 5.6.4 Full Science Operations Stage

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 when the main array is 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.

Although Full Science Operations does not technically start until all main array antennae are released to Operations, 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 (February 2005): this section is a work-in-progress. The final absolute dates cannot be assigned until the Construction milestones have been officially revised. Nevertheless, it is certain that the start of Early Science operations (as it is currently defined) will slip by 12 – 18 months. For now, that date is set to 1 July 2009.*

Quarterly milestones can be derived from the current Construction schedule and the operations stages discussed above. Antenna-related 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 AIV and Commissioning activities.




	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 33 of 94
---	--	--

Year	Q	Relative Date	N1	N2	Milestone
2005	1				
	2	T-50			ALMA Operations Plan accepted by Board <b>Antenna procurement contract signed</b> Recruitment of high-level Chilean personnel starts Recruitment/assignment of high-level ARC personnel begins
	3	T-47			
	4	T-44			
2006	1	T-41			Test interferometer, proto-Commissioning activity at ATF (TBC) Recruitment/training of mid-level and low-level Chilean personnel starts
	2	T-39			
	3	T-36			
	4	T-33			AIV team establishes long-term presence in Chile
2007	1	T-30			<b>First Production Antenna &amp; FE Available at OSF</b> Technical Services personnel & infrastructure ready to transport & support first antenna Begin ARC infrastructure & staffing development
	2	T-27			
	3	T-24			
	4	T-21			
2008	1	T-18			
	2	T-15			Commissioning team establishes long-term presence in Chile
	3	T-12			<i>ARCs ready to support initial Call for Proposals</i> <i>ARCS ready to support end-to-end proposal management process</i> <b>Three-antenna interferometer available at AOS (T-12)</b> 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-9			CfP-01 released (T-8): 1 Nov 2008
2009	1	T-6			CfP-01 proposal deadline (T-6): 1 Jan 2009 Regional proposal review complete (T-4): 1 Mar 2009
	2	T-3			<i>ARCs ready to support end-to-end Phase 2 process</i> <i>Chile team ready to create/manage Long-Term Schedule and Long-Term Queue</i> International proposal review complete (T-3): 1 Apr 2009 Phase 2-01 complete (T-1): 1 June 2009 At least one (1) ACA 12m antennas ready in total-power

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 34 of 94
---	--	--

Year	Q	Relative Date	N1	N2	Milestone
					mode [TBC]
	3	T=0	8	6	<b>Start Early Science Operations (T=0)</b> (1 July 2009)
	4	T+3			
2010	1	T+6			
	2	T+9			
	3	T+12			
	4	T+15			
2011	1	T+18			Pipeline produced images delivered for standard modes
	2	T+21			
	3	T+24			Central Archive & pipeline systems operational at SCO
	4	T+27			
2012	1	T+30			ARC Archive nodes operational
	2	T+33			
	3	T+36			
	4	T+39			Start Full Science Operations [TBC] <b>ACA ready for operation [TBC]</b> <b>All NA, EU, and JA receivers operational in Main Array</b>

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 35 of 94</p>
---	--	---

## 6 General Maintenance Concepts

*Comment (March 2005): during discussions with various Board members, it became clear that this section needs significant revision. Most of the theoretical, non-ALMA specific material could be moved to an appendix. More specific down-time requirements for the general system as well as various sub-systems need to be developed and stated here. These requirements should then drive maintenance planning, spares acquisition, maintenance staff size, etc. This issue needs urgent attention in the next few months. See additional comments by Casoli and Vigroux in Section 15. For now, this section remains essentially unchanged from Draft II.*

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.<sup>12</sup> 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:

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


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.<sup>13</sup> Defined in this way, MDT includes system failures as well as 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.

*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 ALMA Director. It is*

<sup>12</sup> 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.

<sup>13</sup> Acronyms used are defined in MIL-HDBK-338B.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 36 of 94
---	--	--

*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 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 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, 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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 37 of 94
---	--	--

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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 38 of 94
---	--	--

- 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 39 of 94
---	--	--

#### 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:

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

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:

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

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:

$$T_{Month}^{CM} = N^{operational} \times \frac{(MTTRS + MTTR)}{MTBF} \times 732 \frac{Hours}{Month} \quad (6-4)$$


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  $T_{Month}^{CM} \times M$ . For most LRUs, 4 hrs  $\leq$  MTTRS < 12 hrs and  $M = 1$ . For LRUs repaired off-shore, MTTR  $\sim$  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 <sup>op</sup>	MTBF (Hours)	MTTR (Hours)	Spares Min	Spares Rec	T <sup>CM</sup> (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 <sup>14</sup>	NA/EU/JA	2000	70 000	1400	40	120	711

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

<sup>14</sup> 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 40 of 94
---	--	--

## 6.5 Preventive Maintenance

The formal definition of preventive maintenance is:

- 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:

$$\bar{N}_{service} = N^{operational} \times \frac{732 \frac{Hours}{Month}}{MTBM} \quad (6-5)$$

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:

$$\bar{N}_{spares,PM} = N^{operational} \times \frac{MTTS}{MTBM_{PM}} \quad (6-6)$$

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 hours per month per component can be estimated from:


$$T_{Month}^{PM} = N \times \frac{MTTS}{MTBM_{PM}} \times 732 \frac{Hours}{Month} \quad (6-7)$$

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 <sup>op</sup>	MTBM <sub>PM</sub> (Hours)	MTTS (Hours)	Spares Min	Spares Rec	T <sup>PM</sup> (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



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 41 of 94
---	--	--

**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 that would be expensive to rectify (e.g. specific cryogenic 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 Process


### 6.7.1 General Considerations<sup>15</sup>

From a maintenance process perspective, the aim of preventive maintenance is to minimize the amount of required corrective maintenance. Once implemented, well-trained technicians can usually execute a preventive maintenance program. 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.

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.

<sup>15</sup> For a more extensive discussion of the topics presented in this section, see [http://www.ergonetz.e/maintenance/index\\_e.html](http://www.ergonetz.e/maintenance/index_e.html)

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 42 of 94</p>
---	---	---

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.

Preventive maintenance teams shall remain on-duty after preventive maintenance sessions under the on-duty science operations team (i.e. array operator and Astronomer-on-Duty) confirm that the system is functioning properly.

#### 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 desirable. 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 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 43 of 94
---	--	--

#### 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. 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.

*Comment: due to Executive concerns about the stability and continuity of their home or affiliated institutions, it may be appropriate for the Board to approval all maintenance arrangements and contracts established by the JAO for activity at remote facilities. Further Board-level discussion of this point is required.*

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: which LRUs fall into this category, what facilities are needed, and the costs of these activities are all still unclear at this draft. For planning purposes, a budget of 20 FTEs and 200 KUSD per year (split between the Executives) has been assumed under Chile running costs (see Section 14).***

As discussed in Section 10.4, it is expected that the maintenance of the baseline ALMA computing system will also be done remotely. For software maintenance alone, the estimated cost is 20 FTEs per year. These resources are expected to be split between the bi-lateral partners. Hardware upgrades have been budgeted separately.


*Comment: it is currently unclear how these computing resources will be managed, in particular how their priorities will be set.*

#### 6.8 System Performance Diagnostic Software

During both the Commissioning 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.

Additional capabilities will certainly be needed. Definition of these capabilities is beyond the scope of this document.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 44 of 94
---	--	--

## 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. These images shall be calibrated according to the ALMA calibration plan.
- The Joint ALMA Observatory shall be responsible for the 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 produced 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.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 45 of 94</p>
---	---	---

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 complete 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;
- and/or all unexecuted or incomplete scheduling blocks have been administratively removed from the 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 – 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.

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 18 – 24 months after the start of Early Science Operations, the central archive 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-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. These ARC archive nodes will be delivered, commissioned, and activated as soon as possible after the 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.*

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 46 of 94</p>
---	---	---

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 Virtual Observatory (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 shall contain all products created during the life cycle of each project, including links to papers (or equivalent links to the Astronomical Data Service, ADS) published with the data taken for each project.

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

By the time it reaches Full Operations, the ALMA Observatory will be operating Petabyte-class archives at the OSF, SCO, and the ARCs in a coordinated fashion. The operational and technological challenge, as well as the budgetary impact, of this task should not be underestimated. To this end, the ALMA Observatory shall create and actively maintain an **ALMA Archive Development and Operations Plan**. This plan shall be reviewed and updated annually, with participation from all ALMA Archive sites.

#### 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.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 47 of 94
---	--	--

- **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 ALMA 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 act as Transporter Scheduler<sup>16</sup> 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 with high priority.*

## 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](http://www.alma.int).<sup>17</sup> 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.

<sup>16</sup> a.k.a. *Lord of the Transporters* (with apologies to J.R.R. Tolkien)

<sup>17</sup> 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.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 48 of 94</p>
---	---	---

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](mailto: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 Head of Science Operations will work with the ARC Managers to set-up an e-mail monitoring and response 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 the 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 project(s), 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.

*Comment: the organizational structure of the ALMA Web needs careful consideration. Its content will be managed by multiple groups in multiple places and consist of a mixture of operational, science, technical, and public relations information and tools. Ideal, the ALMA Web should be structured in such a way that individual groups can manage their own content within a standard framework.*

## **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 ALMA 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.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 49 of 94
---	--	--

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. Even less complex processes may be possible for the Science Demonstration phase described in Section 5.4.*

### **7.7.2 Proposal Review**

Before each proposal review cycle starts, the ALMA 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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 50 of 94
---	--	--

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 or if they are clearly technically infeasible.

*Comment: the issue of how proposals are assigned to each PRC is still TBD.*

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 with a termination rationale and effective date. At the same time, the ALMA Director shall be informed so that the appropriate LTQ changes can be made.

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 are still TBD.


*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 ALMA 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.<sup>18</sup> During this process, the ALMA Director shall not have the authority to modify scientific priority without the approval by the relevant Executive. Fulfilling this requirement may require modifying the priority of or rejecting a small number of programs, subject to the review and approval of the IPRC. The ALMA Director shall also ensure that the Observatory is meeting its fractional time allocation obligations to the Executives, averaged over some TBD interval.<sup>19</sup>

<sup>18</sup> 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 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.

<sup>19</sup> An interval between 6 and 18 months is recommended.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 51 of 94
---	--	--

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.

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 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<sup>20</sup> – 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 ALMA Director may introduce minor modifications into the LTS or LTQ to accommodate unforeseen scientific, operational or technical activity. The ALMA Director shall notify the ALMA Board and the Executives whenever such revisions are necessary. In particular, at the discretion of the ALMA 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.<sup>21</sup>

## 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 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 to users in their respective regions. In the event of sudden unpredictable Target of Opportunity events, the Chile-based science operations staff will provide Phase 2 support.

All submitted Phase 2 material shall be reviewed by staff from the appropriate ARC. It is a Joint ALMA Observatory goal to automate this review as much as possible.<sup>22</sup> 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.

<sup>20</sup> 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.

<sup>21</sup> 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.

<sup>22</sup> 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.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 52 of 94</p>
---	---	---

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 projects 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

In general, only observations corresponding to programs approved by the Executives and inserted into the LTQ by the ALMA 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 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 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 (if all other technical criteria have been satisfied) 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 bandpass calibrations to spectral line observations and any other meteorological information as may be provided (such as measurements with an FTS).

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 53 of 94</p>
---	---	---

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.

For standard observing modes, the science data pipeline will operate in fully automated mode. The products will be calibrated images. These products will be ingested into the Archive for later quality assurance review and then distribution (first, to principal investigators and later, the community at large). 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.<sup>23</sup> 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 array parameters such as focus, antenna efficiency, and antenna tracking. In Chile, responsibility for data quality assurance rests with the Data Manager within the Department of Science Operations (see Section 9.3.2).


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 telescope calibration pipeline. Based primarily on assessment of  $uv$  data, not images.
- **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,

<sup>23</sup> More specifically, the ALMA Observatory Director is responsible to the Executives via the ALMA Board for the delivery of data of verifiable high-quality.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 54 of 94
---	--	--

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 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 :development of more detailed QA requirements and parameters should be a joint activity between the future Science Operations department, the Science IPT, and the SSR committee of the Computing IPT. Development of QA requirements and parameters should be tied 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.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 55 of 94
---	--	--

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 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, Chile-based staff will do media mastering and delivery. Within 24 – 30 months, this activity will transition to the ARCs.

*Comment: as noted by the ASAC in their May 2004 report, the exact data delivery process is still under discussion. In their report, the ASAC urged a delivery timescale of weeks (preferable one week) after observation execution.*

### 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 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 ALMA Director for review and decision, on behalf of the ALMA Board.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 56 of 94
---	--	--

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<sup>24</sup>

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. 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 ALMA 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 time distributions should be broken down by receiver band and by atmospheric conditions (characterized by TBD bins such as water vapor content). Over some TBD interval, such statistics may be used to re-balance science operations allocated between the ALMA partners, the Republic of Chile, and other countries.

The 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)

*Comment: this issue requires further Board discussion and is related the general topic of observatory governance during operations (see Section 15.1). At the request of the ESO Director General, this section remains unmodified until the ALMA Board develops a definite policy.*

On behalf of the Executives, the ALMA Board controls and manages ALMA observing time. The ALMA Board should consider granting the ALMA 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:

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



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 57 of 94
---	--	--

- 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 ALMA 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 ALMA Director describing the outcome of their project and how the data are being used.

The ALMA 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 ALMA Director, the Head of Science Operations, the chairperson on the International Program Review Committee, and the Astronomer-on-Duty (AoD) at the OSF. It may be appropriate for an alarm to be forward to the on-duty astronomer and operator, rather than relying on e-mail for their notification. The AoD will contact the ALMA Director and/or Head 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,

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 58 of 94
---	--	--

i.e. users cannot post facto request different system configurations. Allocated time will be regarded as a strict offer limit that 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 passed 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 problem report 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 problem report 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 AoD assigns the QA1 status, while the Data Management astronomer monitoring the central pipeline output assigns the QA2 status.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 59 of 94</p>
---	---	---

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.

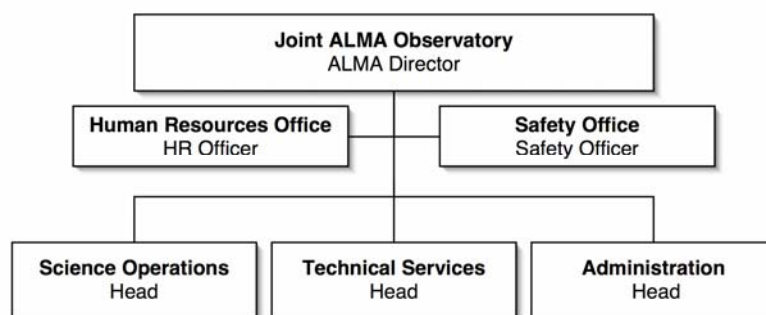
On TBD basis, the Observatory Director will provide reports about system performance and time allocation. These metrics must be defined and built into the system so basic reports can be generated on demand for arbitrary periods. Many of these reports will be based on actual execution history, e.g. time-on-target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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 60 of 94
---	--	--

## 8 ALMA Director's Office

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

The ADO supports the activities of the ALMA Director and Heads of departments. 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 Heads of departments. Each person is provided administrative support as follows: Director (ISM, 5+2, SCO), Head of Admin (LSM, 5+2, SCO), Head of Science Operations (ISM, 5+2, OSF), and Head of Technical Services (ISM, 5+2, OSF). It is assumed that the Head of Admin will spend most working days at the SCO while the Head of Technical Services will spend most working days at the OSF. Since there are Science Operations activities in Santiago and at the OSF, the Head of Science Operations will spend time in both places on a regular basis. The Director will spend all his time on planes, per normal practice.<sup>25</sup>


The ADO shall include a **Safety Office** led by the **ALMA Safety Manager** (ISM, OSF, 5+2). The general responsibilities of the Safety Manager are described in Section 5.1. More specifically, the Safety Office is responsible for safety, medical, and fire fighting operations at all ALMA sites in Chile, including:

- 24/7 paramedic services at the OSF (CSM, 8+6, 3 people);
- An OSF/AOS fire brigade, consisting of trained ALMA staff, organized in coordination with the Facilities Group Manager and the Heads of Technical Services and Science Operations;
- An emergency response program at the OSF, organized in coordination with the Facilities Group manager (see Section 11.3).

The Safety Office shall also include one safety officer per turno (LSM, OSF, 8+6) who shall assist and report to the Safety Manager.

The ADO shall also include a **Human Resources Office** led by a **Human Resources Manager** (LSM, SCO, 5+2) hired to implement and manage the human resource policies agreed upon by the Executives. The HR Manager shall be based in Santiago, report directly to the ALMA Director, and have administrative support (1 LSM, 5+2, SCO). It is expected that the HR Manager will visit the OSF at least monthly.

<sup>25</sup> 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, attending international meetings as necessary.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 61 of 94</p>
---	---	---


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

*Budget Impact: a separate Chile-based Education & Public Outreach officer has **not** been included in this plan. Individual Board members from both of the bi-lateral partners have commented that this may not a good long-term solution and that at some point the organization in Chile should have EPO resources. Requires discussion at the Executive and Board level.*

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 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.

The ADO shall have a high-level goal of minimizing the physical travel of all ALMA managers through the aggressive use of IT technology to conduct meetings, such as telephone and video conferencing.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 62 of 94
---	--	--

## 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 Overview section.*

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

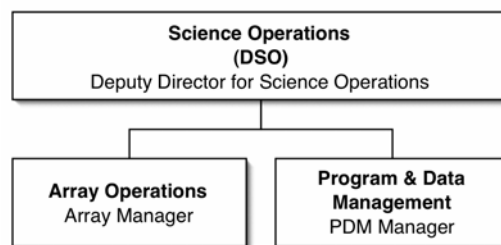
- Array operations, including monitoring & coordination of all AOS activity
- Observation scheduling: Long-Term, Medium-Term, and Short-Term
- Observation execution
- Data processing and quality assurance
- System performance quality assurance
- Maintenance and execution of Calibration Plan
- Delivery of data to end-users, ALMA Archive, and ARCs

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 Head 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 are foreseen to work at the AOS.


*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. Solutions that involve recruiting and re-training astronomers from outside the immediate millimeter-wave community should also be investigated.*

### 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 Head for Science Operations (see Figure 9-1). The Science Operations department will be split into the following groups:

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 63 of 94
---	--	--

- **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 ALMA Director and Head of Science Operations.

*Comment: it would be useful to create a set of Use Cases to provide formal descriptions of the various science operations activities and interfaces, as well as to define the principle actors in each case.*

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 and the SCO. Rest of time is dedicated to research activity at the SCO. Staff astronomers will be expected to make regular visits to the ARCs. Staff astronomers work task-specific turnos as described below.
- **Array Operators:** Local Staff Members responsible for day-to-day array operations at the OSF. 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)


The Array Operations 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 responsible for maintaining the antenna transportation schedule, in coordination with 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. 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, 8+6) are required.<sup>26</sup> 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.*

<sup>26</sup> 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.



	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 64 of 94</p>
---	---	---

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. 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.

### 9.3 Program & Data Management Group (PDM)

#### 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 needed) include:


- 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 related to science operations in Chile
- ALMA instrumentation & systems development

Execution 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-Duty is responsible for the transfer of Scheduling Blocks from the Archive to the array operator for execution on the array.<sup>27</sup> The AoD orchestrates calibration observations to meet observers' goals and to achieve consistency with 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

<sup>27</sup> It is assumed that SBs are validated for accuracy and completeness by ARC astronomers during the Phase 2 process.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 65 of 94
---	--	--

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.


There shall be two (2) AoD shifts per day. 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 astronomers based 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 per 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  $8 \times 4 \times 3.5 = 112$  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). To be conservative, it is assumed that ARC staff will serve 200 OSF AoD shifts per year, roughly evenly split between day and night shifts. Furthermore, it is assumed that each ALMA staff astronomers based in Chile assigned to AoD duty will serve 56 shifts per year.<sup>28</sup> Thus,  $530/56 \approx 10$  staff astronomers are 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, it 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. 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

<sup>28</sup> Total possible work-days per year:  $52 \times 5 = 260$ . 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  $7 \times 8 = 56$  days at OSF plus  $7 \times 2 = 14$  or  $7 \times 4 = 28$  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 spent at SCO working on non-real-time program and data management tasks.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 66 of 94</p>
---	---	---

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.

*Comment: the exact command-and-control relationship during normal operations between the on-duty Array Operator and Astronomer-on-Duty needs to be defined precisely.*

### 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
- 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. Therefore, 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.


PDM staff astronomers spend roughly 20% of their time on data management tasks, mostly in the area of science data quality assurance (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.

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.

When the central Archive resides at the OSF, technical data management tasks will be performed by two (2) archive/pipeline operators per OSF turno (LSM, 8+6, OSF, 5 employees) and one database content manager per turno (LSM, 8+6, OSF, 3 employees).

When the central Archive migrates to the SCO (see Section 7.3), there shall be one (1) archive/pipeline operator per OSF turno (LSM, 8+6, OSF, 3 employees) and one database content manager per turno (LSM, 8+6, 3 employees). At the SCO, there shall be three (3) archive/pipeline operators (LSM, SCO, 5+2, 3 employees) and two database content managers (LSM, SCO, 5+2, 2 employees). Given the mission critical nature of the central Archive, the Data Manager shall take measures to assure the monitoring of central Archive health over weekends and holidays and the availability (on an on-call basis) of support staff to restore Archive functionality as necessary.

Archive operations at all Chile sites are supported by contracted system, network, and database administration staff provide by the Computing Group (see below).

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 67 of 94</p>
---	---	---

*Budget Impact: as the Archive Operations and Development Plan matures (see Section 7.3), these archive technical operations staffing numbers should be reviewed.*

### 9.3.3 System Management 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)
- AIV support (see Section 5.4)

To perform these activities, there shall be three **ALMA System Astronomers** (ISM, SCO/OSF, 3 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 Commissioning 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.*

*Comment: the process of array configuration and its relationship to LTS/MTS/STS management needs further thought. In particular, process by which the System Astronomer(s) can request the AOG Manager to schedule an array re-configuration needs a precise definition.*

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 68 of 94</p>
---	--	---

## 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 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

*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.*


*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.*

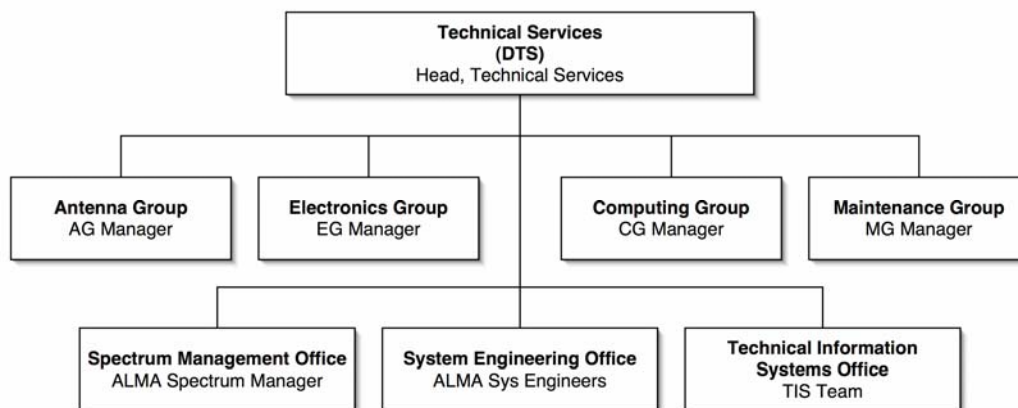
*Budget Impact: the budget (staff, running costs) impact of the ACA and additional receivers to be provided by the Japanese has **not** been taken into consideration in this draft.*

*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

Technical services activities in Chile are the responsibility of the Department of Technical Services, under the leadership of the Head for Technical Services (see Figure 10-1).

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 69 of 94
---	--	--



**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 Specialist** who reports to the Head of DTS<sup>29</sup> and is based in Santiago. This person shall also be responsible for archive and 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 Office (SEO):** responsible for maintaining operations and development system engineering practices. Essentially, it continues the work of the 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.
- **Technical Information Systems Office (TIS):** responsible for the operation and maintenance of the Computer Maintenance Management System (CMMS), Project Documentation Management System (PDMS), and Electronic Document Management System (EDMS).

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

<sup>29</sup> It might be more natural to move the ALMAEDM Manager inside the Systems Engineering Group.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 70 of 94
---	--	--

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 undergraduate science and engineering students from both Chilean and international institutions as co-operants and summer students within DTS should be considered during the development of more detailed operations plans.*

## 10.2 Antenna Group (AG)


*Budget Impact: at the time of this draft, decisions about the production antenna design(s) and vendor(s) were unknown, as were the maintenance and operations impact of those decisions. When these details are known, this section will be reviewed and revised.*

### 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. On these days, the following personnel are needed: one supervisor (LSM, mechanical engineer), two drivers (LSM), four mechanics technicians (LSM), and 4 helpers (LSM). It is assumed that both antenna transporters will be used on these days. The Electronics Group will provide assistance with fiber cable management at the antenna pads and the AOS Technical Building (see Section 10.3.2). After each move, the Science Operations will re-calibrate baselines, delays, pointing, etc (see Section 9.3.3).
- **Transporter maintenance:** the antenna transporters will need maintenance once per month, outsourced to service provider or assigned to Maintenance Group.
- **Antenna minor (in-situ) preventive maintenance:** each antenna will need preventive maintenance once every 2500 hours. For 64 antennas, this implies about 20 preventive maintenance episodes per month. On these days, two (2) mechanical technicians are needed for this task. Additional support from the Electronics Group will be provided on a case-by-case basis. *After training, some of 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 20 days. For 64 antennas, this implies about one (1) event per month. Tasks include painting, panel adjustment, improvements, etc. During these events, the following people are required: one supervisor (LSM, mechanical engineer), two mechanic technicians (LSM), one CFRP specialists (LSM), and one electrical technician (LSM). One transporter round-trip between the OSF and AOS is required, estimated to take four (4) days. *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 require maintenance periods lasting 20 days, plus 4 days for AOS-OSF roundtrip transportation. For 64 antennas, this implies one (1) event per month. Depending on scheduled overhauls, these events could be folded into overhaul events. The resources needed for major corrective maintenance events are the same resources needed for major preventive maintenance, so certain staff positions must be filled twice.
- **AIV Support:** as described in Section 5.4, Operations (i.e. the Antenna Group) will provide the following AIV support starting with Antenna 8 and continuing until all antennas are delivered (in FTE per day): 0.5 mechanical engineer, 0.5 mechanical technician, and 1 control

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 71 of 94
---	--	--

specialist. Additional support will be provided by the DTS Electronics and Computing Groups (see Sections 10.3.2 and 10.4.1) as well as Science Operations (see Sections 9.3.3).

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

- two supervisors (mechanical engineer, LSM, 8+6 = 5 employees)
- two drivers (LSM, 8+6 = 5 employees)
- one mechanic technician (control specialist, LSM, 8+6 = 3 employees)
- one mechanical technician (CFRP specialist, LSM, 8+6 = 3 employees)
- two mechanical technicians (general, LSM, 8+6 = 5 employees)
- two electrical technicians (general, LSM, 8+6 = 5 employees)
- two 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) 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 enhanced oxygen? More input to Ops Group needed here.*

### 10.2.2 Required Equipment & Documentation

These activities are supported by two (2) antenna transporters and an assortment of spare parts bought from the TBD budget. Required operational equipment as well as the initial set of spare parts are assumed to be Construction deliverables.

### 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.


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 cartridge installation:** cartridges returned from off-site repair facilities as well as cartridges being delivered for the first-time (e.g. a new band) must be verified “OK-on-arrival” and installed in FE cryostats.
- **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



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 72 of 94
---	--	--

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
- **AIV support:** as discussed in Section 5.4, Operations (i.e. the Front-end Team) will provide the following support per turno starting with Antenna 8: one (1) electrical engineer and one (1) electronics technician.

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

- FE Lead Engineer: one (1) engineer per shift (electrical, ISM, 8+6 = 2 employees)
- Remove/install receivers: two (2) technicians (electrical/electronic, LSM, 8+6 = 5 employees)
- Repair/test receivers: two (2) electrical engineers (LSM, 8+6 = 5 employees), two (2) technicians (electrical/electronic, LSM, 8+6 = 5 employees)
- Cryogenic/Vacuum support: two (2) technicians (mechanical technicians, LSM, 8+6 = 5 employees)
- AIV support: one (1) electrical engineer (LSM, 8+6 = 3 employees), one (1) technician (electrical/electronic, LSM, 8+6 = 3 employees).

Total FE support staff per turno: 11


### 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 per year per module or 2.4 modules per week); DTS channels (test Bit Error Rate once per year per data channel or 1.5 antennas (12 channels per antenna) per week; checks on maser/laser synthesizer/high frequency LO 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:



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 73 of 94
---	--	--

- BE Lead Engineer: one (1) engineer per shift (electrical, ISM, 8+6 = 2 employees)
- Corrective maintenance (repair): two (2) technicians (electric/electronic, LSM, 8+6 = 5 employees).
- Support for array re-configuration: two (2) technicians (opto-mechanical, LSM, 8+6 = 5 employees)
- Correlator support: one (1) correlator engineer (LSM, 8+6, 2 employees) and one (1) correlator technician (LSM, 8+6 = 3 employees) (hired and trained during initial correlator installation & check-out).

Total BE support staff required per turno: 7.

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
- vehicle electronics
- radio communication gear
- HVAC proportional integral differential (PID) controllers

### 10.3.4 Required Equipment & Documentation


Hardware necessary to support Electronic Group are assumed to be Construction deliverables.

## 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
- Computer and network security

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 74 of 94</p>
---	---	---

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.

*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 ALMA Director. But it is not clear who has day-to-day responsibility or who monitors IT evolution and “the market” to decide when and how to upgrade ALMA IT systems.*

*Budget Impact: the Computing IPT estimates that 20 FTEs per year are needed to maintain and extend the core ALMA computing system, mostly in the area of software, starting in early 2009. This is an Operations cost assumed to be administered by the Executives, and split between North American and Europe. **These FTEs are included under Chile running costs (see Section 14).** 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 content management is the responsibility of the Science Operations Program & Data Management group.
- Each group within ALMA is responsible for Web content management related to their activities, within the (TBD) cross-organizational structure.

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:

- Software Engineering: three (3) software engineers per day at OSF (ISM, 8+6, 9 employees).
- OSF IT Support: one (1) database administrator (LSM, 8+6, 3 employees) and three (3) IT systems support personnel (CSM, 8+6 = 7 employees).
- SCO IT Support: one (1) database administrator (LSM, 5+2) and three (3) IT systems support personnel (CSM, 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.
- MIS Support: to support administration & business systems, two (2) IT contractors (5+2, CSM) based in Santiago but with trips to OSF as necessary.

Total staff per OSF turno: 7. Total staff per SCO workday: 5.

#### **10.4.2 Required Equipment & Documentation**

Initial equipment to be supplied by Construction project. Spares and upgrades have been included in the Chile running costs (see Section 14).

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 75 of 94
---	--	--

#### 10.4.3 Digital Infrastructure Security in Chile

*Comment: this section is based on input from Patrick Murphy (NRAO). It is assumed here that the Construction project (e.g. the Computing IPT) shall be responsible for digital infrastructure security in Chile until such time as the DTS Computing Group is formed and operational.*

The computers, networks, and data that comprise the digital infrastructure of ALMA need to be protected from unauthorized and malicious attempts to gain access to them. To this end, the CG Managers shall be responsible for developing, maintaining, and enforcing a **Joint ALMA Observatory Computer and Network Security Policy**. In general, computer and network access at ALMA facilities in Chile will be restricted when it is not required by other sites or cannot be supported via secure connections (e.g. using encryption) and will be allowed only between specific systems/networks.

Wherever possible, this policy shall be consistent with analogous policies already in place within the Executives. It shall apply only to ALMA facilities in Chile. It is assumed that the Executives will take similar measures to ensure their internal digital infrastructure, including their ARC sites and ALMA Archive nodes. The CG Managers shall develop and maintain liaison relationships with the persons responsible for computer and network security at the ARCs.

The CG Managers, in coordination with the various Heads of Departments, will involve all ALMA employees in Chile in computing security issues by educating them about the risks, measures that can be taken to reduce those risks, and their responsibilities with respect to the security of the ALMA digital infrastructure. Employees found to be in violation of the published policy are subject to disciplinary action after appropriate review by Joint ALMA Observatory management.

#### 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.

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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 76 of 94
---	--	--

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.

## 10.6 System Engineering Office (SEO)

### 10.6.1 Tasks & Personnel

The SEO continues the work of the Systems Engineering IPT during operations. It has the following technical tasks:

- 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
- Manage interfaces to Executive-based system development activity
- Technical certification of equipment
- Maintain computer maintenance management system
- With other DTS groups, develop training programs for DTS staff

These tasks are coordinated by 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.

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: no specific SEO equipment foreseen at this time.*

### 10.6.3 Data Interface Control Board<sup>30</sup>

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,

<sup>30</sup> 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/>.

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 77 of 94</p>
---	--	---

- 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: FITS headers, data structures, XML structures, and instrument configuration descriptions. The data interface also specifies VO compliant data structures and interfaces.

The DICB shall 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.

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 whom 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
- As necessary, work with equivalent offices within the Executives and their funding agencies in pursuit of the same goals

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.*

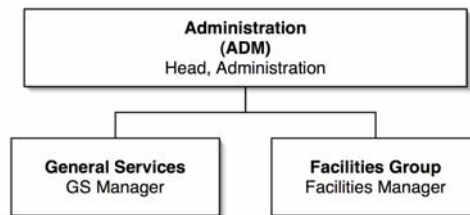
	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 78 of 94
---	--	--

## 11 Administration Department

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

The various business, facilities, and logistics activities under the direct control of the Joint ALMA Observatory in Chile are the responsibility of the Head for Administration (see Figure 11-1). The Executives have elected to maintain control of many typical business services, as described further below.

The ADM department will be split into the following groups:

- **General Services:** based at the SCO, this group is responsible for the business and logistics activities under the direct control of the Joint ALMA Observatory. As necessary, General Services personnel interact with appropriate business services providers within the Executives (see below).
- **Facilities Group:** based at the OSF, this group is responsible for day-to-day facility operations and maintenance at the OSF and AOS.


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.

*Budget Impact: the role and usage of the Construction Project Management and Control System (PMCS) during Operations is not clear. If the PMCS is to be used during Operations, its cost and staffing requirements must be estimated. For now, this plan includes not such costs or staffing.*

### 11.2 General Services

The General Services (GS) group shall be based at the SCO and lead by the **GS Manager** (LSM, SCO, 5+2). The activities of this group shall include:

- **Budget Control:** for internal budget control, there shall be a **Budget Controller** (LSM, SCO, 5+2).
- **Travel Services:** contracted services to arrange all Joint ALMA Observatory related travel (intra-Chile and international) for Chile-based staff (3 FTE, CSM, 5+2). Travel Services also coordinates the Chilean lodging of official international Observatory visitors (e.g. ALMA Board members) during their stay in Chile. Presumably, long-term contracts with one or more Santiago hotels can be negotiated for discounted lodging. In the long-term, it may be desirable to have an additional person placed *in situ* at the OSF.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 79 of 94
---	--	--

- **Logistics Services:** including receiving and dispatch, general merchandise, office supplies, spare part storage & monitoring, packing, shipping (intra-Chile & international), and warehouse management. This activity is lead by the **Logistics Officer** (LSM, SCO, 5+2) and executed primarily by contracted staff.

The main warehouse will be located at the OSF and controlled by the **Warehouse Supervisor** (LSM, OSF, 5+2) who reports to the Logistics Officer. The OSF warehouse shall be staffed and operational every day of the week (CSM, 3 people per turno). The main warehouse should not be seen a merely an inactive storage facility. Rather, it shall provide a proactive service – when items are received, the original request shall be notified and the items shall be delivered to the original requestor (if appropriate). At this time, it seems likely that secondary warehouses shall be located in Santiago and Calama.

The General Services group shall be responsible for the non-technical operation and maintenance of the Santiago Central Office physical plant (e.g. receptionist, custodial services, stocking of general supplies, etc.).


### 11.3 Facilities Group

The Facilities Group (FG) shall be responsible for the day-to-day operation and maintenance of the non-technical OSF and AOS infrastructure. There shall be two **Facilities Managers** (LSM, OSF, 8+6), one designated as leader, the other as deputy, on opposing turnos. Most FG activities shall be executed by contracted service firms. The FG Managers shall develop the required maintenance programs and schedules and, thereafter, monitor their execution. Contractor compliance with the safety regulations is under their responsibility.

The FG has various activities:

- **Facility 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 (LSM, OSF, 8+6 = 7 employees) supported by 1 driver (CSM, OSF, 8+6 = 3 people) and 33 (TBC) persons per turno from service firms.
- **Security:** Includes security services at OSF gatehouses (e.g. entrance & exit registration & control for personnel and material, baggage check) (3 per day, CSM, OSF, 8+6 = 8 people).
- **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 CSM, OSF, 8+6 = 8 employees). Shift is normally Monday – Friday (5+2) but in winter may shift to every day (8+6) to due increased snow removal and road maintenance needs.
- **Civil Works:** Maintain approximate 10 000 m<sup>2</sup> buildings, small paint jobs, floor, ceiling, windows, door maintenance and repair, window treatments (2 CSM, OSF, 8+6 = 5 employees). Minor and major maintenance and modifications contracted out to service firms on a case-by-case basis.
- **Electrical infrastructure:** maintain basic electrical infrastructure, not including the power installation at the antennae and their ancillary instrumentation.
- **Vehicle maintenance services:** for light vehicles (e.g. 4x4 pickups, shuttle vans), oil, tire, shock absorbers, mufflers, etc. as well as small paint jobs and car cleaning (2 car mechanic, CSM, OSF, 5+2). Heavy vehicle maintenance (e.g. construction equipment, antenna transporters) will be executed under a separate service contract and does not require regular on-site personnel.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 80 of 94
---	--	--

- **AOS/OSF transfer shuttle:** for safety reasons, it is envisioned that ALMA employees with tasks at the AOS site will be shuttled back and forth by designated drivers (3, CSM, 8+6 = 7 employees)

During an emergency, the FG 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. This emergency services activity shall be organized by the ALMA Safety Manager in coordination with the Facility Group Managers.

#### 11.4 Executive-based Business Services

In accordance with their internal negotiations, the Executives shall provide additional administrative services consistent with their legal and financial responsibilities in regard to the Joint ALMA Observatory. The Head of Administration shall be responsible for the coordination of these Executive-based services with related Observatory activities.

*The following was extracted from the Project Plan, 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.

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.

*Comment: at the time of this draft, the concepts presented above were still under discussion by the Executives and JAO. Extrapolating from those discussions, the following assumptions have been made.*

Each Executive shall provide at least one (1) accountant in Chile. These accountants shall be located at offices maintained by their respective Executive. They shall take programmatic direction from their respective Executives but provide periodic TBD reports to the Head of Administration. Costs related to these personnel (including salary and benefits) shall be borne by the Executives and not charged directly to the ALMA operations budget.

Each Executive shall provide at least one (1) contracts & procurement officer. These C&P officers shall be located at the Santiago Central Office and take programmatic direction from the Head of Administration. Costs related to these personnel (including salary and benefits) shall be borne by the Executives and not charged directly to the ALMA operations budget.

Each Executive shall provide at least one (1) purchasing agent. These purchasing agents shall be located at the OSF, work a 5+2 turno shift, and take programmatic direction of the C&P officer(s) of their respective Executives. Costs related to these personnel (including salary and benefits) shall be borne by the Executives and not charged directly to the ALMA operations budget.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 81 of 94
---	--	--

## 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 (ISM, ARC, 5+2) who is supported by an administrative assistant (ISM, ARC, 5+2). 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, custodial services, office supplies, 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.

However, estimates for certain operations related running costs (i.e. IT infrastructure and support, research activity support, duty travel, Archive/Pipeline system purchase and upgrades) are included in the budget discussion in Section 14 (and discussed briefly below).

#### 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.

*Budget Impact: it is assumed here that the Executives will absorb the cost of proposal submission management and review. If this assumption is false, then additional FTEs and capital may be needed for that task.*

A suggested model for scientific support staffing is:

- Six (6) staff astronomers (assumed to have 50/50 functional/research split) 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);

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 82 of 94</p>
---	---	---

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

*Budget Impact: the initial hardware for the ARC archive/pipeline system is currently **not** an ALMA Construction deliverable. Estimated start-up cost per ARC for hardware: 250 000 USD. This hardware system will require continuing upgrades to keep down operating costs and keep up with the raising data volume, estimated to be 80 000 USD per year (i.e. complete replacement every 3 years). Software for the ALMA archive/pipeline systems at all sites shall be provided by the Construction project and maintained within the general software maintenance program of the Joint ALMA Observatory.*

*Budget Impact: the physical facility necessary for hosting a Petabyte-class archive is not insignificant and includes such things as separate physical security, high-volume air conditioning, high-reliability power supplies, etc. It has not been determined who bears the cost of setting up such a facility.*

The direct running costs for these scientific services include system and network administration (service contract, 100 K€ per year), IT infrastructure upgrades (100 K€ per year), Internet Service Provider charges (50 K€ per year), staff duty travel (including OSF turno support, 200 K€), and science research activity support (160 K€ per year) – an approximate total of 610 K€ per year. Further details are provided in Section 14.


*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.*

Estimating the number of users to support in each region is not straightforward. The VLA supports about 300 projects per year, similar to the annual number of projects supported per VLT telescope. Most publicly funded 4-m class telescopes support few projects per year (around 150) because they typically award two nights per project. It is unlikely that ALMA will execute many more projects per year unless many micro-projects are allocated time, there are a significant number of programs that use the ACA independently of the main array, or the use of sub-arrays for independent projects is common practice. Here, a mean number of 300 projects per year is assumed, corresponding to 150 projects per region. A science staff of four (4) scientists for data analysis support and four (4) astronomers for all other user support tasks implies a support load of 35 projects per year per person, which seems reasonable since data analysis support is separated from other support.<sup>31</sup>

Based on the assumptions in Section 9.3.1, the FTE cost of providing AoD support can be estimated as follows: 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 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 astronomer 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

<sup>31</sup> In reality, the support load per person will be reduced to about 23 projects per year for two reasons: the Japanese and Chilean communities will each receive 30% and 10% of the total time, respectively.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 83 of 94
---	--	--

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: 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 ALMA 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.

*Comment: the costs of remote repair support and computing maintenance are discussed in Sections 6.7 and 10.4, respectively.*

#### **12.1.3 Development support services**

As discussed elsewhere in this document, each Executive shall provide development support services, as recommended by the ALMA 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.


*Comment: the costs of supporting activities in Chile have been included in Chile running costs section below (see Section 14).*

### **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.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 84 of 94
---	--	--

### 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.*

<i>Budget Impact: SCO requirements, and thus costs, are still under development.</i>
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#### 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 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 Head of Science Operations 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 co-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. There are library materials in Socorro that have also been earmarked for ALMA. 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.*

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 85 of 94
---	--	--

*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. These computer labs will need separate physical security, high-volume air conditioning, high-reliability power supplies, high-speed data switches, etc. 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 personnel work mostly at the OSF. At the SCO, one (1) single office is required for the Department Head, 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 (as described in Section 11.4). This office space is analogous to the Executive embassies maintained during the ALMA Construction phase.

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

*Comment: these requirements are not final.*


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

	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 86 of 94</p>
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## 14 Budget Overview

Starting with Draft J1 (2005 March 7), the Budget Overview has been moved to a separate document. Until further notice, the budget overview is only available by permission of the ALMA Director.



	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 87 of 94
---	--	--

## 15 Commentary and Unresolved Issues

*This section provides brief descriptions of unresolved issues affecting ALMA operations planning, as well as commentary on a variety of issues. 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.*


*David Silva wrote the commentary in this section. The commentary does not necessarily represent the views of the ALMA Operations Working Group or the JAO.*

### 15.1 Board-level areas of concern

It is not unexpected that the creation of a detailed Operations Plan has illuminated areas of concern that require Board-level discussion or decisions. In some cases, the Board may decide to delegate resolution of the concern to the JAO or Executives.

At the time of this writing (early March 2005), some of these issues seem **fundamental**, i.e. operations development cannot proceed without resolution. These issues are:

- **ALMA-B Construction schedule:** the official milestones for the bi-lateral project (ALMA-B) as listed in the Project Plan (September 2004) are clearly invalid at this point due to the on-going slippage in ALMA-B antenna procurement process. Without an official, Board-approved schedule, it is impossible to finalize operations development planning.
- **Impact of ALMA-J:** at the direction of the Board, the current Operations Plan draft ignores the impact of the Japanese contributed components of ALMA (ALMA-J). Although it is obvious that there will be an impact in the steady-state costs, the more time-critical issue is assessing the impact on operations ramp-up. No matter what happens with the ALMA-B project, the impact of ALMA-J must be factored into operations planning during 2005.
- **Observatory governance:** the question of ALMA Observatory governance during operations continues to be controversial and is hindering operations development. *The fundamental question: during operations, will the ALMA Observatory be a joint venture with a wide latitude of day-to-day independence from the Executives or will the Executives require significant control over most day-to-day operations?* From this fundamental question flow many other secondary questions such as: is the ALMA Director a director or a site manager? Does the ALMA Director report to the Board or to the Executives? Are personnel in Chile employees of the ALMA Observatory or of the Executives? Do operations personnel in Chile report to the ALMA Director or to managers within the Executives? Who controls the promotions and career paths of personnel in Chile? Who makes tenure and/or indefinite contract decisions – the ALMA Director or the Executives? Who exercises direct budgetary control on a day-to-day basis – the ALMA Director or the Executives business managers? Without resolving the fundamental question in a clear and concise manner, these secondary questions cannot be answered, hindering an efficient and cost-effective implementation of operations. (Section 4 but also rest of document).
- **Hiring of local staff in Chile:** will there be a separate company formed in Chile to hire staff or will staff be hired directly by the Executives? Resolving this issue is **very urgent** as the hiring of such staff should begin in the second half of 2005. (Section 4, footnote 2)
- **Model for Department of Administration:** in Section 11, a model for the Chile-based Department of Administration is presented. Among other things, it includes a description of certain Executive-based Business Services (Section 11.4). Many of these structures need to be put into place **during 2005** to allow operations development to proceed in Chile. It is **very urgent** that the Board and Executives review the proposed structure as soon as possible and approve it or provide definite guidance on how to proceed.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 88 of 94
---	--	--


- **Automatic generation of images:** the delivery of commissioned, off-line software for data calibration and imaging, as well as document and cookbooks tested and verified by staff astronomers is a mandatory requirement for the start of Early Science operations. However, there has been a lot of discussion at the Board level about when ALMA should deliver images generated **automatically** by a pipeline. Making this a requirement for the start of Early Science operations presents a risky technical challenge if enough time is not allowed for commissioning the pipeline with the real system or leads to a potential delay in the start of Early Science to allow time to complete pipeline and calibration plan commissioning. Delivering a large fraction of automatically produced but faulty images near the start of ALMA operations would clearly be a disaster. The Board needs to provide clearer direction to the Project on this topic and then adjust the budget and/or schedule appropriately.

Other issues seem **secondary**, i.e. they can be resolved later. These issues include:

- **Various concerns about maintenance concepts:** Fabienne Casoli and Laurent Vigroux have raised various concerns about Section 6 (Maintenance Concepts). See further comments below (Section 15.3).
- **Award of maintenance contracts:** due to Executive concerns about the stability and continuity of their home or affiliated institutions, it may be appropriate for the Board to approve all maintenance arrangements and contracts established by the Joint ALMA Observatory for activity outside of ALMA facilities in Chile. (Section 6.7.4)
- **Director's Discretionary Time (DDT):** in principle, this issue is not urgent, although it is related to the Observatory governance issue raised above (Section 7.17).
- **Chilean user community support:** this operations plan contains no explicit and/or implied user support for the Chilean user community. Thus, there is currently no support for proposal preparation, observation preparation, data product analysis, archive management or archive usage. ALMA policy in this area is unclear. More specific guidance from the JAO and/or Board is needed in this area.
- **Education and Public Outreach (EPO) activity:** the Operations Working Group understands that the Executives have reserved EPO activity to themselves in coordination with the JAO. A more centralized approach managed by the JAO in coordination with the Executives might provide a more unified face to the community (Section 8).
- **Data proprietary period:** the Board needs to set a time limit for data proprietary rights. Values of 12 – 18 months seem to be typical. (Section 7.14)
- **Technical activity in Santiago:** in the past, the possibility of technical activity in Santiago was considered absolutely forbidden. Yet, it is likely that the overall size of the engineering and technical staff at the OSF could be reduced if some activity was moved to Santiago for one simple reason – the number of turno positions could be reduced. Of course, this implies that the physical plant of the Santiago Central Office would have to be expanded to include lab space. If the Board wishes, this topic could be revisited.
- **Various aspects of proposal review:** the Board needs to provide guidance on the following topics: selection and priority of Chilean observing projects, role and responsibility of International Program Review Committee (IPRC), management of duplicate or overlapping projects from different regions, special project types (e.g. Legacy, Treasury, Large), and review process of proposals with authors from multiple regions. (Section 7.7.2)

## 15.2 Items for discussion between JAO and Executives

It is also not unexpected that the creation of a detailed Operations Plan has illuminated areas of concern that require discussion between the JAO and the Executives. In some cases, Board-level guidance may be needed.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 89 of 94
---	--	--

These areas of concern include:

- **Spare parts strategy and budget:** it appears that the initial costs related acquisition of spare parts will be covered in the re-baselined ALMA Construction budget. As the Board has not received or accepted a final re-baseline plan, the issue of spare parts remains open (Section 6).
- **Management of computing maintenance resources:** it has been estimated that 20 FTEs are necessary to maintain the ALMA computing system during operations. It has been proposed that these FTEs be based outside of Chile, presumably split between the bi-lateral partners. Has this proposal been accepted? If yes, who manages these people and sets their priorities? Does the ALMA Director have some influence on this process? Related to the observatory governance problem discussed above. (Section 10.4.1)
- **Remote repair facilities:** it has been assumed that certain back-end and front-end modules will be maintained at facilities outside of Chile. The estimated cost of this activity is 20 FTEs and 200 KUSD per year. Who manages these people and sets their priorities? Does the ALMA Director have some influence on this? Does some or all of this work ever migrate to Chile? Related to observatory governance problem (Section 6.7.4).
- **Management of on-going development outside of Chile:** a rigorous development program is envisioned for ALMA. It is clear that the ALMA Board approves proposals for development projects and their priorities. But how manages these projects, in particular in the areas of standards? (Section 4, see also budget overview in separate document).
- **Business Services staffing model & budget:** the Executives expect to operate certain business services in Chile. Is the model description in Section 11.4 correct?
- **Front-end integration center at OSF:** there seems to a consensus within the technical project that a front-end integration center at the OSF is mandatory for several reasons: not all initial FE cartridges will reach the regional integration centers before the cryostats must be shipped, it seems likely that under any maintenance model re-integration of repaired cartridges at the OSF will be needed, and new sets of cartridges will be built in the future. However, there is as yet no announced official decision on this issue.
- **AOS oxygenation:** oxygenation of (at least) the office area of the AOS Technical Building remains controversial. From a safety and efficiency perspective, oxygenation of (at least) these areas seems highly desirable. Needs discussion and resolution as soon as possible.
- **Antenna Group size and skill mix:** the proposed Antenna Group size and skill mix may have to be adjusted after the bi-lateral antenna vendor(s) is selected. (Section 10.2).


### 15.3 Maintenance Concepts: Comments by Casoli and Vigroux

As part of their review of Draft I1, Fabienne Casoli and Laurent Vigroux submitted the following comments about Section 6 (General Maintenance Concepts):

The sentence “the JAO should take measures to minimize system down-time consistent with available resources” is totally inadequate. At reverse, the ALMA Board should define the objectives to be met, and the JAO should put all their effort to meet the goals. In case of failure, they should go back to the Board, asking for more resources, or a de-scoping of efficiency goals. But clear goals should be defined.

They also wrote:

In general, we think that this chapter [Section 6] is too detailed, with a large number of definitions, which can be found in text book, about reliability. It also contains assumptions about subsystems MTBF and MTTR, which are useful to define a maintenance plan but are irrelevant in an operation plan. This chapter should be refocused on the few items which are relevant for the observatory: time fraction allocated to calibration, configuration changes,

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 90 of 94
---	--	--

engineering, technical down time, ... This document should contains specifications, and not description of the way to achieve the goals. This way should be the content of another document produced by the JAO, explaining what are the tools and actions they will implement to meet the overall efficiency specifications for the observatory. The Maintenance plan should also be produced by the JAO, and the JAO should demonstrate that the project definition, in terms of spare parts, and maintenance operations, staffing and budget is compatible with the operation specifications described in the operation plan. The present version of the operation plan mixes up different aspects, which belong to different areas of responsibility.

This chapter should be simplified, with more emphasis on the specifications, withdrawing the tools and procedures to ensure that the ALMA observatory will be run in a way that fulfill its efficiency goals.

In general, these are issues for discussion between the JAO and the Board. When this section was first written in mid-2004, it was the first attempt within the Project to grapple with these topics. Now that better information is available, it would clearly be helpful for a more complete and separate document to be written. Until such a document exists, however, Section 6 should remain as a focus point for discussion.

The definition of a metric to judge the ALMA observation efficiency should be one of the main items of the operation plan. We disagree that it is beyond the scope of this document [as stated at the end of Section 6.1]. The operation plan is the main document to define the operation. It should contain a detailed description of the various indicators that will be used by the Director to optimize the efficiency of the observatory. Further versions of this document should include detailed analysis of the efficiency indicators.

Such efficiency indicators should be specified here, as well as in a more comprehensive maintenance and availability description document. Specification of such indicators requires further cross-Project discussion and is deferred to a later version of the Operations Plan. Such discussion should encompass the Japanese systems. The final result is largely dependent on the choice of antenna vendor(s) and hopefully these discussions can be completed by the end of 2005.

As Roy Booth has suggested, it might be better to move all the maintenance theory in Section 6 to an appendix and only discuss the ALMA specific issues. In particular, real down-time requirements for the general system as well as various sub-systems need to be developed and presented in Section 6. Such requirements could be used to drive maintenance planning, spares acquisition, size of maintenance staff, etc.

#### **15.4 Impact of weather on ALMA operations**

Roy Booth has pointed out that not enough attention has been given to the affects of weather on ALMA operations. In particular, the impact of major snow storms (e.g. filling up all depressions on site, including antenna dishes) needs to be taken into account. Eventually, a separate document is needed to discuss these issues and how ALMA operations will deal with them.


#### **15.5 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 Head of for SciOps.

#### **15.6 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

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 91 of 94
---	--	--

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.

### 15.7 Director, Department Head work shifts

In Section 8, the Director and Department Heads are assumed to work Monday – Friday on a regular basis. For the Head of Administration, 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 the Head of 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 Head of Technical Services, as the responsibilities of this person will always reside exclusively at the OSF. It may be necessary to have two people in this role.

### 15.8 Summary of Unresolved Budget Impact Issues


All items marked as Budget Impact in proceeding sections are summarized below. Although not all items have the same magnitude, the total aggregate additional cost could be as high as several million USD per year. **Understanding these costs as soon as possible is obviously critical.**

These items include:

- AOS security model: unclear, no budget estimate
- 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
- The number of staff needed for archive technical operations at the AOS and OSF should be reviewed after the archive development and deployment plan matures.
- 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 require revised staffing level and/or skill mix.
- Skill mix and required number of staff for Antenna Group needs review after antenna vendor(s) decision is finalized.

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA Date: 2005-05-15 Status: Provisionally Accepted Page: 92 of 94
---	--	--


- Electronics Group has assigned miscellaneous tasks – exact list needs review
- Responsibility and authority for ALMA computing development, maintenance, and prioritization during Operations is unclear.
- 20 FTEs per year to maintain and extend core ALMA computing system included, presumed split between bi-lateral partners. FTEs to support Japanese provided systems not included.
- The role and usage of the PMCS during Operations is unclear – and therefore, budget impact is also unclear.
- Staffing model of Business Services team needs clarification with Executives
- It is assumed that proposal submission management and review costs will be absorbed by the Executives.
- ARC archive/pipeline systems are not Construction deliverable and will cost 250 000 USD per ARC.
- 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
- User support concepts for Chilean astronomical community are unclear

	<b>ALMA Project</b>  <b>ALMA Operations Plan</b>	Doc # : ALMA-00.00.00.00-002-A-PLA  Date: 2005-05-15  Status: Provisionally Accepted  Page: 93 of 94
---	--	--

## Abbreviations and Acronyms (Repeated from Section 2.5)

ACA	ALMA Compact Array
ADO	ALMA Directors Office
AIV	Assembly, Integration, and Verification
AIVC	Assembly, Integration, Verification, and Commissioning
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
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



	<p><b>ALMA Project</b></p> <p><b>ALMA Operations Plan</b></p>	<p>Doc # : ALMA-00.00.00.00-002-A-PLA</p> <p>Date: 2005-05-15</p> <p>Status: Provisionally Accepted</p> <p>Page: 94 of 94</p>
---	---	---

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