Science IPT
Statement of Work

ALMA-00.00.00.00-000-A-SOW

2005-Jan-18

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Change Record

Revision	Date	Affected Paragraphs(s)	Reason/Initiation/Remarks
Draft 1			

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1 Introduction and Overview

This document discusses the Science IPT's work in developing certain aspects of ALMA, such as the configuration and the calibration scheme, and in commissioning and verifying the scientific performance of the Array for ALMA. Its purpose is to ensure that the IPT, Executives and the project have a common understanding of the process, and of the exact nature, timing and composition of all deliverables that form part of, and are costed as part of, this work. It will be used by the Joint ALMA Office to ensure the IPT deliverables are consistent with the overall project plan, and also serves the IPT as input to its planning and costing efforts. The intended audiences of this document are the Science IPT staff, the Executive project managers and the Joint ALMA Office.

2 Scope

The "Development Phase" of the ALMA project was completed in 2002. The construction phase of ALMA started in 2002 and will extend until the end of 2011 (current baseline plan). The planned start of full science operations is early 2012. This statement of work (SOW) describes development associated with the construction phase, and represents work described by the following ALMA WBS elements:

- 1.09.380.3040 ALMA Science

3 Applicable and Reference Documents

3.1 Applicable Documents List (ADL)

The following documents, of the exact issue shown, form part of this SOW. In the event of conflict between the documents referenced here and this document, this SOW shall take precedence.

No.	Document Title	Reference
AD 01	ALMA Product Assurance Requirements	ALMA-80.11.00.00-001-B-GEN
AD 02	Front End Sub-System Technical Specification	ALMA-40.00.00.00-001-A-SPE
AD 03	Interface Control Document Between: AOS Facilities And: Ancillary Calibration Devices	ALMA-20.01.04.00-90.05.13.00-A-ICD

3.2 Reference Documents List (RDL)

No.	Document Title	Reference
RD 01	ALMA Project Plan, Version II	Dated September 23rd, 2004
RD 02	ALMA Design Reviews - Definitions, Guidelines And Procedures	ALMA-80.09.00.00-001-B-PLA
RD 03	ALMA Product Tree	ALMA-80.03.00.00-001-M-LIS

3.3 Definitions, Abbreviations and Acronyms

SOW	Statement of Work
AD	Applicable Document(s)
RD	Reference Document(s)
ADL	Applicable Documents List

ICD	Interface Control Document
PMCS	Project Management Control System
IPS	Integrated Project Schedule
JAO	Joint ALMA Office
PSI	Prototype System Integration

4 Project Definition

4.1 Item Definition

90 Science ***General 90.00***

The Science IPT is tasked with setting specifications and interacting with the project to devise engineering and operating solutions in ways to maximize ALMA science.

90.00.00 General

90.00.01 Operations planning, including Commissioning and Science Verification and transition into ops

90.00.02 Science Software Requirements advice and consent

90.00.03 General engineering requirements advice and consent.
serving on the CCB (in coordination with the PS anyway),
expert opionion at reviews and e.g.
topics de jour: continuum sampling rate, RFI, ripple amplitudes

ASAC 90.01

90.01.00 In the lieu of the Project Scientist, the Science IP has been maintaining project contact with the ASAC, ANASAC, ESAC and general Scientist Outreach.

Configuration 90.02

90.02.00 General

Array Configuration -- mostly delivered and bathing in the DAR process. We will deliver intermediate configuration station populations as appropriate.

Calibration 90.03

90.03.00 General

Calibration

Many aspects. We have SoWs on several external contracts. We presume management is aware of these and no further SoW is needed.

General 90.03.00.00

90.03.01 Amplitude

General 90.03.01.00

Amplitude Calibration -- which device can reach required accuracy, testing to ensure that this occurs. The external contracts are nearing completion; we anticipate a decision on the basis of reports by April. We expect tests conducted at the ATF to provide verification of the amplitude calibration strategy.

90.03.02 Phase Calibration

General 90.03.02.00

WVR implementation and the interplay of this system with fast switching are under investigation by the Cambridge group.

90.03.03 Total Power

General 90.03.03.00 Total Power calibration will be tested at the ATF.

90.03.04 Other

Imaging 90.04

90.04.00 General

Imaging—Algorithms for ALMA imaging continue to be investigated by the Science IPT.

General 90.04.00.00

90.04.01 Simulation

General 90.04.01.00—The Science IPT has developed several simulation packages in use throughout the project.

90.04.02 Techniques

General 90.04.02.00

Total Power Imaging 90.04.02.01

Stability Requirements 90.04.02.01.01

Nutator Requirements 90.04.02.01.02

On-The-Fly Interferometry 90.04.02.02

Mosaicking 90.04.02.03

Site Characterization 90.05

90.05.00 General

Site characterization is defined in the site characterization document:

9. Site Characterization and Monitoring - Specifications and Requirements

Doc Number:

ALMA-90.05.00.00-001-A-SPE

This is an approved ALMA document. Equipment falling under this SoW includes the following items:

90.05.01 NRAO container

General 90.05.01.00 This houses the NRAO instrumentation in general, except that contained in the radiosonde container below. This container will be decommissioned once its function is replaced by operations phase site characterization.

Photovoltaic system 90.05.01.01 This system provides power for the NRAO container. This system will be decommissioned once ALMA power is available at the site and the container is decommissioned.

90.05.02 ESO container 1

General 90.05.02.00 These containers house the ESO instrumentation in general, except that contained in the radiosonde container below. This container will be decommissioned once its function is replaced by operations phase site characterization.

Photovoltaic system 90.05.02.01 This system will be decommissioned once ALMA power is available at the site and the container is decommissioned.

90.05.03 ESO container 2

General 90.05.03.00 As above.

Photovoltaic system 90.05.03.01 This system provides power for the ESO containers. This system will be decommissioned once ALMA power is available at the site and the container is decommissioned.

90.05.04 Radiosonde container

General 90.05.04.00 This contains equipment used for launch and tracking of radiosondes to sound the atmosphere above the site. This container will be decommissioned once its function is replaced by operations phase site characterization.

Photovoltaic system 90.05.04.01 This system provides power for the radiosonde container. . This container will be decommissioned once its function is replaced by operations phase site characterization.

90.05.05 Container Network Systems

General 90.05.05.00 This is the system which interconnects computers and communications among the containers. This system will be decommissioned once ALMA networking is available at the site and the container is decommissioned.

Computer Network 90.05.05.01

Communications Network 90.05.05.02

90.05.06 225 GHz tipping radiometer

General 90.05.06.00 This device derives from the four radiometers originally built by NRAO for site testing studies in the 80s. A similar device at the CSO has provided data there for years. The largest set of homogeneous site testing data comes from this instrument. It will be moved to a different location but continue data collection during the ALMA operations phase, at least initially.

90.05.07 11.2 GHz interferometer

General 90.05.07.00 Several interferometers operate on a 300m baseline at the site. Although experiments were contemplated in which these were used for different baselines, in practice they observe satellites at somewhat different elevations and are otherwise extremely similar. One will be moved to a different location but continue data collection during the ALMA operations phase, at least initially.

90.05.07 11.2 GHz interferometer See above.

90.05.08 183 GHz radiometers

General 90.05.08.00 Two radiometers operate at 183 GHz; these data are correlated with the data from the interferometer to study atmospheric phase variations. These will be decommissioned when WVRs at this frequency become available at Chajnantor.

90.05.09 Submm tipping radiometer

General 90.05.09.00 This device operates at 350 microns and probes the weather at the highest frequencies at which ALMA will operate on the site. This will be moved to a different location but continue data collection during the ALMA operations phase, at least initially.

90.05.10 Frost point hygrometer

General 90.05.10.00 Installed in late 2001, this instrument is providing data which is being used in atmospheric modeling of the site. This instrument may be an element of the complement of instruments operating during operations phases.

90.05.11 Weather stations

General 90.05.11.00 ESO and NRAO operate four weather stations near the main containers and one station near the radiosonde launch container. Similar weather stations will be deployed during operations as described in SCID-90.05.13.00-001-A-SPE *'Ancillary Calibration Instruments Specifications and Requirements'* soon to be released by the Science IPT. These or similar instruments may be an element of the complement of instruments operating during operations phases.

Davis 90.05.11.01

Monitor Sensors 90.05.11.02 Temperature profiler. The purpose of this device is to measure the temperature profile in the atmosphere as a function of altitude. It is assumed that this will be done using a multi-channel radiometer operating on the side of the O_2 absorption band at ~60 GHz. Semi-commercial systems exist but will probably require modification (e.g. different channel frequencies) to give optimum performance on the ALMA site. This device will play a key role in showing when an inversion layer is present and at approximately what altitude. There is a question about the effect of clouds on such a device. Probably a single device pointing straight up will be adequate. The requirements are:

- Height resolution: 1 km from 5 to 8 km and 2 km from 8 to 12 km (altitude above sea level)
- Precision 1 K and accuracy of 2 K from 5 km to 8 km and twice these figures from 8 to 12 km.
- Time for measurement – 10 minutes.
- (Numbers are based on estimates of accuracy that can be achieved on existing systems. Modeling is underway to determine whether this performance is adequate.)
- Status: High priority
- Cost: ~100 k$
- Possible supplier: Radiometrics

Other weather instruments 90.05.11.03 A lightning detector, seismometer, surveillance cameras and GPS are also installed at the site. These or similar instruments may be an element of the complement of instruments operating during operations phases. The surveillance cameras are Axis 2120 network cameras and have performed well.

90.05.12 Radiosonde equipment Radiosondes carried by weather balloons provide in situ measurements of pressure, temperature, humidity, and wind speed and direction over the launch site. From these data we learn about the stratification of the water vapor over Chajnantor and about shear layers that may generate turbulence. Two surplus radiotheodolites was acquired by NRAO, upgraded by the manufacturer, tested in Tucson, and deployed at Chajnantor. In 2001, the radiotheodolites were again upgraded to accommodate switching to a different type of radiosonde package. Beginning in 1998 October, balloon flights have been made whenever appropriate personnel are at the site.

Data obtained during the radiosonde launches is in a draft memo form, available from the Science area of almaedm.

4.2 Project Phase Definition

4.2.1 Preliminary Design Phase

Preliminary Design for the Configuration was held in Grenoble, France, 26-27 Feb, 2001.

Preliminary review for the calibration strategy was held in Cambridge, U. K. 21-22 June 2001.

4.2.2 Detailed Design and Pre-Production Phase

The detailed configuration design review was held in Socorro, N. M. 23-25 January 2002. As a result of this review, the design was submitted

4.2.3 Production phase

4.2.4 Acceptance and delivery

4.2.4.1 Acceptance sequence of events

Acceptance and delivery will occur in the following sequence:

1. Preliminary in-IPT acceptance
2. In-house Provisional Acceptance
3. On-site Provisional Acceptance
4. Commissioning, verification, final tests
5. Acceptance

The IPT will deliver to the Project Scientist a draft Science Commissioning Plan which lists the method and sequence of commissioning of all ALMA science modes. It shall also list the characteristics to be verified on subsequent articles. Feedback from the JAO on the draft Science Commissioning Plan will be incorporated by the IPT into a final Science Commissioning Plan.

The In-house Software Acceptance Test Plan and Test Procedures should be delivered at least 4 months prior to the planned test date, and a final copy incorporating feedback at least 2 months prior to the planned test date.

The IPT will deliver to the JAO a draft Test Plan and Test Procedures detailing the process of preliminary acceptance in-house (PAI) and provisional acceptance on-site (PAS), at least 4 months prior to the first planned test date, and a final copy incorporating feedback from the JAO at least 2 months prior to the first planned test date. The goal is to verify all performance and functional characteristics at the PAI test, with only a final proof of fit and demonstration of overall performance to be made after delivery.

4.2.4.2 Delivery and handover

The Project Engineer will approve shipment of each subassembly after a successful in-house preliminary acceptance. The IPT is solely responsible for the costs of all packing, shipping and insurance of all deliverables to the OSF, in accordance with ALMA policy (AD??).

Provisional acceptance and provisional handover to the project may be granted by the Project Director upon recommendation of the Project Engineer when the IPT has demonstrated for each unit, through successful Provisional Acceptance On-Site procedures, that the unit has been shipped successfully and with reasonable confidence that it has the same performance and functionality as when tested in-house. The first and second units will have PAS performed by the IPT, while subsequent units should have PAS performed by AIV staff on the IPT's behalf and under the IPT's instruction. Following provisional acceptance, the FE IPT will lead the integration and checkout of the first FE subsystem onto the antenna. As part of this process, the IPT will train the AIV team on installation, operation and maintenance of the FE subsystem.

Final acceptance may be granted by the Project Director upon recommendation of the Project Engineer when safety, performance, functionality and conformance to ICDs are demonstrated at the telescope.

4.3 Deliverables made by the IPT

The Science IPT will deliver to the Project the following items:

4.3.1 PSI Deliverables

The Science IPT will provide the following to PSI at the Antenna Test Facility:

a) Manpower
b) A prototype science commissioning plan involving one baseline.

4.3.2 First Unit Deliverables

The Science IPT will provide one of each of the following, delivered to the ALMA OSF unless otherwise stated:

a) Manpower

4.3.3 Every Unit Deliverables

4.3.4 Other IPT Deliverables

Algorithms for data processing will be delivered to the Computing IPT.

4.4 Deliverable Documents List (DDL)

The mandatory development process, including documentation requirements at each step, is described in RD2: ALMA Reviews Definitions, Guidelines and Procedures as well as AD2: the ALMA Product Assurance Requirements.

4.4.1 Document deliveries with first unit only:

As part of delivery of the first unit to OSF, the following documentation is expected:

- **Product Final Specifications**
  - Detailed subsystem specifications, including embedded software specification, (down to the item level) in MS Word and PDF formats.
- **Interface Control Documentation**
  - Detailed interface control documents (down to the LRU level) in MS Word and PDF formats
- **Drawings and Diagrams**
  - Models
  - Assembly drawings
  - Detailed manufacturing drawings, including wiring and cable harness drawings
  - Circuit diagrams
  - Control Loop diagrams
  - Parts drawings
  - Software design description and flow chart.
  - Source and binary files for all field programmable logic devices.

Drawings will be delivered in both native CAD format (including any custom libraries etc. which may be necessary to use the drawing files) and in PDF format, with a tabulated index of drawing numbers and names.

- **Assembly, Test, Installation and Commissioning Documentation**
  - Parts list in sufficient detail to enable ordering replacements
  - Assembly and alignment procedures, detailed to a level that a skilled technician could perform the assembly and alignment.
  - Test plans, procedures and nominal test results as used in the FEIC

All of the above will be delivered electronically in both Word and PDF formats, in addition to print copies where stated.

- **Maintenance Documentation**
  - Three (3) printed copies of service manuals, including recommended preventive maintenance schedules and procedures. Manuals should be complete enough that a trained technician could successfully perform maintenance procedures.
  - Any custom equipment needed for maintenance.
  - Spare parts and suppliers (list only).
  - Test equipment list.
  - Shipping, handling and storage specification and equipment list.

All of the above will be delivered in both Word and PDF formats.

  - Fault record for the unit.

- **Operations Documentation**
  - Three (3) printed copies of the User's Manual and Operations Manual (including any safety concerns), as well as electron copies in Word and PDF format.
  - Safety data package.

4.5 Document deliveries with every unit.

As part of delivery of each unit to OSF, the following documentation is expected:

- **Configured Items Data List (CIDL)**

The Configuration Item Data List (CIDL) identifies all the documentation of the product. Configured items shall include:

- ALMA applicable documents (AD's and RD's)
- Documents comprising the review data package
- Product engineering documents (e.g. specifications, ICD, drawings, procedures)
- Sub-system or unit acceptance reports or certificates
- Sub-system or unit safety compliance assessments
- Change requests and requests for waivers
- Correspondence
- Errata to manuals (e.g. User's, Operations and Maintenance Manuals).

Configured items shall be identified in the list with their reference, issue or revision number, date of issue, originator and status (e.g. approved by NRAO, if applicable) so that documentation associated with each unit can be unambiguously identified.

- **Assembly, Test, Installation and Commissioning Documentation**
  - Characterization results, in native and PDF format, including the archive of raw data.

- **Maintenance Documentation**
  - Fault records for the unit.

4.6 Deliverables made to the IPT

- Amplitude Calibration Device, from FE
- WVR, from FE

4.7 Post-delivery Activities & Responsibilities

Following the successful assembly, integration and engineering verification of ALMA the Science IPT will provide on-site assistance in the commissioning, demonstration science and Early Science phases of ALMA. The amount of effort in Chile is anticipated to be six (6) six SI scientists five years parallel for 30 FTE. The August 2002 plan is shown in the table below.

A structure for the management of AIVC+ Demo Science was discussed at the AIVC meeting in Socorro held 2005 January 13-15. The 3 main characters were Project Engineer (PE), Commissioning Scientist (CS) and Head of Science Operations (HSO). AIV is clearly the responsibility of the PE, but tests must be agreed/signed off on by the

CS. We presume that primary responsibility passes to the CS (with tests agreed and signed off on by the PE, of course) when antennas are handed over at the start of "commissioning" on our current summary of events. Line management of the development team (including scientists) would be by the PE and that all other staff except the CS would be under the Head of Science Operations. Demonstration Science is a responsibility of the Project Scientist executed by the group headed by the HSO.

Hybrid model six SI scientists five years parallel

Title	Grade	2002	2003	2004	2005	2006	2007	2008	2009	2010
NAScientist	2	-	-	X	X	X	X	X	X	X
EUScientist	2	X	X	X	X	X	X	X	X	X
SIPersonA	3		X	X	x	x	x	ops	ops	ops
SIPersonB	3		X	X	x	x	x	ops	ops	ops
SIPersonC	3				0.5x	x	x	ops	ops	ops
SIPersonD	3				0.5x	x	x	ops	ops	ops
SIPersonE	3					x	x	x	x	ops
SIPersonF	3					x	x	x	x	ops
NAPersonA	3	X	X	X	X	X	ops	ops	ops	ops
NAPersonB	3	X	X	X	X	X	X	ops	ops	ops
EUPersonA	3		X	X	X	X	ops	ops	ops	ops
EUPersonB	3		0.7X	X	X	X	X	ops	ops	ops
NAPdocA	4			0.5x	0.5x	0.5x	x	x	x	ops
NAPdocB	4					0.5X	X	X	X	X
EUPdocA	4			0.5x	0.5x	0.5x	x	x	x	ops
EUPdocB	4					0.5X	X	X	X	X
Totals-Const		3	6.7	9	10	14	14	9	8	4

Totals-Ops	2	7	8	12

X=NA/EU; x=Chile; gr 2 LOE 2 months 90 budgeted 108 ; gr3 LOE 2 months 106.2 budgeted 108; gr3 SI LOE 4 months 64 budgeted 60; (but 2FTE 2yrs at ATF, not Santiago); gr4 LOE 4 months 60 budgeted 60; where X for NA signifies a person at the prototype interferometer; some of these people migrate to Chile in early-2007 to replicate qualification/verification of equipment on the prototype interferometer in Chile, where they are joined by two new hires as antennas, receivers and other equipment arrives in the latter part of 2006. As commissioning ramps up in 2007, two new hires join them. As EarlyScience commences in 2008?, operations personnel begin replacing construction personnel, with some construction personnel remaining to commission instrumentation until late in 2010.

Science IPT will train the operations staff in Chile on the acquisition and calibration of the the ALMA data product. Science IPT will provide remote support from the ARCs as needed in the Chilean commissioning of subsequent units.

4.8 Project Activity IDs

The project schedule, in sufficient detail to examine inter-task dependencies and monitor approximately bi-weekly progress of work, will be maintained by the IPT using the IPS. The schedule shall incorporate the following Activity IDs. Dates shown here are the initial baseline and can be updated according to the established procedures.

Activity IDs	Date
Commissioning commences – first closure phase AIV&C_25.8.1	2009 February 11
Issue of first call for proposals – four months after above.	2009 June 11
Start of early science: 12 months after start of commissioning.	2010 February 11

5 Project management and control

5.1 Project management

The Project Scientist leads the Commissioning Scientist, the regional Project Scientists, and the construction phase Science IPT.

5.2 Project plan and PMCS

Information on changes to the Science IPT schedule occasioned by changes in the Integrated Project Schedule are propagated by PMCS to the Project Scientist, the Commissioning Scientist, and the regional Project Scientists,

5.3 Project reporting

The regional Project Scientists will be responsible for scheduled reports to their respective funding agencies. The Project Scientist is responsible for submission of the Science IPT portion of the JAO Quarterly Report. The Project Scientist and regional Project Scientists will conduct regular monthly teleconferences to exchange information. Red-flag reports will be communicated from any of these three through the Project Scientist to the JAO, or from the JAO through the Project Scientist and on to the regional scientists.

5.4 Progress meetings and reviews

The Science IPT expects to maintain its current series of monthly general telecons. Weekly telecons may be held within the regional divisions, as they currently are within North America.

6 Configuration control and data management

Changes will follow the change request procedure for those changes with effects external to the Science IPT. Internal changes will be discussed at the monthly telecons between Project Scientist and regional Project Scientists. Changes will be documented in the 'Science Documents' section of almaedm.

7 Product assurance plan and safety analysis

The Science IPT will hold periodic reviews of the ALMA safety plan disseminated by the ALMA Safety Officer.

Notes on scope changes:

This page is a scratch sheet to keep notes on potential scope changes during the development of this SOW. It is intended that this page will be deleted once the SOW is approved and its substance reflected in PMCS records.

1. Oxygen sounder not anticipated in site monitoring equipment in budget but appears necessary [haw].