Integration and Test Plan

Version 2.2

Authors: Michael Hecht, Project Manager

Revision Date: April 16, 2014

Table of Contents

Applicable Documents

APP Project Plan

APP Requirements Document

APP Computing Management Plan (ALMA-05.11.60.01-001-A-PLA)

Commissioning and Science Verification Plan (ALMA-05.11.10..01-001-A-PLA)

Back End ICD (2013-03-25-ALMA-05.11.10.49-50.00.00.49-A-ICD)

Site ICD (2013-04-22-ALMA-05.11.10.49-20.00.00.49-A-ICD)

Correlator ICD (2013-04-22-ALMA-05.11.10.49-60.00.00.49-A-ICD)

Computing ICD (2013-04-22-ALMA-05.11.10.49-70.00.00.49-A-ICD)

General Safety Design Specification (ALMA-10.08.00.00-003-B-SPE)

System Technical Requirements (ALMA-80.04.00.00-005-B-SPEALMA)

System Electrical Design Requirements (ALMA-80.05.00.00-005-C-SPEALMA)

System Electromagnetic Compatibility (EMC) Requirements (ALMA-80.05.01.00-001-B-SPEALMA)

Product Assurance Requirements (ALMA-80.11.00.00-001-D-GENALMA)

Environmental Specification (ALMA-80.05.02.00-001-B-SPEALMA)

Operations Plan (ALMA-00.00.00.00-002-A-PLAALMA)

Seismic Design Specifications for ALMA-AOS and ALMA-OSF (SYSE-80.10.00.00-002-B-REP)

ALMA Interface Management Plan (ALMA-80.07.00.00-001-D-PLA)

Mark6 Users Manual (draft)

APP Optical Fiber Link system design (ALMA-05.11.40.01-0001-A-DSN)

Phasing Interface Card Manual (ALMA-05.11.31.05-0001-A-MAN)

Document Change Log

DATE	SECTIONS AFFECTED	REASON FOR CHANGE	VERSION/ REVISION
10/3/13	All	Response to CDR RIDs	Version 2.0
4/7/14	Chap. 4	Scope reduction for SITR, addition of TRR prior to pre-PAI testing, and other minor clarifications.	Version 2.1
4/7/14	Fig. 2-2a, Fig 3-1	Updated I&T snapshot	Version 2.1
4/7/14	Section 3	• Scope of OSF testing has been reduced, and software tests eliminated. • Provision has been made for early shipment of some items. • Discussion of testing to prove no deleterious effects on ALMA moved to 3.3.4 (CSV) • Note on correlator weekly tests following changes	Version 2.1

1 Document Overview & Scope

This document describes how the ALMA Phasing Project hardware and software shall be integrated and tested for: Basic functionality; adherence to Back End, Site, Correlator, and Computing interface control documents (see Applicable Documents); and compatibility with relevant ALMA requirements documents. For each such requirement and specification, the verification methods are described and (when relevant) it will be noted whether all instances or a representative sample are verified. The actual laboratory experimental equipment and procedures used for this verification will be described in a Test Procedures document, to be completed prior to the corresponding Test Readiness Reviews (TRR), and in the Commissioning and Science Verification Plan (see Applicable Documents).

APP hardware requirements are defined at the functional level (See the APP Requirements Document), augmented by interface control documents (ICD) as well as various ALMA documents that describe environmental constraints, safety procedures, etc. However, in response to the high level of maturity of the APP hardware, there has ben no explicit effort to develop hardware specifications at the subsystem level distinct from those presented in the design and description documentation. Correspondingly, there is no explicit verification of specifications. The ALMA system engineer has approved this departure from practice.

As shown schematically in Figure 1-1, the functional requirements specified in the APP Requirements Document are divided into *design* and *performance* requirements. Detailed test procedures for the performance requirements are further described in the Commissioning and Science Verification Plan and are the responsibility of the Science Team. The design requirement test procedures will be described in the Test Procedures documents.

APP software specifications follow ALMA practice in being fully traceable to functional requirements, and are extensively documented at the design level rather than deriving from detailed specifications (see APP Computing Management Plan). Testing of software has been integrated into the normal ALMA software release process.

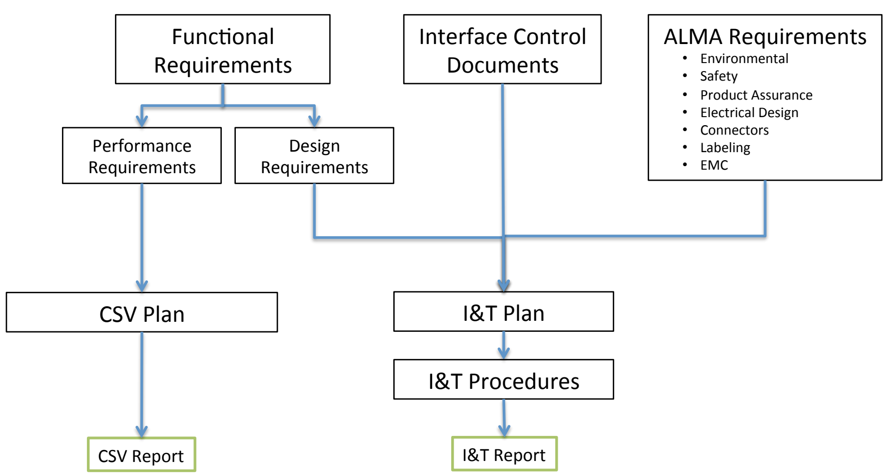

Figure 1-1: The APP detailed design satisfies (a) Functional requirements, comprising both performance and design requirements (b) Interface Control requirements, and (c) ALMA requirements. Verification of performance requirements is described in the Commissioning & Science Verification Plan. This document describes integration as well as verification of all other requirements

2 Design overview

This section is provided for contextual reference, but is superseded by information in the formal design documents.

The following are essential features of the plan for ALMA phasing:

- Correlator upgrades are in parallel with the existing hardware/firmware and do not affect the normal data path
- Only relatively minor software enhancements to the ALMA code base are required.
- All of the phasing corrections are performed in the correlator and supporting computer system with no front-end or Local Oscillator modifications required.
- Development of the system is fault-tolerant in that the critical path involves minimal risk to commissioning
- No new technical development is required for the project (i.e. this plan involves a straightforward implementation of existing technologies).
- The phasing system includes a commercial hydrogen maser to provide a high stability, spectrally pure frequency standard to ALMA for routine operations as well as VLBI.
- ALMA operates normally during VLBI observations so that all of the normal interferometric capabilities of ALMA are available while the VLBI data is being captured.

2.1 Hardware

Figure 2-1(a-c) is a schematic of the new hardware and firmware components to be delivered and installed by APP. "Firmware" in this context is used to describe the new micro-processor code (primarily the ALMA C167 chips in the existing correlator boards) as well as personalities for some of the Xilinx FPGAs.

Firmware modifications to existing correlator components are subject to regression and functional testing through normal ALMA processes as they are completed and checked in. These are designed to have no impact on normal ALMA operation, and should be ready for use when CSV activities begin.

Cable responsibilities shown in Fig. 2-1, as well as responsibility for tools, fixtures, and test equipment required for installation and testing, have been assigned and documented in the corresponding Bills of Materials.

Sparing is described in the Reliability and Maintainability report ALMA-05.11.10.03-0002-A.4-REP, and is reflected in the Bill of Materials. APP will deliver a full spare Mark 6 recorder, and spare cards and components for PIC assembly as appropriate. The maser is on a long-term service contract. While the OFL is not expected to require maintenance, all necessary components are commercially available.

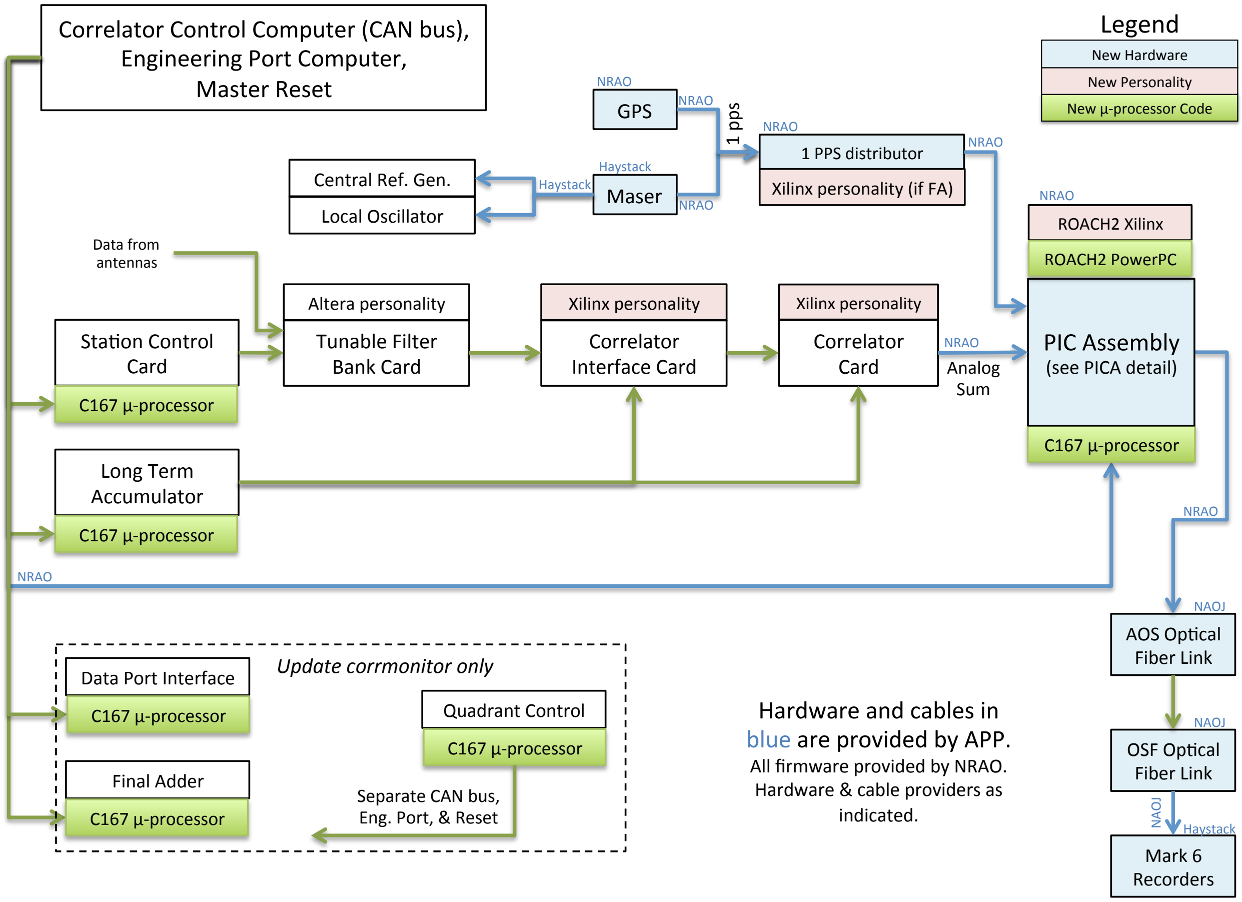

Figure 2-1a: APP delivery of the PIC assembly includes correlator upgrades to the components shown. Hardware downstream of the PIC assembly (optical fiber link and recorders) has no effect on existing ALMA systems. Upstream of the PIC, the new maser replaces the existing ALMA Rb clock, with a new GPS provided as part of the system that ensures the integrity of the PPS system.

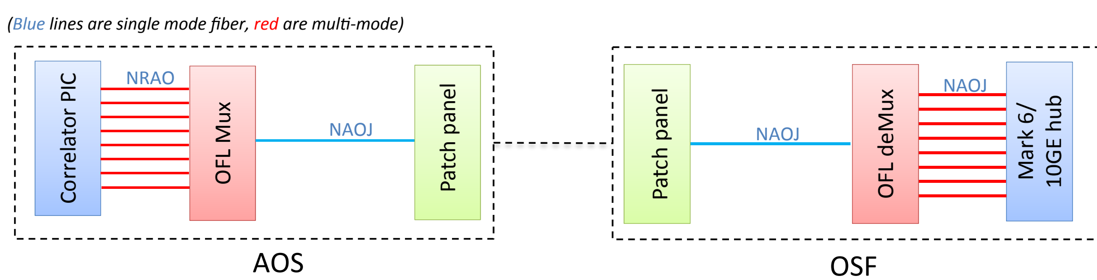

Figure 2-1b: Detail of the Fiber mux system indicating responsibility for single- and multi-mode optical cables. The patch panel is an existing ALMA component; MIT-HO provides the recorder, NRAO the PIC, and NAOJ the Optical Fiber Link (OFL).

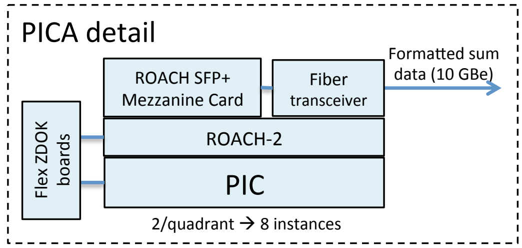

Figure 2-1c: Detail of the PIC assembly, showing the ROACH-2 controller and the mezzanine card that produces optical signals for the optical fiber link.

2.1.1 Maser

A Hydrogen Maser supplied by the APP will serve as the frequency reference for the entire ALMA facility. The APP has procured a modern Hydrogen Maser frequency standard (an iMaser 3000, commercially available from T4 Science) to be installed at the AOS. Space for this unit (WxDxH is 60 x 80 x 95 cm, 100kg weight) at the AOS has been identified; it requires 100W in normal operations and has a warrantee extendible in 7-year increments.

This maser provides two 5 MHz and four 10 MHz sine-wave outputs (13 dBm at 50 ohm) and a TTL compatible 1PPS signal. The current Rubidium frequency reference will be retained as a facility backup for the maser, which will enable ALMA to quickly recover from a failure of the maser.

The maser will be shipped directly from Haystack Observatory to ALMA, and will not be used for testing at Charlottesville. Prior to CDR, it was discovered that the existing 10 MHz signal from the Central Reference Generator (CRG) to the Local Oscillator, which is derived from the maser 5 MHz signal, suffers from thermal drift and noise and is inadequate for VLBI. A plan to replace that signal with the 10 MHz signal directly from the maser was accepted by the ALMA System Engineer.

2.1.2 Recorder

The Mark 6 is the latest in a line of digital recorders for VLBI, increasing the recording rate to 16 Gb/s per unit. Four Mark 6 units will be required for APP. Haystack Observatory works closely with the vendor, Conduant, to define the hardware configuration, and the software is provided directly by Haystack. In addition to speed and capacity, the Mark 6 is the first in the line to be based entirely on commodity electronics, and will therefore be easily maintainable.

The Mark 6 is in the final stages of development under another program. Basic specifications have been met and hardware components have been selected. Configuration of the Mark 6 units for APP will require some integration and testing of the software at Haystack Observatory. Procurement of the components is in progress. For the purposes of APP, the Mark 6 is considered a commercial unit and its development is not under review at CDR. Performance characteristics are described in *Mark6_users_manual_draft*.

2.1.3 Fiber Optic links

The Optical Fiber Link system transmits the antenna sum data from the AOS to the OSF. Eight 10 GbE data streams are wavelength- division-multiplexed onto one fiber at the AOS for transmission to the OSF, where it is demultiplexed and routed to the appropriate recorder sub-system. The optical fiber link system (a pair of a transmitter and a receiver) is fully symmetric and the two devices are interchangeable. The device is a passive participant in the VLBI phasing system, with no packet monitoring capability.

The multiplexor and demultiplexor units were procured, integrated, and delivered to NAOJ, where they underwent network connection and reliability testing. Details of the design are provided in ALMA-05.11.40.01-0001-A-DSN, and test results are provided in ALMA-05.11.40.02-0001-A-xxx.

2.1.4 Phasing Interface Card (PIC) Assembly

The NRAO (Charlottesville) ALMA Correlator group is responsible for PIC assembly development and the corresponding correlator upgrades. The PICs serve as the VLBI backend for ALMA, aggregating all coherent sums and formatting the data in a standard VLBI Data Interchange Format (VDIF). Resulting 10 GbE packets are sent to the fiber optic link system for transport to the VLBI recorders at OSF. A maser-derived 1PPS tick (whose alignment with GPS is known) is used by the PICs to ensure synchronization with other VLBI sites around the globe.

The main function of the PIC is to format the phased sum data into frames suitable for recording. It maintains the "look and feel" of the correlator (standard timing signal interfaces, form factor, etc.) to simplify software development and mechanical constraints. The PIC includes the standard ALMA Correlator microprocessor and the standard connection to the Correlator Bin Motherboard. The ROACH2 FPGA provides the signal processing power for formatting the data.

Prototype PICs have been received at NRAO, including adapters and connectors necessary for testing. Basic acceptance tests have been completed and all ICD details defined. ROACH FPGA firmware is now under development.

A general description is provided in the Phasing Interface Card Manual.

2.1.5 1 PPS Distribution System

The 1 pulse-per-second (PPS) Distribution system, while not strictly necessary for phasing operation, ensures that all timing systems used in the phasing process are producing consistent signals. It compares signals from the maser, the ALMA GPS, the correlator GPS, and the timing signals synthesized from the correlator output (ultimately derived from the maser), and generates alarms if any inconsistency is observed. There is no automatic response to these alarms, but they serve to warn of maser or other failures.

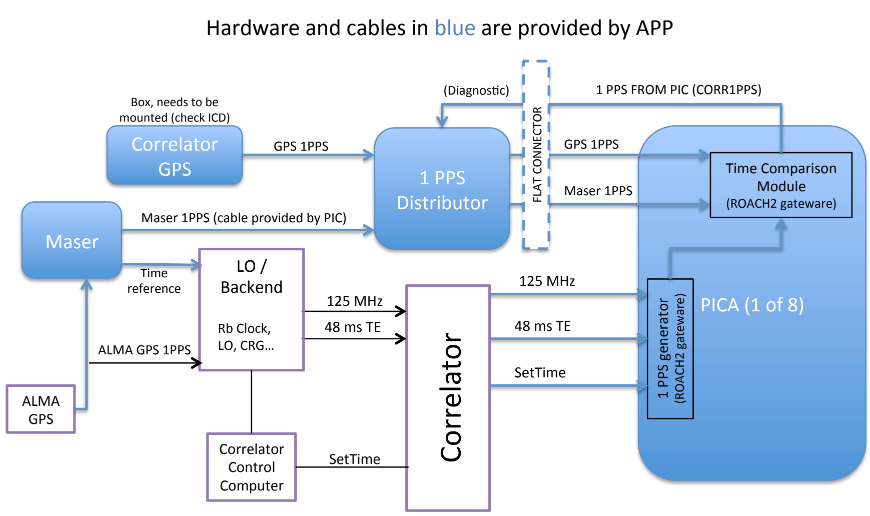

Figure 2-2: 1 PPS Distribution detail. The 1 PPS data are for a consistency check only, not saved with the data.

2.1.6 Correlator upgrades

The correlator upgrade directs ALMA data to the Phasing Interface Cards (PIC). It involves a firmware modification to the summing logic in the Correlator Cards, which provides the sum of the antenna signals in the 2-bit format required by the PICs and Correlator Interface Cards (CIC). The new Correlator Card FPGA personality (under development at NRAO) will facilitate the formatting and testing of the output sums. The addition of up to 64 2-bit values is represented with 8 bits using a tree of adder chips. The final 2-bit sum of N antennas is achieved by scaling via a lookup RAM in the Xilinx FPGA. This logic is applied to each of the 32 channels to provide the signals sent to the PIC. For testing purposes, it is possible to substitute pseudo-random data or an incrementing count for the sum data.

The CIC Xilinx personality was modified before delivery of the fourth correlator quadrant to accept an alternate input for the 64th antenna (CAI-63). The antenna sum will be routed to this alternate input, providing the capability of correlating the sum against any of the other 63 antennas connected to the correlator. This important test feature is useful in evaluating the effectiveness of the phasing.

Approximately 275 LVDS cables will be routed in the existing cable trays in the correlator to transport the sum signals and timing signals to the PICs. The PICs will also be cabled into the multi-drop bus. Two small modules will be added to one of the computer racks to distribute Maser and GPS 1 PPS signals to the PICs. A 1-PPS distributor, a GPS receiver, and a PIC power supply will also be provided.

Firmware upgrades are summarized in Table 2-1.

CAN Protocol		FPGAs affected			C167s affected					
Name	Description	R2	CIC	CC (4)	PIC	LTA	SCC	DPI	FA	QC
DOWNLOAD_ANTENNA_SUM_MASK	Provides a mask to select antennas to sum			X		X				
SET_ANALOG_SUM_MODE	Used to select between normal and test data			X		X				
SET_CIC_INPUT_SWITCH	Sets the state of the CIC input switch		X			X				
DOWNLOAD_SUM_SCALING_DATA	Provides threshold for 8-bit to 2-bit conversion			X		X				
GET_SUM_STATUS	Status from above commands			X		X				
SET_DATA_OUT_TIMING	Adjusts timing of sum data outputs			X		X				
DOWN_VDIF_HEADER	Downloads header for VDIF frame	X			X					
GET_DOWNLOAD_VDIF_HEADER_STATUS	Status from above command	X			X					
APPLY_VDIF_HEADER	Above Header becomes active in frame data	X			X					
GET_APPLY_VDIF_HEADER_STATUS	Status from above command	X			X					
SET_PIC_CONTROL	Downloads control bits to PIC	X			X					
ROACHON / ROACHOFF	Powers ROACH2 up and down	X			X					
GET_PIC_STATUS	Status from addressed PIC, complex	X			X					
1PPS	Monitors 1-PPS deltas	X			X					
APPLY_TFB_PHASES	Applies delivered phases at next TE						X			
GET_TFB_PHASE_STATUS	Status from above command						X			
(N/A)	Update Corr Monitor to include PIC				X	X	X	X	X	X
CORRPIC	Tests data paths from correlator boards to PIC	X		X	X	X				

Table 2-1: Firmware upgrades are organized by the corresponding CAN protocol and implemented on one of three FPGAs (ROACH-2, Correlator Interface Card and Correlator Card) or one of 6 microprocessors (the PIC PowerPC and C167s on the Long Term Accumulator, Station Control Card, Data Port Interface, Final Adder, and Quadrant Control). The latter three only need a minor change to a correlator monitor table.

2.2 Software

Code development and testing is distributed among NRAO, Haystack Observatory, MPIfR, and ASIAA. The overall software development is led by MIT-HO. Testing passes through the standard ALMA release process, and is timed to the anticipated release cycles as shown in Figure

2-2 (a-c).

2.2.1 Device control

Three new Control Devices (hardware components) are being added to ALMA, each requiring a device software abstraction. The maser runs autonomously, producing status data but requiring no commanding. The PICs reside in the four ALMA correlator quadrants, accepting commands from and providing monitor data to the CCC computer using the same CAN buses as the remainder of the cards in the correlator, but with new protocols. The standard ALMA data process is unaffected, running in parallel to the PIC processing. The data generated by the PIC card in the ALMA correlator (high site) is passed directly to the VLBI recorders (low site) via an optical fiber link. The optical fiber system, like the maser, is always operational, but may produce some health data to be monitored. Aside from some configuration commands, the recorders mostly receive simple scan start/stop commands.

Device control is the responsibility of MIT-HO.

2.2.2 Observing Mode

The VLBI Observing mode (VOM) is the ALMA observing mode to be used for VLBI operations. The VOM is an enhancement of the existing Single Field Interferometry Observing Mode, adding two new controllers and modifying an existing one. It requires new interfaces, specified through the Interface Definition Language. VLBI mode and phasing mode are implemented in separated controllers, allowing the phasing system to work independently of VLBI observations. See ALMA-05.11.61.01-001-A-DSN for additional description.

Observing Mode is a joint development of MIT-HO and NRAO.

2.2.3 Correlator Development

As shown in Table 2-1, new commands will be added to the correlator to provide new features (Long Term Accumulator Protocols), support for the PICs, and revisions to the tunable filter bank protocols to facilitate phasing corrections. The correlator side of the phasing loop and the fast loop calculations are also a part of this package. In addition, minor simulation infrastructure changes are provided to support development.

Correlator Development is primarily the responsibility of NRAO, with MIT-HO contributing to the phase update routine.

2.2.4 Phase Solver (TelCal)

Phase Solver is the phasing system that computes and publishes the phasing solutions to be consumed by the VOM and eventually forwarded to the Correlator subsystem. TelCal will also provide information about the quality of the obtained phasing solutions and will respect manual/automatic weighting/masking of antennas.

In parallel with routing data to the recorder, the correlator continues to produce its normal correlation products. Correlated baseline data are transferred to the Correlator Data Processor (CDP) computer cluster, where the complex visibilities are sent to a new phasing software routine coded within the CDP and TelCal systems. This solver routine uses the phases of the baseline visibilities to solve for residual antenna phases ($\Delta\phi$), which are then transmitted to the TFB cards to correct the input antenna signals. The TelCal computer also provides a measure of the quality of the phasing solution.

To close the feedback loop, the antenna phase solutions are sent to the Correlator Control

Computer (CCC), which commands the TFB to apply the solutions.

The phase updates are calculated by the phase solver software, which takes the channel-averaged data from the ALMA correlator and generates periodic phase shift updates. The phase solver is implemented within the TelCal component, which uses these data products for calibration purposes and thus already supports the necessary data interfaces. It generates a linearized solution that the CDP uses to generate fast time scale phase shift commands for the TFB. Finally, the summed product is fed back into the ALMA correlator for a real-time correlation with one selected antenna, which is monitored to determine and report the efficiency of the phase solver in real time and make appropriate adjustments.

Implementation and release of the Phase Solver component is being realized in several steps by incrementally adding in more advanced features. Phase Solver is the responsibility of MPIfR. See *ALMA-05.11.62.01-001-A-DSN* for additional information.

2.2.5 Polarization Calibration

ALMA receivers are dual orthogonal linear polarization, while other VLBI sites record dual circular polarization. Circular polarization avoids getting polarizations crossed during correlation due to parallactic angle differences between VLBI stations.

Polarization calibration is under development by MPIfR with assistance of Onsala University, Sweden, and will be integrated in DiFX by ASIAA (see Polarization Conversion for ALMA Phasing).

2.2.6 VLBI Scheduling

To avoid modifications of the existing ALMA Scheduling subsystem, APP software ingests VLBI scheduling instructions in the form of a VLBI Experiment file (VEX), and converts it to an ALMA VOM file. The VEX file contains a description of the configuration of all of the participating VLBI sites, the timing of the scans to be recorded, and other ancillary information. The VOM interacts with the ALMA operators through a new status panel incorporated into their existing displays. Since each session runs synchronously with the remote stations, there is no actual commanding for the operators, except perhaps for extreme contingencies.

VEX to VOM translation is the responsibility of MIT-HO, in consultation with MPIfR.

2.2.7 Graphical User Interfaces (GUI)

The APP requires enhancements to the existing development and operator GUIs to monitor status of the several components in the APP system and to perform some corrective actions. The GUIs are implemented at MPIfR and at MIT-HO.

2.2.8 Post-processing (DiFX)

The VLBI Correlator software (DiFX) requires certain enhancements to allow the correlation of ALMA VLBI data. This is not a deliverable to the ALMA software system. DiFX modifications are provided by ASIAA.

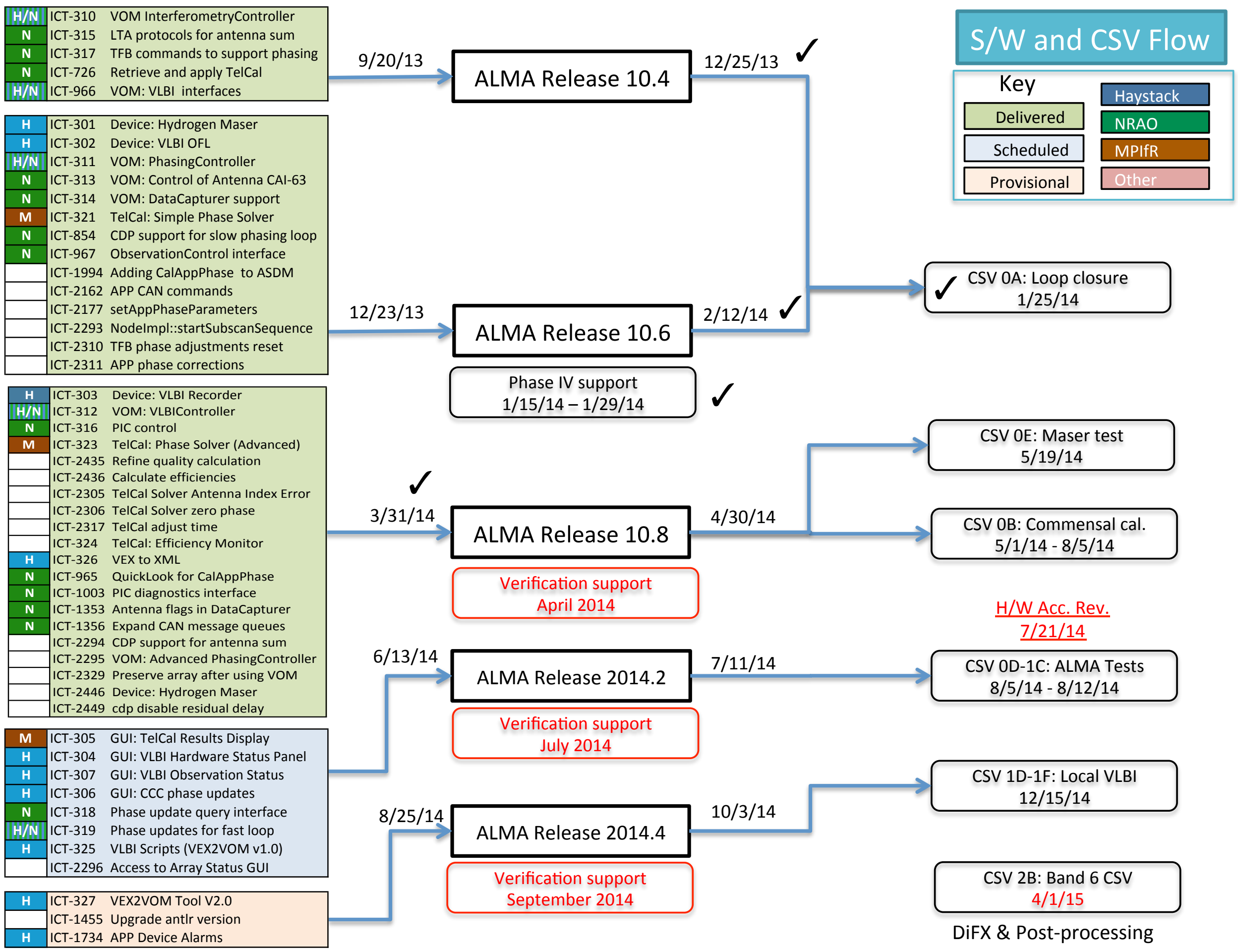

Figure 2-2a: Software to be run on ALMA computers is developed by MIT-HO, NRAO (Socorro), and MPIfR under overall coordination of MIT-HO. This is submitted to the even numbered ALMA release cycles on 3-month centers, in coordination with the CSV test planning. Dates assigned to the release process are approximate, and the specific assignment of features to Releases is subject to ALMA priorities.

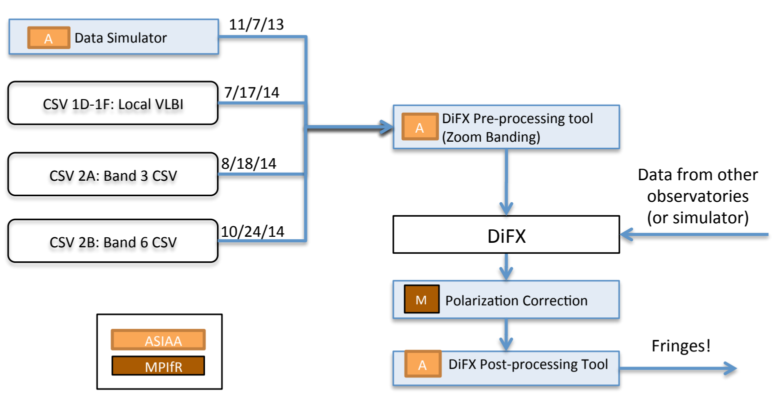

Figure 2-2b: Data from ALMA and other VLBI observatories is processed at a VLBI correlator site (MIT-HO). This processing includes a polarization conversion from linear to circular, specific to ALMA data. A Data Simulator has been developed to enable full testing of the system prior to receipt of CSV data.

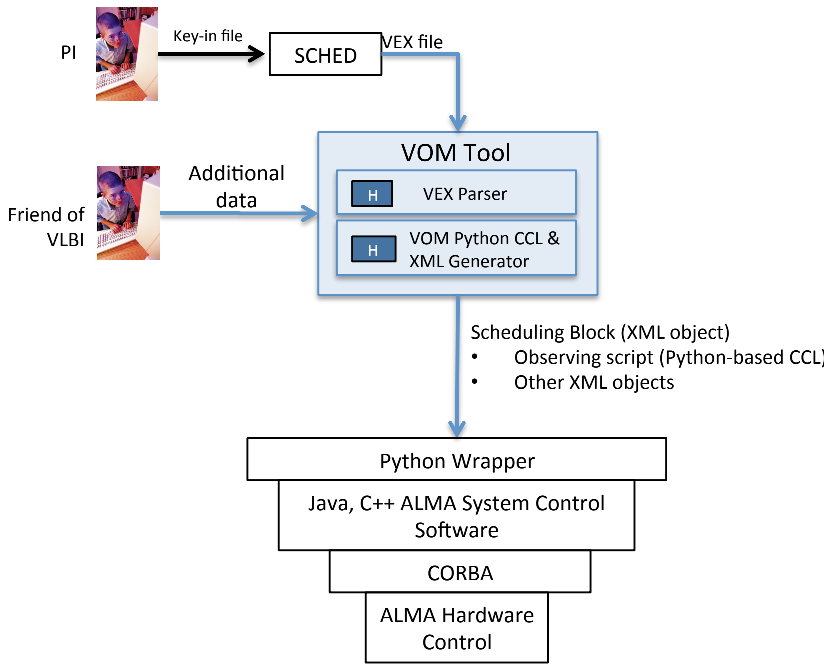

Figure 2-2c: An observing plan for ALMA is developed from the VLBI observing tool SCHED, which produces a VLBI Experiment (VEX) file to be distributed to each participating observatory. APP provides ALMA with a VEX-to-VOM translation tool to generate files required by the new ALMA VLBI Observing Mode (VOM). This capability will be tested through the ALMA release process, and will generally require a "Friend of VLBI" at ALMA for validation and tuning of the automatically generated VOM files.

3 Integration and test flow

Testing is incremental at the component, module, subsystem, and system levels as appropriate. Software and electronics will be tested in a simulation of the ALMA configuration at the NRAO Central Development Lab at Charlottesville, VA. A System Integration and Test Review (SITR) will precede all testing activities.

Detailed test procedures will be developed prior to SITR, defining 16 test sequences that collectively satisfy all requirements verification and validation, as well as ensuring system health and proper operation. These are described in Table 3-1, along with estimates of ALMA resources required to implement them.

The Charlottesville integration and test activity will serve as a "dry run" for reassembly and health tests after shipment to Chile. Detailed procedural instructions will be updated throughout the sequence, and a log of tools (voltmeters, temperature sensors, etc.) and materials will be carefully recorded. Subsequent to the tests, equivalent tools and materials will be identified at ALMA and set aside for OSF integration to form the Basic Toolkit referred to in Table 3-1; Unique items will be kitted at Charlottesville for transport to ALMA and addition to the Toolkit. Among the Toolkit contents are temperature sensors and a tape measure.

Table 3-1: Successful execution of these 16 test sequences will satisfy verification and validation of all requirements. Duration (hrs) is approximate.

Test		Campaign				Array Access		Test equipment@ALMA	
#	Title	PAI	PAS	AcRv	CSV	hrs	subsystems	APP provided	ALMA provided
1	Health check (intensive)	X		X		3	correlator	Basic toolkit	DVM, thermal camera
2	Health check (status)	X	X	X	X	1	correlator	N/A	N/A
3	Document inspection and review	X		X		0	N/A	N/A	N/A
4	Software release			X	X	0	N/A	N/A	N/A
5	Off-line correlator & PIC tests	X	X			0	N/A	Basic toolkit	Oscilloscope, DVM
6	Off-line OFL tests	X	X			0	N/A	Basic toolkit	Optical power meter
7	Off-line maser tests			X		0	N/A	N/A	N/A
8	Off-line recording system extended test		X			0	N/A	N/A	N/A
9	Simulated observation	X				0	N/A	N/A	N/A
10	Back-end interface tests			X		3	correlator, back-end	N/A	N/A
11	Computing interface tests	X	X	X		3	correlator, maser, computing	N/A	N/A
12	Correlator interface & environmental tests			X		21	correlator, computing	Basic toolkit	Oscilloscope, DVM, thermal camera
13	Site interface tests			X		0	N/A	Basic toolkit	N/A
14	On-sky interferometric observation*				X	41	All	N/A	Beacon
15	Electrical, mechanical, safety, and labeling walk-through	X		X		0	N/A	N/A	N/A
16	On-sky VLBI tests				X	72	All	GPS & quartz crystal	OSF antenna & LORR

3.1 Approach

Since all APP hardware subsystems are provided by consortium members, not directly by vendors, it is assumed for the purposes of this plan that testing at the subsystem level has been competently performed by the responsible institution. In practice, this activity is coordinated by Project Management while each institution uses their own internal processes and procedures.

The overall flow of testing is illustrated in Figure 3-1. Integration and preliminary testing at the

NRAO Charlottesville facility is preceded by an informal System Integration and Test Review (SITR), and followed by a Test Readiness Review (TRR) prior to the test sequence leading to the provisional acceptance in-house review (PAI). The system is then shipped and reassembled at OSF (some components will have already shipped where multiple instances allow this to be done without compromising the NRAO testing). Following the first of two informal TRRs, a representative set is tested again and reported at a provisional acceptance on-site (PAS). It is reassembled for the final time at AOS (except for components that stay at OSF) and the complete system is tested following a second (TRR). Commissioning and Science Verification is initiated after successful test completion and an Acceptance Review (AcRv).

All tests derive from a plan, follow a detailed procedure, generate a test report, and are explicitly linked to requirements verification.

3.2 Responsibilities

Integration and Test, and the associated Product Assurance are the responsibility of NRAO, led by the I&T Manager (R. Lacasse) and the P.A. Manager (R. Treacy). The sole exception is the CSV, which is led by MIT-HO (L. Matthews). Technical support of local site installation at ALMA is the responsibility of the University of Concepcion (N. Nagar).

3.3 Test flow

3.3.1 NRAO Integration and Test

The PIC Assembly and at least one instance of all *downstream* elements of the data path will come together in Charlottesville and be prepared for testing. This excludes the maser, which will be replaced by a precision crystal for testing purposes.

Tests in Charlottesville will verify basic functionality as well as many of the APP requirements (test descriptions in Table 3-1 are cross-referenced in the requirement matrices in Chapter 5). These tests will exercise the data path and control functions downstream of the front end, utilizing a single complete signal chain consisting of a single PIC integrated with the OFL and a single recorder. A 2-Antenna Correlator test fixture has been constructed as a representative subset of the 64-Antenna Correlator, incorporating the APP correlator upgrades. In this test fixture, various types of test data can be generated, a “sum” (from one antenna) can be computed and the sum data can be formatted by a PIC. Data from the PIC will be routed through the OFL system to the recorder and tested for integrity.

Tests in Charlottesville will emulate the ALMA hardware and control software context to the extent possible, but some limitations exist. Testing with the new maser will only occur in CSV, as it is impractical to ship it to Charlottesville or even to OSF prior to installation at AOS. Instead, a crystal clock will be used for system tests. The control software is logically divided into two controllers, one for phasing and one for the VLBI data path. The limitations of the two-antenna correlator do not allow thorough testing of the phasing system, but that testing is part of software verification for release 10.6. The integration testing in Charlottesville will therefore focus on the VLBI controller, exercising and verifying relevant hardware protocols for the PICs and recorders.

A PAI will be held at the conclusion of tests in Charlottesville.

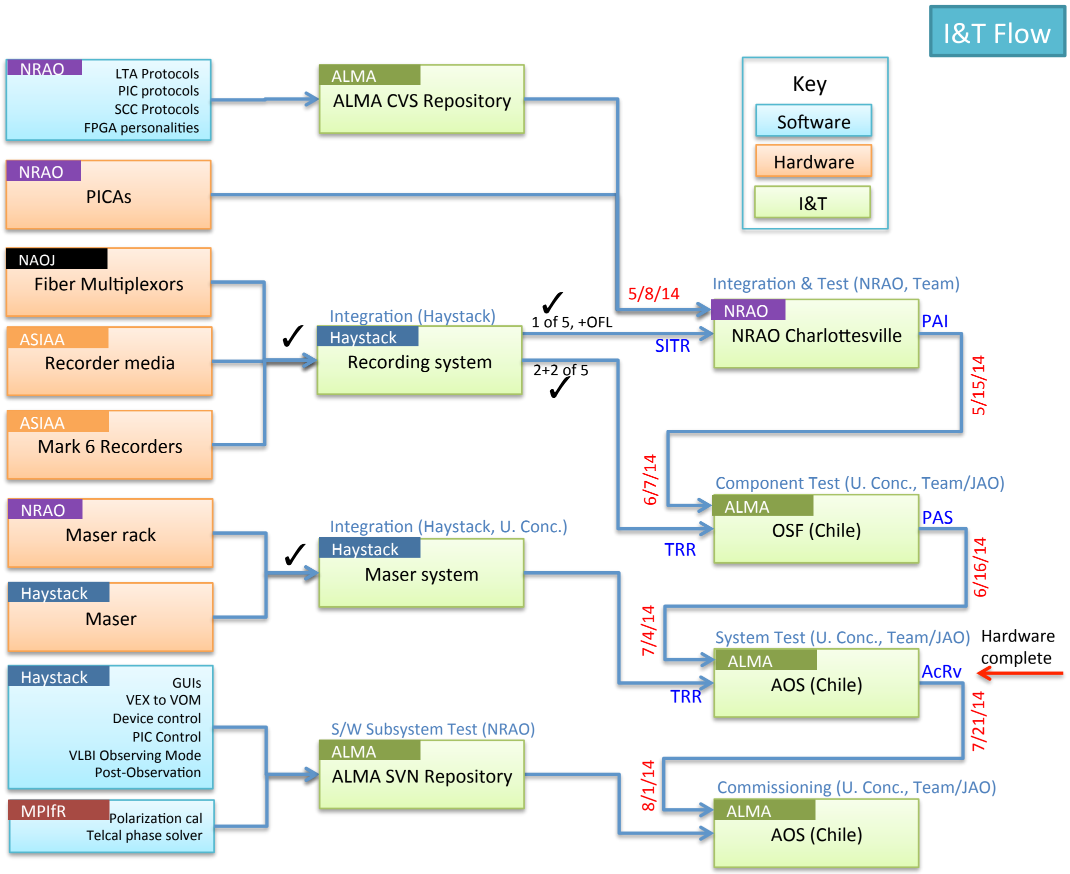

Figure 3-1: APP hardware and software is developed by 5 institutions, which are part of a larger consortium. The first stage of integration occurs, as needed, at Haystack, ALMA, or NRAO. A complete subsystem (except for the maser) is integrated and tested at NRAO Charlottesville prior to shipment to Chile. The entire system is then integrated with components already at ALMA and tested first at OSF, then at AOS in preparation for commissioning and science verification. Reviews and approximate dates are also shown. Refer to APP Schedule for latest dates.

3.3.2 OSF Tests

Components will be tested at OSF in the most convenient way possible to verify that nothing was damaged during transit, or responds differently due to the environmental configuration, with many components in their final intended location. A PIC assembly will be installed in a 2-Antenna Correlator at the OSF. As in Charlottesville, test signals will be generated in the 2-Antenna Correlator, signals from 2 antennas summed in a Correlator Card and formatted by a PIC. Unlike the Charlottesville tests, all four recorders and all OFL channels will be exercised.

Installation of components and testing will be coordinated with the ALMA observational schedule, taking best advantage of maintenance periods. The testing sequence will be followed by a PAS.

ALMA resources required (also see Table 3-1): With the assistance of Computing, Alejandro Saez and an ALMA technician will set up communications to the recorders. APP personnel will require access to the Correlator Lab and Archive Room, and will borrow an ALMA oscilloscope and infra-red camera, which Saez has available. The Basic Toolkit will cover other needs, such as temperature sensors, tape measures, or tools to clean fibers before installation. APP personnel will also need access to the site network to talk to the recorders. Testing should take about 10 days. One or two trips to the AOS may be taken for planning purposes.

3.3.3 AOS/OSF Tests

The final test sequence, with all components in their permanent locations, will verify all remaining requirements designated for AcRv in the Verification Matrix. Tests will follow a procedure similar to that followed in previous tests for the data path. Testing of the H-maser will include both short-term performance (1 to 2 seconds measured against a good crystal) and long term (>~ 10 minutes, measured against GPS). Environmental tests will also be conducted (e.g., effect on CLO room temperature stability).

Using the incremental testing approach to minimize impact on ALMA observations, much of the equipment in the data path will be installed during maintenance and test periods prior to the start of formal testing. A suite of tests will be run to satisfy all remaining requirements in the verification matrix. Some examples include functional testing of the data path from the input of the correlator at the AOS to the recorders at the OSF using built-in tests; accuracy and stability measurement of timing signals (TE and 1-PPS from various sources) using oscilloscopes and built in tests; verifications of environmental parameters such as voltages, currents and temperature rise of key components using hand-held instruments already available at the OSF and used for correlator PAS testing.

First we will utilize low-level methods to verify the hardware installation, including control through the engineering port. Second, as part of the software verification process, we will exercise the hardware using the ALMA control system. These and previous steps supply the material for the AcRv.

ALMA resources required: While some equipment will be installed ahead of time during maintenance periods, there will be a need for AOS access to install the remainder.

There is an estimated 82 hours of work to be done, not including transportation time to the AOS. With 4 people working together, we plan to complete this work in ~40 hours, spread over up to 3 weeks. During the testing, the correlator will be out of service but no other systems need to be taken down (it may be possible to use the Japanese correlator for observations at this time). APP will make every effort to coordinate this work with other ALMA maintenance activities. The testing does not require good *observing* weather, as long as the facility can operate.

3.3.4 Regression testing

To confirm that new components do not have any deleterious effect on the ALMA system, the correlator weekly test is performed when any components are added to the correlator, or after existing components are modified (typically firmware).

As a result of consultation with ALMA staff in January 2013, an additional test sequence was added to the CSV plan to help ensure that ALMA performance is not adversely affected by APP components.

After commissioning of APP, regression tests will verify that subsequent changes to ALMA software, firmware, or hardware do not adversely affect phasing capabilities, or that subsequent changes to the phasing configuration do not affect other ALMA capabilities. Both of these objectives will be accomplished within existing ALMA processes. As indicated by the APP Computing Management Plan, the APP team will supply algorithms to be integrated into the regression tests that are already part of the ALMA software release process. This will be an ongoing interaction as new APP features are submitted for release. Similarly, as indicated by the Commissioning and Science Verification Plan, a subset of on-sky CSV tests that verify basic phasing functionality will be consolidated in a short automated sequence and submitted to the ALMA CSV team for incorporation in their own regression testing process.

4 Reviews and Reporting

Figure 3-1 indicates the relationship of the various reviews described below to the delivery, integration, and test campaigns.

4.1 System Integration and Test Review (SITR)

This review essentially replaces the Manufacturing Readiness Review, which has been waived as not applicable to the APP. The SITR will be held at NRAO in Charlottesville, nominally after receipt of the test subsystems, during integration, and prior to the initiation of the first set of verification tests (i.e. those marked for PAI review in the verification matrices).

The following information will be reviewed:

- Response to assigned CDR RIDs
- Departures of delivered hardware and software from the design presented at CDR
- Post-CDR updates to this Integration and Test Plan and other critical documents
- Waivers, non-conformances, and changes to requirements

4.2 Test Readiness Reviews (TRR)

A TRR will be conducted prior to initiation of pre-PAI testing at NRAO, a second prior to pre-PAS testing at OSF, and a third prior to the pre-AcRv tests at AOS. These will be informal "stand-up" reviews before a limited group of people involved in testing. The purpose will be to make sure all test procedures are understood.

4.3 Preliminary Acceptance In-house (PAI) and on Site (PAS)

The PAI will be held in Charlottesville subsequent to the initial system tests, and will serve as a pre-ship review prior to transporting the APP system to Chile. The PAS will be held at OSF and will precede the transfer of the PIC assemblies and the OFL transmitter subsystems from OSF to AOS. Both will follow standard ALMA practice and be held informally in front of cognizant APP and ALMA personnel. It is expected that both will be conducted largely by telephone and videoconference. Subject matter includes:

- Summary of system test and verification results
- Plans for rectifying or waiving failed or incomplete tests and non-conformances.

4.4 Acceptance Review (AcRv)

The AcRv will be held subsequent to the completion of verification testing. The audience will include APP and ALMA science personnel as well as cognizant engineering personnel, and successful conclusion of the review will signify readiness to initiate CSV observations that utilize the hardware. Topics to be reviewed include:

- A description of the test system
- A summary of verification results including any failures and waivers
- Detailed CSV procedures that are specific to the hardware

5 Verification Matrices

As shown in Figure 1-1, the test program will verify three categories of APP requirements: Functional (science) requirements, ICD requirements, and relevant ALMA requirements. These are described in the Tables 5-1 though 5-3. Detailed procedures will be documented prior to the System Integration and Test Review (SITR).

Table 5-1: Verification of Functional Requirements. Test numbers refer to Table 3-1. In some instances separate test methods are applied to a single test unit and the full set of units, indicated as A/B (single/all). Detailed procedures for blue-highlighted requirements are described in the CSV plan.

Rqmt #	Requirement	Test	Verification Method
General			
APP0010	**Frequency reference:** All ALMA local oscillators shall be phase-locked to a common frequency standard.	14	Once the Hydrogen Maser frequency standard has replaced the Rb standard, a normal ALMA interferometric observation using 2 or more antennas and the baseline correlator shall be used to demonstrate phase stability between antennas.
APP0020	**Spectrum**: The APP shall be capable of processing 8GHz of input spectrum per polarization	3,8/10	Inspection of the system block diagram shows that the system contains 8 data paths from the correlator to the recorder and that each data patch is capable of handling 2 GHz of bandwidth and one polarization. At NRAO, one-eighth of the system capacity will be demonstrated using test data. At AOS, the fully specified record capability will be demonstrated.
APP0030	**Polarization:** The APP shall generate dual-polarization signals.	3,9	Review of the system block diagram as in 1.2 above. The feedback mechanism of the phase sum back to the ALMA correlator shall be used for testing.
APP0040	**Polarization purity:** The APP shall not introduce more than 3% polarization leakage .	16	Detailed analysis of VLBI observation on a polarized source.
APP0050	**Data capture**: The APP shall have the capability to record 64Gbps of data and associated framing data.	1	At NRAO, the recording of one channel of 8 Gbps data shall be demonstrated. At AOS testing all 8 channels, each at 8 Gbps shall be demonstrated. Test vector generator will provide the data; error checker will confirm recording accuracy.
APP0060	**Line Replaceable Unit Reliability (LRU):** All installed APP hardware shall satisfy ALMA LRU requirements.	15	<Superseded by Reliability and Maintainability plan>
APP0070	**Environmental:** All hardware permanently installed at AOS/OSF shall meet ALMA altitude/environmental	3, 12, 13	See Table 4-3, Environmental, for detail.

Rqmt #	Requirement	Test	Verification Method
	requirements.		
APP0080	**Environmental:** The recording systems shall be compatible with operation at OSF altitudes.	8	Media have been tested at Mt. Graham, AZ extensively. A pair of Mark 6 units shall be tested at OSF (one transmit, one receive) for at least 200 hrs. In addition, the operational plan will include a conditioning procedure for media to detect possible unit failures.
APP0090	**Data transmission:** A high speed data 80Gbps connection shall link the equipment at the AOS to the OSF	10	For AOS Testing the normal operational data rate of 64 Gbps shall be demonstrated.
APP0100	**Environments:** The APP system shall be operable whenever ALMA is.	3,12	It shall be determined by review that APP hardware and software operation is compatible with normal ALMA operation.
Maser			
APP0110	**Maser status:** The Maser status / health information shall be accessible via a network interface and recorded at least once every 10 minutes.	4	During AOS testing, the software shall be exercised and the status/health data shall be inspected.
APP0120	**Maser stability:** The Maser shall be stable to: 10^{-13} Allen Variance for 1 sec integration time and 2×10^{-14} for 10 second integration time.	7	This stability is guaranteed by the maser specifications. It shall be verified on site after installation by comparison to a precision crystal oscillator.
APP0130	**Frequency source:** Switching between the ALMA rubidium clock and the APP Maser shall be a manual procedure.	15	Cables and connectors will be available for this in the LO Room at the AOS.
Phasing			
APP0140	**Phasing efficiency (stability):** The APP phasing efficiency shall be as stable as the atmospheric coherence timescale of the median antenna of the array.	14, 16	This shall be determined from analysis of commissioning data through comparison between local VLBI data and ALMA data.
APP0150	**Phasing efficiency (quality):** The phasing system shall achieve 90% of the theoretical SNR expected for a compact 4 Jy source at 230 GHz operated with 15 antennas with baselines less than 2km with no more than 0.8mm precipitable water vapor and	14, 16	Commissioning observations shall characterize observing efficiency as a function of atmospheric stability and baseline length. This shall be extrapolated, to the extent possible, to the required conditions. (Early in the project, before NRAO testing, analysis of ALMA data sets will provide some efficiency data to verify this.)

Rqmt #	Requirement	Test	Verification Method
	mean RMS path fluctuations no more than 0.125 mm.		
APP0160	**Phasing efficiency (monitoring):** The phasing system shall monitor the efficiency of its solutions.	4	This shall be verified as part of the software acceptance process.
APP0170	**Phasing data**: Channel average data from all relevant baselines and WVR data shall be available at the baseband cadence.	3	No verification needed. This capability currently exists at ALMA
Correlator			
APP0180	**Correlator output:** The correlator shall operate in a mode where it provides to the PICs the antenna-summed data for each quadrant: 2 pol x 32 ch x 62.5 MHz, 2bits / sample, 16Gbps , 128 LVDS pairs	3	No verification needed. This capability currently exists at ALMA in certain modes, including Mode 13.
APP0190	**Correlator configuration**: The antenna summed data shall be provided as CAI-63.	3	This is clear by Inspection of the design documentation.
APP0200	**Correlator self test**: Test capabilities shall be provided by the ALMA correlator to verify correct PIC operation.	5/12	Several tests, similar to existing correlator tests, shall be designed and executed as part of NRAO and AOS testing.
PIC			
APP0210	**PIC output:** The output format of the PIC phased sum data shall be VLBI Data Format (VDIF) packets	3/9	This shall be determined by review of the design documentation. The contents of the VDIF frames shall also be tested by the recorders during NRAO and AOS testing (scan check)
APP0220	**PIC timing:** A 1pps clock synchronized with the maser shall be supplied to the PIC	3/9, 14	This shall be determined by review of the design documentation. During NRAO and AOS testing, the offset between an internally generated 1PPS and the maser 1PPS shall be monitored.
APP0230	**VDIF format:** The VDIF packet shall support 8, 16 and 32 channels.	3/9	This shall be verified by review of the design documentation. During NRAO testing the various operating modes shall be verified by placing unique signatures in each channel.
APP0240	**VDIF encapsulation:** The VDIF packet shall be encapsulated as UDP/IPv4 payload.	3/9	The design element used by the packetizer uses the specified encapsulation. The recorder shall verify that the packet format is as expected.
APP0250	**Ethernet mtu:** The Ethernet interface shall support jumbo frames.	3/9	The design element used by the packetizer supports jumbo frames. The recorder shall verify that the packet format is as

Rqmt #	Requirement	Test	Verification Method
			expected.
APP0260	**Ethernet bandwidth**: The Ethernet interface shall be 10Gbps.	3/9	The design element used by the packetizer supports 10 Gbps and the system design is predicated on this. The recorder shall verify that the packet format is as expected.
Optical			
APP0270	**Network infrastructure**: The data communication system linking AOS to OSF shall support multiplexing eight 10 GbE bi-directional channels onto a single fiber.	3 ,14	The combination of the Fiber Mux, Fiber DeMux and ALMA-installed cable supports this mode of operation by design. During AOS testing, test packets which utilize the 8 10 GbE bidirectional channels shall be transmitted and checked using installed equipment. Bi-directionality shall be verified by review of equipment specifications.
APP0280	**Data distribution:** The data shall be evenly distributed at 8Gbps over all optical channels.	3	This is inherent in the design of the system.
Recorders			
APP0290	**Recording system:** The recorders shall be able to record at an aggregate rate of 64 Gbps.	8/10	Each of the recorders shall be tested using test data with two 8 Gbps data streams.
APP0300	**Data integrity**: The recording system (recorder + optical fibers) shall capture at least 95% of the data packets.	8/14	Each of the recorders shall be tested with an 8 Gbps data stream with known patterns and serial numbers, making it possible to determine the fraction of lost packets.
APP0310	**Recorder control:** Commands to the recorders shall adhere to the VLBI Standard Software Interface Specification (VSI-S).	3	This shall be verified by inspecting the software documents detailing the recorder communications protocols
APP0320	**Recorder media:** The data shall be recorded to standard disks.	3	This shall be verified by inspecting the recorder design documents.
APP0330	**Media processing:** The disks shall be shippable for VLBI processing of data.	3	This shall be verified by inspecting the recorder design documents.
APP0340	**Media insertion:** Reliability of the connectors / cables between the recorder and the module shall be consistent with at least 5 years of operation	3	This shall be verified by inspecting the recorder design documents, in particular the specifications for the connectors and cables.

Rqmt #	Requirement	Test	Verification Method
APP0350	**Media capacity:** The disk modules will hold a minimum of 9 hours of data.	3, 14	This shall be verified by inspecting the recorder design documents. During AOS testing, this shall be verified by recording data for at least 9 hours.
Experiment			
APP0360	***Experiment session:*** Each VLBI session shall be described in a manner compatible with existing VEX file systems in use at 3 mm and 1.3 mm observatories that are expected to participate in VLBI observations with ALMA.	3, 14	This shall be verified by inspecting the VEX file. During AOS testing, a VEX file shall be used to control an experiment.
APP0370	**Session duration:** The APP system shall support sessions lasting up to 18 hours.	3	It will be confirmed by inspection that sufficient recording media capacity is provided for such sessions.
APP0390	**Interscan gap:** The APP system shall support scans separated by a minimum of ***10*** seconds.	3, 14	This shall be verified by recording scans 10 seconds apart (or less).
APP0400	**Scan duration:** The APP system shall support scan durations between **10** and **900** seconds.	3, 14	This shall be verified by recording scans of various duration.
APP0410	**Experiment scans:** The APP system shall complete at least ***90*** % of scheduled scans.	3, 14	This shall be verified by recording 100 (TBR) scans
APP0420	**Scan scheduling:** The APP system shall support scans scheduled in UTC time and shall start/stop within 2 seconds of the scheduled time.	3, 14	This shall be verified by recording 100 (TBR) scans
APP0430	**Band support:** Band 3, 6 receivers shall be fully supported.	3, 14	By design, the system is capable of recording data from any ALMA band. The phasing algorithm is key to meeting this requirement. Simulations of the phasing algorithm using real ALMA data shall demonstrate the phasing capability at band 6. Phasing shall be demonstrated for bands 6 by incremental addition of antennas (see Commissioning Plan) as a quality metric. Band 3 does not need to be tested if Band 6 is verified.
APP0440	**Minimum bands:** APP shall support simultaneous use of one to four ALMA frequency basebands	3, 14	By design, the system is capable of recording data from one to four quadrants, and thus up to four frequency basebands. During AOS testing, the processing and recording capability for one to four quadrants shall be demonstrated.

Rqmt #	Requirement	Test	Verification Method
APP0450	**IF frequency:** The APP system shall support faithful programming of the IF band specified by the VEX file.	3, 14	Log information acquired during AOS tests shall be examined for relevant system configuration information. Spectra taken with phased antennas shall be compared with spectra taken in a "normal" observation.
APP0460	**TFB tunings:** The TFB channel placement shall be capable of being made compatible with the 2^n MHz sampling schemes of traditional VLBI.	3, 16	For NRAO testing, a description of the method used for accommodating 2^n MHz sampling schemes shall be available. The method shall ultimately be verified by cross-correlating ALMA data with data from antennas which use a 2^n MHz sampling scheme.
Observing			
APP0470	**Observing correlator**: The ALMA correlator shall operate in a single Nyquist sampled, single region frequency division mode covering the full 2 GHz bandwidth on each quadrant	3, 14	This is a standard correlator mode that has already been commissioned (Mode 13). During AOS testing, we shall verify that the correlator is indeed in this mode.
APP0480	**LO Tuning:** All Antennas shall have the same LO tuning	3	No verification needed. This is an existing ALMA mode
APP0490	**Antenna participation:** The phasing system shall be capable of phasing up an array consisting of an arbitrary odd number of antennas <64.	3, 14	This capability is obvious by inspection of the design. During AOS testing, summing various numbers of antennas shall be tested. The maximum number, however, will depend on antenna availability and weather during AOS observations.
APP0500	**Antenna 63:** The antenna assigned to CAI-63 shall be part of the observing array but omitted from the phased sum	3, 14	This capability is obvious by inspection of the design. The "CAI 63 input" to the correlation matrix shall be used as an input for the phased sum. At AOS the auto and cross correlation of this input against others shall be used to demonstrate that the phasing is working correctly.
APP0510	**Log archival:** Information necessary for the post-observation (VLBI) correlation and analysis shall be archived.	3, 14	This capability is clear from inspection of the software design documentation. Inspection of the logs generated during AOS observations shall demonstrate this capability.
APP0520	**Independent systems:** The phasing and recording systems shall be operated separately.	3, 14	This capability is clear from inspection of the software design documentation. The capability shall be demonstrated at AOS.
APP0530	**Independent quadrants:** The APP system shall support independent operation of the four correlator quadrants.	3, 14	This capability is clear from inspection of the software design documentation. The capability shall be demonstrated at AOS by configuring the four quadrants to operate independently.

Table 5-2: Verification Method for ICD requirements. Test numbers refer to Table 3-1.

Item #	Item	Test	Verification Method
Back End			
BAK-0010	Maser Rack Cabling	10	Compare maser rack cabling to Interconnect diagram
BAK-0020	CRG 5 MHz input power level	10	Verify that the 5 MHz input power is between 10 and 15 dbm at the input to the CRG
BAK-0030	CVR 10 MHz input power level	10	Verify that the 10 MHz power at the CVR inputs is between 0 and 5 dbm (2 units)
BAK-0040	1-PPS levels	10	Verify that the 1-PPS signal level at the 1-PPS Distributor in the Correlator Room is compliant with LVDS signal levels and has a rise time of 10 ns or less.
Computing			
COM-0010	Protocol verification.	**11**	Individually verify by protocol-appropriate means (e.g. readout of downloaded parameters via engineering port). Test by successful configuration and execution of an observation.
COM-0020	Recorder NTP capability.	11	Use linux *ntpstat* command or equivalent for one recorder.
Correlator			
COR-0010	Items to be delivered	12	Compare shipping documentation to checklist. Inspect received equipment for mechanical damage.
COR-0020	PIC assemblies fit in Final Adder slots of correlator bins	12	Demonstrate that one assembly fits in the test fixture's final adder slot, which is mechanically identical to the slots in the correlator.
COR-0030	Rack temperature increase due to PICs	12	Measure and document the temperature rise in the slot above one PIC. Verify that the chips in this zone are operating in a safe thermal environment.
COR-0040	Cabling additions	12	Inspect installed cables to verify all were installed per the ICD and any detailed cable lists.
COR-0050	PIC Comm. Ethernet card	12	Verify that it is possible to communicate via Ethernet to each ROACH via the Engineering Port Computer
COR-0060	Power dissipation	12	Measure the current consumption of one PICA in maximum dissipation mode and multiply by 8.
COR-0070	Firmware deliveries	12	Verify that all the correct microprocessor and FPGA personalities are installed by inspecting checksums. Verify that they are committed to the repository. Document the version used for testing.
Site			
SIT-0010	Component power dissipation.	13	Verify power dissipation under normal operating conditions for one or more of each of the following installed components: • Maser rack (3.1.5.1.1) • 1-PPS distributor (3.2.1.1) • Fiber Mux/DeMux (3.3.1.1) • Recorder (3.4.2)
SIT-0020	Correlator upgrade cabling	13	Verify that all required cabling related to the Correlator Upgrade is correctly installed.

Table 5-3: ALMA requirements pertinent to APP are summarized in the table below. Detailed test procedures will be released prior to the test readiness review. Test numbers refer to Table 3-1. Under "other" are listed documents such as electrical codes that will be reviewed for compliance in their entirety by designated experts.

Requirement #	Requirement	Test	Verification Approach
Environmental			
ENVI-00070-00 / R	[AOS] All ALMA equipment shall be compatible with an ambient air pressure of 550 mbar ± 60 mbar, which corresponds to an air density of 0.7214 kg/m3 (typical average).	3, 13	This applies to the maser and correlator boards. The boards will be subject to a test in the racks. The maser will rely on manufacturer's specification.
ENVI-00040-00 / A	[Operating and non-operating compatibility with] The levels of earthquake acceleration that are likely to occur at the OSF and AOS	3	This applies to the maser rack. It will rely on analysis by analogy to existing racks. Compliance with load limits on OSF racks will also be verified.
ENVI-00050-00 / R	Occurring downtime and time to repair for the equipment must be defined in each sub-system specification.	3	This will be part of the final system documentation.
ENVI-00121-00 / R	[AOS operating and non-operating compatibility with] Maximum expected Gamma ray dose rates are 3.14 mSv/year	3	This affects FPGAs and will be based on manufacturer specification.
ENVI-00122-00 / R	[AOS operating and non-operating compatibility with]Maximum expected neutron dose rates are 0.80 mSv/year	3	This affects FPGAs and will be based on manufacturer specification.
ENVI-00270-00 / R	[OSF] All ALMA equipment shall be compatible with an ambient air pressure of 750 mbar +/- 100 mbar, which corresponds to an air density of 0.96 kg/m3 (typical average).	3, 12	This affects disk drives and will be addressed by extended test.
ENVI-00311-00 / R	[OSF Operating and non-operating compatibility with] maximum expected Gamma ray dose rates of 1.70 mSv/year.	3	This affects FPGAs and will be based on manufacturer specification.
ENVI-00312-00 / R	[OSF operating and non-operating compatibility with] Maximum expected neutron dose rates of 0.25 mSv/year.	3	This affects FPGAs and will be based on manufacturer specification.
Safety			
SAFD-0050-00/	The essential characteristics, the recognition and observance of which will ensure that electrical equipment will be used safely and in applications for which it was made, shall be marked on the equipment, or, if this is not possible, on an accompanying notice.	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm conforming labeling
SAFD-0060-00/	The designers or brand name or trade mark shall be clearly printed on the electrical equipment or, where that is not possible, on the packaging.	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm conforming labeling
SAFD-0090-00/	Persons are adequately protected against danger of physical injury or other harm which might be caused by electrical contact direct or indirect;	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm appropriate protection against harmful electrical contact
Product Assurance			
PA-00240-00/	Each configuration item shall be uniquely identified by serial number.	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to

Requirement #	Requirement	Test	Verification Approach
			confirm conforming labeling
PA-00250-00/	A serial number shall be permanently affixed to each configuration item using a method appropriate to the item which may be indelible ink, engraving, coded electronically readable chip or a combination of the above or equivalent methods. Serial numbers shall not be hand-written.	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm conforming labeling
PA-00860-00/	The documentation supplied in the Acceptance Data Package shall reflect the "as-built" version of the delivered equipment and shall contain sufficient information for the installation, operation and maintenance of this equipment.	15	This will be ascertained at the final delivery review.
PA-00920-00/	All commercially purchased test and measurement equipment used in the execution of formal acceptance testing shall satisfy the requirements for metrology and calibration specified in Table 4.	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP test equipment for this purpose
PA-001000-00/	When appropriate, the accompanying documentation shall be in the outer packaging layer and shall include the Acceptance Data Package, which includes the storage, handling, transportation, packing/unpacking procedures and relevant notes of caution and safety procedures.	15	APP Product Assurance personnel shall perform an inspection of APP packaging prior to shipping to confirm conforming documentation
PA-001020-00/	Labeling of shipment containers shall include: 1. nomenclature, model name and serial number (if applicable) of the item; 2. caution/warning notes for dangerous or toxic contents; 3. package orientation arrows; 4. for large items, weight and centre of gravity, handling and lifting points; 5. conditions and instructions for handling and unpacking, and 6. name, address, phone number of sender and recipient.	15	APP Product Assurance personnel shall perform an inspection of APP packaging prior to shipping to confirm conforming documentation
PA-001030-00/	Labeling of shipment containers shall be permanent and legible and protected against wear.	15	APP Product Assurance personnel shall perform an inspection of APP packaging prior to shipping to confirm conforming documentation
Other			
APPGEN-001	APP-provided hardware shall conform to all applicable requirements and guidelines for identification and labeling of ALMA equipment as specified in ALMA-80.02.00.00-016-A-SPE	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm conforming labeling
APPGEN-002	APP-provided connectors shall conform to all applicable requirements specified in Standard for AC Plugs, Socket-Outlets, and Couplers: ALMA-	15	Designated ALMA and APP Product Assurance personnel shall perform a joint inspection of APP hardware to confirm conforming connectors

Requirement #	Requirement	Test	Verification Approach
	80.05.00.00-004-B-STD		
APPGEN-003	APP-provided hardware shall conform to all applicable ALMA System Electrical Design Requirements as specified in ALMA-80.05.00.00-005-C-SPE	15	Designated ALMA and APP Product Assurance personnel shall participate in a joint review of APP electronics to confirm conforming design
APPGEN-004	APP-provided hardware shall conform to all applicable ALMA System EMC Requirements as specified in ALMA-80.05.01.00-001-B-SPE	15	Designated ALMA and APP Product Assurance personnel shall participate in a joint review of APP electronics to confirm conforming design

Acronyms

AcRv	Acceptance Review
ALMA	Atacama Large Millimeter/Sub-millimeter Array
AOS	(ALMA) Array Operations Site
APP	ALMA Phasing Project
ASIAA	Academia Sinica Inst. of Astron. and Astrophys.
CAN	Controller Area Network
CCC	Correlator Control Computer
CDP	Correlator Data Processor
CDR	Critical Design Review
CIC	Correlator Interface Card
CLO	Central Local Oscillator
CORBA	Common Object Request Broker Architecture
CRG	Central Reference Generator
CSV	Commissioning and Science Verification
CVR	Central Variable Reference
CVS	Concurrent V ersions System
DiFX	Distributed Fourier Transform (Correlator)
FPGA	Field Programmable Gate Array
GbE	Gigabit Ethernet
GPS	Global Positioning System
GUI	Graphical User Interface
ICD	Interface Control Document
I&T	Integration and Test
JAO	Joint ALMA Office
LRU	Line Replaceable Unit
LTA	Long Term Accumulator
LVDS	Low Voltage Differential Signaling
MIT-HO	Mass. Inst. of Tech. Haystack Observatory
MMR	Monthly Management Review
MPIfR	Max Planck Institute for Radio Astronomy
MTU	Maximum Transmission Unit
NAOJ	National Astronomical Observatory of Japan
NRAO	National Radio Astronomy Observatory
OFL	Optical Fiber Link
OSF	(ALMA) Operations Support Facility
PA	Product Assurance
PAI	Provisional Acceptance In-House
PAS	Provisional Acceptance on Site
PIC	Phasing Interface Card
PICA	PIC Assembly
PPS	Pulse Per Second
RAM	Random Access Memory
RID	Review Item Discrepancy
RMS	Root Mean Square
ROACH	Reconfigurable Open Architecture Computing Hardware
SCC	Station Control Card

SITR	System Integration and Test Review
SNR	Signal to Noise Ratio
SVN	Subversion (Apache)
TE	Timing Event
TFB	Tunable Filter Bank
TRR	Test Readiness Review
UTC	Coordinated Universal Time
VDIF	VLBI Data Interchange Format
VEX	VLBI Experiment File
VLBI	Very Long Baseline Interferometry
VOM	VLBI Observing Mode
VSI-S	VLBI Standard Software Interface Specification
WVR	Water Vapor Radiometer
XML	Extensible Markup Language